MADOFF & KHOURY LLP

ATTORNEYS AT LAW

PINE BROOK OFFICE PARK
124 WASHINGTON STREET, SUITE 202
FOXBOROUGH, MASSACHUSETTS 02035

TELEPHONE: (508) 543-0040
FAX: (508) 543-0020
Email: khoury@mandkllp.com

January 26, 2023

SECOND SUPPLEMENTAL MEMORANDUM IN SUPPORT OF APPLICATION FOR SPECIAL PERMIT AND SITE PLAN APPROVAL AT 157-165 LOWLAND STREET, HOLLISTON, MASSACHUSETTS

The affiliated Massachusetts business entities Holliston Asphalt & Concrete Inc. and M & M Estates LLC, together with their equity holders and affiliates Master Paving Corporation and Middlesex Asphalt Services, Inc., submit this memorandum in support of their amended Application for Special Permit and Site Plan Approval dated as of May 17, 2022[1].

A. Specific Relief Sought Under Bylaw

1. Allowance of Right or By Special Permit for Asphalt and Concrete Work.

By the Application, the Applicant seeks this Board's approval under **Section III(G)(2) and/or (G)(3) of the current Zoning Bylaws** of the Town of Holliston (the "**Bylaw**") as last amended as of May 13, 2022), of a special permit for the continuation and improvement of the asphalt and concrete manufacturing and recycling operations located at 157-164 Lowland Street, Holliston, Massachusetts (the **"Property**") that have been conducted thereon since the 1960's at the latest (and perhaps earlier) . The Property is located within the "Industrial District" as prescribed by the Bylaw.

(a) **Subsection III G(2) of the Bylaw, as amended as of May, 2022**, provides that within the Industrial District in which the Property is located "*general industrial uses, including manufacturing, storage, processing, fabrication, packaging and assembly comprised not more than 15,000 square feet of floor area devoted to such use and otherwise in compliance with local, state and federal laws, rules and regulations, but not including any use which involves the manufacture,*

[1] On April 13, 2021, the Applicants filed their original Application for Special Permit and Approval of Site Plan with this Board. Following the effective date of the certain amendments to the Holliston zoning bylaw taking effect as of May 13, 2022, the applicants filed an amended application referenced above on May 17, 2022

storage and transportation and discharge, or disposal of hazardous or toxic or radioactive waste, hazardous, toxic or radioactive materials" are allowed as of right.

(b) Alternatively, the Applicants seek special permit for the continuation of the asphalt and concrete processing and recycling operations that have been conducted at the Property for over the past 60 years **under Section III(G)(3)** of the Bylaw, as amended as of May, 2022 as " *general industrial use, including manufacturing, storage, processing fabrication packaging assembly that occupy more than 15,000 square feet of floor area not including Warehouse* ***....*** "

2. Need for Approval of Ancillary Outdoor Storage of Materials, Heavy Equipment and Trucks.

Further, as ancillary and essential to such primary fabrication and recycling activities, the Applicants seek the Board's approval for the outdoor storage of the asphalt, concrete and other construction materials, processed materials and the fabrication, crushing and recycling equipment at the Property.

As described below and in the Site Plan, as revised, submitted with the Application, the Applicants propose to maintain storage piles, relocated to improve and make more efficient stormwater drainage and acoustical issues, of pre- and post-processing asphalt and concrete materials and to maintain the equipment needed for such fabrication and recycling in the outdoor locations shown on the Site Plan. Accordingly, and pursuant to **Section III (H) (10), (11) and 12) of the Bylaw, as amended as of May 2022**, the Applicants seek this Board's approval of the outdoor storage of these materials and equipment.

(i) Under **Section III(H)(10),** the Bylaw permits ***as of right*** the maintenance of building materials and equipment exposed to view to the extent actually necessary during active continuous construction work on the same lot. While the Applicants submit that the materials and equipment proposed to be maintained at the Property are not engaged in construction of a particular building or roadway project being installed at the Property itself, the work and materials being performed are necessary to the construction material fabrication and process being undertaken on a regular basis at the Property.

This Bylaw section does not require by its terms that the materials and equipment be used in building an industrial, office or other building, roadway or project to be located at the Property; the Bylaw language does not specify that the ultimate building or project for which the work is undertaken be located at the Property – all that it requires per the plain language of the Section is that the equipment and materials be "*actually necessary during active construction work on the same lo*t."

Such is the case here – the processing and recycling work is construction work (work undertaken in connection with construction activities) and the storage of the equipment and materials is maintained on the Property where the work is done.

(ii) Alternatively, if Section II (H)(10) of the Bylaw is interpreted to imply that a specific construction project (i.e., a building, roadway or other project) must be installed on the same lot on which the storage is maintained, the Applicants submit that this Board's issuance of a special Permit under Section III(H) (11) of the May 2022 Bylaw is appropriate. The Section provides that, in an Industrial District, this Board has the authority to issue a Special Permit which allows:

"*commercial open storage of raw materials, finished gods or construction equipment not associated with active permitted construction or agricultural uses"*

The Applicants submit that this Section also does not specify that the active construction work be associated with a building construction on the Property, and that the use of the Property for active continuous construction activity providing materials to projects being constructed at other locations should qualify under Section III(H)(10), but to the extent the Board disagrees with that interpretation of Section III(H)(10), the Applicants request approval of a Special Permit from this Board for those same outdoor storage of equipment and raw and finished materials necessary to the Applicant's continuation of the asphalt and concrete work under **Section III(H)(11) of the May 2022**

(iii) Lastly, and again, if this Board finds allowance by right under Section III(H)(10) , the Applicants request that this Board grant a Special Permit for the accessory outdoor storage of equipment and materials under Section III(H) (12) which authorizes this Board to issue a Special Permit in and Industrial District for "accessory outdoor storage clearly necessary to the operation and conduct of a permitted industrial or commercial use."

3. Parking of Trucks and Equipment Not Directly Associated with Work Being Done on Site.

In addition to the outdoor storage of trucks, equipment and materials at the Property needed to support the asphalt and concrete processing operations, the Applicants seek to construct at the portion of the Property shown on the Site Plan a garage which would provide for overnight parking of trucks and other items of equipment that the affiliates of the Applicants use in other operations off-site

Curiously, the Table of Uses in the Bylaw does not address use of properties within the Town for vehicular parking in any section thereof, whether as to commercial, industrial or other properties. The parking of unrelated trucks and equipment for overnight storage for most of the year and seasonal (winter) long-term storage would be limited to the garage and the area surrounding it, and would be conducted in such a manner, with modifications to the Property, as to limit adverse traffic, noise, environmental and other impacts. Again, the Property has been used since at least the 1960's for the parking and storage outdoors of trucks by third parties, as has a number of other properties in this same zoning district and on Lowland Street itself. The Applicants submit that this Board should permit such parking, within and around the garage area, as a continuation of a use of the industrial property that prior owners of the Property and prior and current owners of neighboring properties on Lowland Street and other roads in the Industrial District have been permitted to do currently and historically

4. Site Plan Approval under Section VII of the Bylaw for Modifications to Land, Construction of Garage and Related Improvements.

As shown on the Site Plan and as set forth in the materials presented by the Applicants' engineer Connorstone Engineering, Inc.("**Connorstone**"), the Applicants are proposing upgrade the site with a new garage replacing the dilapidated structures on the rear portion of the Property, to be used for storing paving company trucks. This garage and surrounding area would be served by paved aprons for paving equipment storage and employee parking. In addition, the Applicants propose to extend the back berm of the Property to enhance noise control and wish to install an additional noise barrier fence near the garage (these proposals will be fleshed out in modifications to the Site Plan that will accompany an acoustic study report currently in process. The Applicants also propose to upgrade the stormwater management system at the Property, as Connorstone has and will present both to the Board and to the Town's Conservation Commission. Finally, the Applicants will upgrade all utility connections and the septic system on the site.

The Applicants seek this Board's approval of such modifications and improvements to the Property pursuant to Section VII of the Bylaw – Site Plan Review.

While the Applicants submit that the parking usage and areas at the Property and the storage of outdoor materials and equipment will not be increased beyond that historically used by prior owners of the Property, including the preceding property owner under this Board's 2011 decision, the Applicants are proposing to install a garage at the Property at the location shown in the Site Plan and are proposing material modifications to the Property which will beneficially impact the neighboring properties, the Applicants seek this approval of the Site Plan under **Section VII (4) and (5) of the Bylaw, as amended in May 2022**.

In accordance with Section VII (5) of the Bylaw, the Applicants submit that the Site Plan presented under the Application satisfies the criteria for site plan approval in that:

(a) It provides improvements to the acoustic and stormwater protections currently in place at the Property which will substantially improve effects of the activities which have historically been undertaken both prior to the applicable zoning requirements of the Bylaw and in accordance therewith under relief previously granted by this Board;

(b) The Site Plan and related materials provide for material upgrades to the stormwater management systems in place at the Property, which Connorstone has and will detail for this Board;

(c) The Site plan provides for a replacement septic system to serve the Property which is a material improvement from the current essentially non-existent facilities on site;

(d) The proposed new garage and other improvements will provide safe vehicle storage and the relocation of certain material piles on the Property are proposed to improve the overall conditions at the Property for the benefit of the users thereof and of the neighboring properties and their occupants.

(e) The Site Plan provides superior access for regular operations on site, along with access for emergency situations, and t with the materials supporting the plan, present superior designs for loading, unloading and parking f vehicles incidental to the operations proposed to be conducted on site.

Again, the provisions proposed by the Applicants under the Application and the Site Plan substantially improve the uses and configuration of asphalt and concrete processing at the Property along with related parking, storage and other accessory activities that have been in operation at the Property since at least the 1960's. By the Application, the Applicants seek only to continue such operations, with substantial upgrades to mitigate the environmental, noise and traffic issues with neighboring properties. The Applicants submit that the uses to which they propose to put the Property are not only an improved continuation of the uses to which prior owners put the Property predating the current zoning requirements, but also fit within the substantially similar industrial and other uses which non-residential neighbors are currently operating in the Industrial District.

B. History and Specifics Regarding the Property

The Property is located within an Industrial District under the Bylaw and was originally developed as a concrete batch plant which, following the closing of that plant, has been used since at least the late 1960's, as an active materials recycling facility, initially operated by the Simeone Corporation, then by Independent Bituminous Co., Inc. (Mr. Benjamin Montenegro), then Aggregate Industries and most recently by the Applicant's predecessor owner and operator American Recycled Materials, Inc. ("**American Recycled**") The Applicants purchased the Property from American Recycled Materials Inc in March of 2022 and filed its original Application in April 2022, followed in May 2022 with an amended Application, incorporating and referencing the amendments to the Bylaw approved as of May 13, 2022.

Pursuant to that Certificate of Action Special Permit and Site Plan Review Decision of the Town's Planning Board (the **"Board")** dated August 11, 2011, a copy of which is attached hereto as **Exhibit "A"** (the **"2011 Decision"),** the prior owner of the Property, Michael Brumber and his entity American Recycled (collectively, the **"Seller")** operated a facility at the Property which processed and recycled asphalt and concrete materials and stored the same outdoors on a year-round basis, along with the gravel, loam and wood chips.

To conduct such operations, the Seller maintained and operated at the Property portable crushers, screeners, conveyors, and loaders which process and moved the recycled and other materials on-site. By 2011 Decision, the Board authorized the Seller's storage and processing of asphalt, concrete and other materials as identified on the site plan approved in connection therewith in outdoor piles labeled raw and processed materials. The perimeter of the site was and remains surrounded by concrete barriers and earthen berms.

In addition to the 2011 Decision issued by the Board, the Seller obtained from the Massachusetts Department of Environmental Protection (the **"MDEP")** a Permit for Recycling, Composting or Conversion operations (the **"RCC Permit"),** a copy of which is enclosed here with. Under these approvals, the Seller processed and recycled asphalt and concrete building materials which were stored within the Property and processed and stored gravel and loam on the site. The Applicants have applied for a transfer of the RCC Permit, and the MDEP informs that approval for the transfer is pending.

Paragraph 1 of Conditions of Approval set forth in the 2011 Decision specifically stated that the Special Permit and other approvals therein were not transferrable or assignable and thus, despite the Seller's recording of the 2011 Decision at the Norfolk County Registry of Deeds in 2011, the 2011 Decision does not *"run with the land,"* and the Applicants hereunder seek the Board's approval of **a modified and improved site plan and operations proposal under the same provisions of the Bylaw in order to operate a similar, but improved, asphalt and concrete recycling operation at the Property, in line with the use of the Property over the past half century, yet respectful of and responsive to the interests and rights of the neighbors in the industrial District in which the Property sits, along with the proximate residential property owners and occupants.**

C. Features of the Property and Stormwater, Noise and Parking Issues and Proposed Improvements to Such Conditions

The Property is situated on a gravel outwash of highly permeable sandy soil and is surrounded by large earthen berms. No rainwater runoff or dust control water (which is pumped out of the sentiment pond on the Property) can leave the site due to the surrounding berms and a large underground stone leaching facility covering the southwest corner of the Property, positioned in a triangular area which is the lowest aspect of the Property. The storm water is fully contained on the site via an existing stormwater operation and plan which includes a complete stormwater management/ containment berm that surrounds the entire yard as well as the large retention pond of the western edge of the site and an in-ground infiltration basin. The Property and the operations thereon are located so that storm water is collected in the Southern corner of the Property where any residual sediment and material is collected for re-use. A portion of the stormwater runoff is directed into a retention pond where the sediment is allowed to settle and periodically recovered for re-use.

As outlined in the Application, the Applicants are proposing to significantly improve the stormwater management process in its proposed future operations.

By the Application, the Applicants seek the relief to utilize the Property in an equivalent manner as allowed under the 2011 Decision, provided, however, that the Applicants are proposing to make improvements to the site to reduce and streamline the recycling facilities and the operations maintained on the Property.

The Applicants have proposed in the Application to limit the processing of concrete and asphalt product to cleaner quality of such materials, with the goal of eliminating associated debris. Further, the Applicants shall not engage in the processing of loam, wood chips and other earth materials formerly processed by the Seller under the 2011 Decision and will eliminate the processing of brick materials.

Also, the Applicants seek under the Application the Board's approval to construct a new office, garage and operations center as identified in the Application. The location is in the current area of the equipment storage and smaller repair shelter. The structures currently existing will be razed and a new facility will be constructed which will reduce the noise generated at the Property upon start-up of trucks and other vehicles.

Further, the Applicants propose to extend the berm to wall off sound transmission to the West and Southwest and to install fencing on the top of that berm. The Applicants also propose to install fencing for noise barrier along the Southeasterly property line, at which a large ditch exists (abutting the property at 175 Lowland Street), to install a wall at the trailer on the Property to mitigate noise to the Southwest. Materials processing would take place with machinery on the lower floor of the site and delivery and dumping of incoming material will continue with a proposed reduction in the time that trucks loaded with the materials to be recycled and having recycled materials will be reduced.

As discussed in the Application, parking needs at the Property are limited, and parking areas for limited number of employees and visitors are proposed to be located at the prospective garage building and the existing trailer.

Most traffic at the Property will be from construction trucks entering and leaving the facility, with loaded trucks entering the site being directed to climb the dumping ramp on the South side of the Property and will leave through the 'yard area' (denoted on the plan submitted with the Application). Trucks picking up material will be loaded in the yard area.

The proposed garage building will have doors on each side. Trucks typically will enter from the southeast and exit on the opposite side. Outdoor storage of equipment will be northwest of the garage, at the processing location (crushers, loaders etc.) and at various work locations on the Property.

As stated above, the Applicants propose to eliminate all brick recycling operations undertaken by the Seller pursuant to the 2011 Decision together with all loam operations. Further, while keeping the existing recycling operations essentially where previously located, the Applicants will present to the Board additional noise barriers and other acoustic enhancements along with an acoustic study showing the positive impact on the sound levels of the work at the Property for neighbors. Further, the Applicants propose to house most trucks stored at the Property in the new garage to be built, so as to substantially reduce the outdoor vehicle storage that the Property's prior owners employed as well as many current neighbors of the Applicants.

D. Relief is Appropriate as a Continuation of Prior Non-Conforming Use

The Applicants submit that the proposed uses of the Property, as detailed in the Application, should be permitted, whether as by right Sections III (G)(3) of the current Bylaw, under Special Permits within the Board's authority under Sections III (G)(3) and (H) (10), (11), and/or 12, by variance or such other relief as the Board may deem appropriate

In line with the continuing use of the Property since the 1960's, the Applicants seek to operate at the Property an asphalt and concrete processing and recycling operation in support of off-site construction projects and roadway work, along with accessory equipment and material storage. The federal and state governments have since the 1970s emphasized the importance of recycling of demolished asphalt and concrete for use in new projects, thus reducing the need for wasteful dumping of such materials that do not biodegrade. The Federal Highway Administration, together with the American Association of State Highway and Transportation Officials issued a report in September 1980 entitled "*Guidelines for Recycling Pavement Materials*" emphasizing the critical need for recycling of asphalt and concrete torn up in roadway and other improvements for use in new construction. It is estimated that since the 1970's, all asphalt and concrete processing operations have incorporated a material percentage of recycling in their production. See copy of narrative portion of this report attached hereto as **Exhibit "B."**

The Applicants understand that the Seller had a volatile and antagonistic relationship with this Board, the Town and the neighbors. The Applicants pledge to this Board and the abutters that they do not intend to, and will not, create any unreasonable or impermissible disturbances and will operate in full acknowledgment and respect of the noise, traffic and stormwater drainage considerations that the Town and the owners of the surrounding properties are concerned about.

The Applicants are prepared to detail shortly with a revision to the Site Plan and accompanying noise study specific improvements to be made to the Property to limit the impact of the noise generated by the material recycling operations and the traffic considerations and will work with this Board and the Town in setting reasonable limitations on traffic coming in and out of the Property.

Section 5 of Article VI-E of the Bylaw requires the Board, before granting a Special Permit, to consider the proposed use in relation to the site as well as the adjacent uses and structures and shall find that there will be no significant adverse effects to the neighborhood or the Town, considering the following criteria:

(a) The degree to which the proposed use complies with the dimensional requirements of the Bylaw, is in an appropriate location and does not significantly alter the character of the neighborhood; whether the project is compatible with existing uses and other uses allowed by-right in the district and is designed to be compatible with the character and the scale of neighboring properties.

(b) To the extent feasible, the proposal has been integrated into the existing terrain and surrounding landscape, minimizing the impacts to the aquifer and/or recharge area, wetlands, steep slopes, and floodplains.

(c) Adequate and appropriate facilities shall be provided for the proper operation of the proposed use, including screening and provisions for convenient and safe vehicular and pedestrian circulation within the site and in relation to adjacent streets and properties.

(d) The proposed project shall not create any significant emission of noise, dust, fumes, noxious gases, or any other adverse environmental impact including stormwater, erosion, and sedimentation.

(e) There shall be no unreasonable glare from lighting, whether direct or reflected, onto ways, the night sky or onto adjacent properties.

Massachusetts General Laws Chapter 40A, Section 6, provides as a general rule that:

> a zoning ordinance or by-law shall not apply to structures or uses lawfully in existence or lawfully begun, or to a building or special permit issued before the first publication of notice of the public hearing on such ordinance or by-law required by section five, but shall apply to any change or substantial extension of such use, to a building or special permit issued after the first notice of said public hearing, to any reconstruction, extension or structural change of such structure and to any alteration of a structure begun after the first notice of said public hearing to provide for its use for a substantially different purpose or for the same purpose in a substantially different manner or to a substantially greater extent

except where alteration, reconstruction, extension or structural change to a single or two-family residential structure does not increase the nonconforming nature of said structure.

The Property has been used for the proposed uses since the 1960's in various forms and this Board approved the use of the Property for the same uses that the Applicants propose in the 2011 Decision, which by its terms is not of right transferrable or assignable to any successors in interest to the Property. The Board's concerns are justified given the history between the Town and the Seller following the 2011 Decision. But the Applicants are not the Seller and have and will propose substantial improvements to the Property that, while modifying the use, in fact improve and reduce the activities and byproduct (noise, drainage, etc.) over which the Board is justifiably concerned. The test then "*turns on whether, and to what extent (if any), those operations are a "change or substantial extension*" of the uses that existed" on the subject property prior to the current zoning ordinance which would be used to prohibit it, such examination turning on

1. Whether the use reflects the "nature and purpose" of the use prevailing when the subject bylaw took effect.

2. Whether there is a difference in the quality or character, as well as the degree, of use.

3. Whether the current use is "different in kind in its effect on the neighborhood."

MS&G Lakeville Corp. v. Town of Lakeville, Massachusetts Land Court, 15 LCR 259, 260, (2007 WL 1576144) (2007); citing Powers v. Building Inspector of the Town of Barnstable, 363 Mass. 648, 653, 296 N.E.2d 491 (1973); see also Bridgewater v. Chuckran, 351 Mass. 20, 23, 217 N.E.2d 726 (1966).

The Applicants shall present to the Board those noise, stormwater and traffic mitigation elements that will improve and limit adverse impact on its neighbors to levels that fall within objective standards for the same as established for the Property, thus alternatively justifying this Board's approval of the permitted uses as a reduction of the long-standing historical use of the Property or establishing the uses proposed, while constituting a change in the historical use, are reductions and improvements which strongly support the Board's approval of a Special Permit therefor.

Attached hereto as **Exhibit "C"** is a former version (post-1995) of the Table of Uses adopted in the Bylaw which reflects at Items 42 and 42a (page 21) that slightly modified versions of Section III (G)(2) and (3), permitting general industrial uses, including manufacturing, processing, fabrication, packaging and assembly activities, in floor areas of up to and more than 15,000 square feet. This confirms that both of these Sections were added as of the May 1995 Town meeting. Further, the limitations on outdoor storage of equipment and materials imposed under Section III(H)(10), (11) and (12) were added to the Bylaw in modified forms as of 1981 – see Uses 46, 48 and 49 at page 23 of **Exhibit "C."** Such dates of bylaw adoption all follow the commencement of the asphalt and concrete processing, and equipment, vehicle and material storage that the Property has been put to for decades.

The proposal for development and usage of the Property as outlined in the Application is fully in line with and constitutes an improved and reduced level of use of the Property that has been conducted since the late 1960's within the Town's designated Industrial District. The Town has previously approved similar uses on Lowland Street – see for example,

(a) the 1978 decision issued by the Town's Zoning Board of Appeals to Independent Bituminous Co., Inc. permitting the production and recycling of earthen building materials on Lowland Street for many years; and
.
(b) That July 2020 decision of this Board granting approval to the property owner and 75 Lowland St. to continue outdoor storage of equipment and materials processing of wood chips and related activities, in light of the fact that the work had been conducted at the subject property for over 35 years.

See copies of each of these decisions attached hereto as **Exhibit "D."**

In this case, the Applicants propose that this Board, following a full presentation and review of the traffic, acoustic and stormwater studies submitted to date and to be presented, that the proposed uses of Property under the Site Plan and the configuration of the improved, modified and reduced level of such operations are a significant improvement upon the uses to which the Property has been put in the past including those uses and activities of the Seller which were admittedly contentious and troublesome for the Town and the neighboring property owners. The Applicants submit that the continuation of asphalt and concrete processing and recycling operations at the Property, subject to the improvements proposed which will mitigate a great deal of the issues that the Town and neighbors had with the Property's operation under the Seller's control within the objective standards and limits adopted by the Town in the Bylaw, will make more than appropriate this critical industrial use in this designated Industrial District. Further, the processing and recycling of concrete and asphalt as proposed by the Applicants provide a significant environmental and societal benefit. See, e.g., Paulini Loan LLC v. Ottaviani, Massachusetts Land Court, 23 LCR 436, 2015 WL: 4158239 (2015) (finding that, subject to the noise, traffic, dust and other mitigation efforts of the applicant were appropriate to address the concerns of the Town of Framingham over permitting a concrete batch plan, such use not being per se subject to denial where sufficient mitigation efforts are found); see Oakham Sand & Gravel Corp. v. Town of Oakham, 54 Mass. App. Ct. 80, 84, 763 N.E.2d 529 (2002),(contrasting situation where pre-existing use is expanded beyond prior use such that the expanded use must thjen comply with current zoning)

Further, and with regard to truck and equipment storage, since the applicants purchase of the property in April 2022, the site has lain dormant, this Board instructing that nothing can be done at the Property unless and until this Board issues new special permit. The Applicants have been fully respectful of the Town's demand for a complete cessation of all use of the Property, to their great economic and operational detriment. Despite the Applicants' ownership of the Property that has been used for decades this very purpose, along with other uses, the Applicants have tabled their intention to store trucks and other equipment at the property and rented costly alternative space pending this Board's consideration of the Application. The Applicants request that the Board consider the interim use of Property for reasonable truck and equipment storage within the Industrial District as has been done historically and as is being done by the neighboring industrial operations surrounding the Property.

<u>EXHIBIT ”A”</u>

Certificate of Action Special Permit and Site Plan Review- Michael Brumber
Dated August 11, 2011

<u>EXHIBIT “B”</u>

Portion of Federal Highway Administration Report entitled “*Guidelines for Recycling Pavement Materials*” September 1980

EXHIBIT "C"

Former Table of Uses Incorporated into Zoning Bylaw for Town of Holliston

EXHIBIT “D”

Decisions of Town Boards Regarding Uses on Lowland Street

TOWN OF HOLLISTON
PLANNING BOARD
TOWN HALL

HOLLISTON, MASSACHUSETTS 01746

2011 AUG 17 PM 2:07

OFFICE OF THE TOWN CLERK HOLLISTON, MASS.

Elizabeth T. Greendale

CERTIFICATE OF ACTION
SPECIAL PERMIT AND SITE PLAN REVIEW – MICHAEL BRUMBER

Decision Date:	**August 11, 2011**
Applicant:	**Michael Brumber**
Address:	**157 Lowland Street, Holliston, MA**
Owner:	**BA Simeone c/o Aggregate Industries, 400 Green Street, Wrentham, MA 02093**
Site Location:	**157 Lowland Street**
Assessors' Reference:	**Map 12, Block 4, Lot 34**
Zoning District:	**Industrial (I)**

2011 00160885
Bk: 57463 Pg: 292 Doc: DECIS
Page: 1 of 5 09/19/2011 08:50 AM

It is hereby certified by the Planning Board of the Town of Holliston, Massachusetts, in accordance with the Rules and Regulations of the Holliston Planning Board, Article VII, Site Plan Review, a duly called and properly posted public hearing of said Planning Board was held on July 28, 2011 and continued to August 11, 2011. At a duly posted meeting on August 11, 2011, it was voted to **approve** a Special Permit and site plan application based on a plan entitled "Site Plan of Land in Holliston, MA" prepared for Michael Brumber of 815 Highland Street, Holliston on a motion made and duly seconded. The plan set was prepared and stamped by Bruce E. Wilson, Jr., PLS of GW Site Solutions Inc. of Franklin, MA. The application was filed with the Planning Board Office on July 7, 2011 and concerns a 7.07-acre property on Lowland Street in the Lowland Industrial Park identified as Map 12, Block 4, Lot 34.

Hearing notice under the requirements of the By-Law and MGL, c. 40A included the following:
1. Publication of a hearing notice in the Metrowest Daily News on July 13 and 20th,
2. Posting of the public hearing notice with the Town Clerk on July 7th, and
3. Abutter notification (including surrounding towns) by mail on July 12th.

The Applicant filed with the Planning Board the following, which are contained in the records at the Planning Board office and are incorporated into this Decision by reference:
1. Application and narrative for Site Plan Review filed with the Planning Board and Town Clerk on July 7, 2011 signed by the Applicant and Owner's Representative.
2. Plans entitled "Site Plan of Land in Holliston, MA", consisting of two sheets, dated July 7, 2011 (revised through August 11, 2011) prepared and stamped by Bruce Wilson, Jr. PLS.

Owner of record: Simeone Corp
Bk 11841 Pg 582
Bk 14708 Pg 121

The Planning Board also received correspondence from the Town of Holliston Fire Chief (dated July 27) and Police Chief (dated August 2) as well as Richard T. Westcott, PE of Westcott Site Services, civil engineering consultant for the Planning Board (dated July 18, 2011). The aforementioned are contained in the Planning Board files and are incorporated into this Decision by reference.

PUBLIC HEARING AND FINDINGS

During the course of the public hearing, the following individuals made appearances on behalf of the Applicant and Owner: Michael Brumber (applicant), Attorney Mark Helwig, Dennis Lydon of Aggregate Industries (owner), Bruce Wilson, PLS of GW Site Solutions, Inc.(surveyor), Russell Waldron of AES Applied Ecological Sciences (wetland ecologist) and J. David Simmons, Esq. of Angle Tree Consulting. No abutter or other party of interest was in attendance.

The Applicant explained that the property, which is the subject matter of several historical Zoning Board of Appeals Special Permits and Variances and this application, is located on Lowland Street within the Lowland Industrial Park. The existing buildings, parking, and outdoor storage areas are all located within the Industrial zoning district. The Applicant will occupy one of the buildings as an office and will store excavating equipment, construction materials and the company's fleet on site.

The Applicant requested a Special Permit under the Holliston Zoning By-Laws, Section III-A Schedule of Use Regulations (#42a "General industrial uses..." and #49 "Outside storage of building or other materials not covered elsewhere in this by-law") for processing and outside storage of building materials and equipment year-round. The exterior material storage areas are not proposed to be individually enclosed but are identified on the site plan with piles labeled as raw and processed materials, and the site perimeter is primarily comprised of concrete barriers and earthen berm. The Applicant is primarily engaged in processing and recycling of asphalt and concrete rubble material to produce "recycled aggregate" materials suitable for construction projects. Such processing requires a Determination of Need (Large Operation) from the Massachusetts Department of Environmental Protection (BWP SW 02). The quantity identified in that permit application totals 125,000 tons per year with a maximum of 1,000 tons received per day (300 tons on average). This aspect of the operation – receiving unprocessed materials -- is limited to approximately 6 months per year (April – October). Materials will be acquired from rehabilitation and construction of roadways, parking areas, storage area restoration and construction sites as well as demolition of bridges, buildings and other structures. The Applicant has indicated that a maximum amount of 10,000 tons of materials will be stored while "in process" and 10,000 tons of processed materials will be stored prior to shipment. Approximately 20 tons of non-recyclable residue (primarily rebar and wire mesh) have been identified and will be stored until shipped to another recycler.

Proposed site improvements were described, including truck circulation, screening, parking and security. Manufacturer specifications for a portable track-mounted crusher which will feed a portable screener that will sort and disperse recycled asphalt material into assorted sizes from ¾" to 3" have been provided.

At the public hearing sessions, no abutters offered testimony for or against the proposal. Upon motion made and duly seconded, the public hearing was closed on August 11, 2011.

Special Permit and Site Plan Certificate of Action
Michael Brumber, 157 Lowland Street

Having reviewed all the plans and reports filed by the Applicant and his representatives and the representatives of the Town, considered the testimony at the Public Hearing and having viewed the site, the Planning Board has determined that the Application for Special Permit and Site Plan Review is consistent with the requirements of Sections III-A and VII of the Zoning By-Law.In connection with the application for Special Permit for Use pursuant to Section III-A, the Board makes the finding that the use is in harmony with the general purpose and intent of the By-Law.

The Site, as noted, is presently vacant within a planned industrial park. The proposed use of the site for outside storage of materials (sand & gravel, recycled asphalt and concrete products, and equipment) is consistent with the uses allowed under the zoning by-law within the Industrial district. The Board finds that the aforesaid uses can be made at the Site in a manner that is not detrimental to the surrounding areas provided that the conditions of this decision and that of the Commonwealth are complied with.

The Board finds that the intended use and associated traffic will not have a negative impact upon safety, as Lowland Street is a planned industrial roadway and that the entry provides for appropriate sight distance for vehicles exiting the site. Finally, the Board finds that the completion of the facility will result in improvement of the Site and will promote business development in the community. The Board also finds that the proposal meets the General Conditions for approval specified in Section VII (2)(a-g) of the Holliston Zoning Bylaw.

CONDITIONS OF APPROVAL

The Board's decision to grant the Application for Site Plan Review is subject to the following conditions:

1. This Special Permit is issued solely to the applicant and is not transferable or assignable. The Special Permit is not valid until recorded and indexed at the Registry of Deeds in accordance with the provisions of MGL, c. 40A, s. 11. The copy of the decision to be filed must contain a certification by the Town Clerk that 20 days have elapsed since after the decision was filed and that no appeal has been filed or if such appeal has been filed, that it has been dismissed or denied.
2. **A copy of the recorded decision and revised plan set shall be presented to the Inspector of Buildings.** Unless amended with the approval of the Planning Board, the endorsed plan set shall be the plan of record and operations shall proceed in accordance with the improvements shown on said plan and this Certificate of Action.
3. The Applicant shall not receive or process asphalt and concrete rubble material requiring a Determination of Need (Large Operation) from the Massachusetts Department of Environmental Protection (BWP SW 02) until said "permit" is presented to the Inspector of Buildings.
4. No corrections, additions, substitutions, alterations or any changes shall be made in any plans, proposals, and supporting documents approved and endorsed by the Planning Board without the written approval of the Planning Board. Any requests for modifications shall be made in writing to the Planning Board for review and approval and shall include a description of the proposed modification, reasons the modification is necessary, and any supporting documentation.

5. A copy of this decision shall be kept on site and shall be made available to all site contractors.
6. Non-security lighting shall be extinguished overnight within 30 minutes after close of operations.
7. Prior to commencement of authorized site activity, the Applicant shall provide to the Planning Board Office the name, address and business phone number of the individual(s) who shall be responsible for all activities on the site. Additionally, the Police and Fire Departments should be provided with an emergency notification sheet.
8. Street numbers (5-6" in height) are to be added to any freestanding sign installed along Lowland Street.
9. Outside storage of materials and equipment not associated with site environmental cleanup is limited to areas designated on the site plan. Pile heights are limited to 25' and safe site circulation must be maintained at all times.
10. The applicant shall install/repair the dust suppression system prior to commencement of processing operations and shall operate that system at all times when the crusher and screener are operating.
11. The applicant shall not cause a nuisance to residents due to dust and/or odors. If, in the opinion of this Board, the above measures do not sufficiently mitigate noise and dust migrating off the property, the Board will notify the Applicant in writing and the Applicant shall supply a corrective action plan within thirty (30) days for the Board's review and approval. The Inspector of Buildings may take additional measures as the Town's Zoning Enforcement Officer.
12. No outside activity, including loading of materials is allowed on-site prior to 7:00 a.m. or after 7:00 p.m. Monday through Saturday with the exception of seasonal snow plowing activity and properly-noticed overnight activity to receive millings. Notification must be given to the Building Department and Police Department a minimum of 24-hours in advance of overnight activities. A maximum of 20 nights for such activities are allowed per calendar year. No processing shall occur after 6 p.m.
13. The Applicant shall take measures to prevent vehicle queuing at the site entrance and along Lowland Street, especially before 7 a.m.
14. The applicant shall also direct his vehicles as well as deliveries to utilize the industrial roads in the area in order to minimize impacts to residential areas. This includes utilization of Jeffrey Avenue and Whitney Street to access Washington Street.
15. The responsibility for the maintenance and operation of the drainage system will be the responsibility of the applicant. The applicant shall maintain the drainage system and shall provide semi-annual inspection of the sedimentation basin to the Planning Board. If necessary, the Applicant shall clean the basin so as to maintain the system in proper working order.
16. The Board reserves the right to impose additional requirements in the event that the drainage system fails and water overflows, creating a safety issue.
17. Prior to the issuance of a Certificate of Occupancy, the Applicant shall submit an as-built plan stamped by a professional engineer certifying that all site improvements are completed in accordance with the approved plan. The Applicant shall submit a statement certifying that all conditions of approval of this decision have been met.
18. Prior to the issuance of a Certificate of Occupancy, the Police and Fire Department shall be provided with keys to any proposed gates and buildings (e.g. Knox box) and an accurate materials list depicting the contents of the storage areas (including MSDS).

19. The double-walled aboveground fuel storage tank shown on the site plan shall be inspected and approved by the Holliston Fire Chief.

Planning Board Vote
The Board's vote in favor of granting Special Permit and Site Plan approval for Michael Brumber is as follows on a motion made and duly seconded:

John J. Donovan	Yes
Parashar Patel	Yes
Jonathan Loya	Yes
Geoffrey Zeamer	Yes
Warren Chamberlain	Yes

HOLLISTON PLANNING BOARD
BY:

Jack Donovan
D.L.

John J. Donovan
Chairman

I hereby certify 20 days have elapsed since after the decision has been filed in my office and that no appeal has been filed or if such appeal has been filed, that it has been dismissed or denied.

Elizabeth S. Greendale Date: Sept. 16, 2011

Elizabeth Greendale

Town Clerk

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 224

GUIDELINES FOR RECYCLING PAVEMENT MATERIALS

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT **224**

GUIDELINES FOR RECYCLING PAVEMENT MATERIALS

J. A. EPPS, D. N. LITTLE, AND
R. J. HOLMGREEN
Texas A&M University
College Station, Texas
AND
R. L. TERREL
University of Washington
Seattle, Washington

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:

- PAVEMENT DESIGN AND PERFORMANCE
- BITUMINOUS MATERIALS AND MIXES
- CEMENT AND CONCRETE
- CONSTRUCTION
- GENERAL MATERIALS
- MAINTENANCE
- (HIGHWAY TRANSPORTATION)
- (RAIL TRANSPORTATION)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. SEPTEMBER 1980

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP Report 224

Project 1-17 FY '77
ISSN 0077-5614
ISBN 0-309-03029-3

L. C. Catalog Card No. 80-83199

Price: $9.20

Notice

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the National Academy of Sciences, or the program sponsors.

Each report is reviewed and processed according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved by the President of the Academy upon satisfactory completion of the review process.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its Congressional charter of 1863, which establishes the Academy as a private, non-profit, self-governing membership corporation. The Council has become the principal operating agency of both the Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the Academy of Sciences. The Transportation Research Board evolved from the 54-year-old Highway Research Board. The TRB incorporates all former HRB activities but also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America.

FOREWORD

By Staff
Transportation
Research Board

The recycling guidelines contained in this report will be of special interest to individuals involved in the planning, design, and construction of pavement rehabilitation projects. Rehabilitation is rapidly becoming a major factor in the use of available highway funds, and the recycling of pavement materials has become an important pavement rehabilitation alternative. The guidelines contained herein are based on a thorough review of literature on pavement recycling, field experience gained from Federal Highway Administration Demonstration Project 39 ("Recycling Asphalt Pavements") and other projects, and an experimental program involving laboratory and field studies. These guidelines provide the practicing engineer with the latest information on recycling of pavement materials, particularly with regard to material selection, structural design, and construction specifications.

The need to reuse or recycle existing pavement materials for the reconstruction and rehabilitation of both asphaltic and portland cement concrete pavements is of increasing importance in order to optimize the utilization of available materials and energy supplies as well as funds for operating our highway systems. The objective of the research conducted under NCHRP Project 1-17 was to develop realistic guidelines for recycling of pavement materials for the reconstruction and rehabilitation of existing pavements.

The Texas A&M University researchers had previously prepared a state-of-the-art report published as *NCHRP Synthesis of Highway Practice 54,* "Recycling Materials for Highways." This report provided a basis for the Project 1-17 literature review. However, because of the rapidly evolving nature of pavement recycling technology, much of the information for the preparation of the guidelines was obtained from experience in the field during the design and construction of pavement recycling projects. Additionally, the researchers conducted a field evaluation of the performance of previously constructed recycled pavements, and laboratory studies were performed on recycled asphaltic concrete mix design and modifiers. The research covered recycling of both asphaltic and portland cement concrete pavements. Because of the extensive field experience and more advanced state of the art with asphaltic pavement recycling, the guidelines are more complete for this type of pavement.

The final report as submitted by the researchers consisted of three volumes. Volume 1 contained the research report. Volume 2 included a large number of appendix items covering the various portions of the laboratory and field studies. Volume 3 documented the guidelines and another group of appendix items. This report (*NCHRP Report 224*) combines major portions of the research report from Volume 1 and the complete guidelines plus the more significant appendix items from Volume 3. Although not included in the published document, copies of the remaining Volumes 2 and 3 appendix items have been printed by the research agency as Supplement A and Supplement B. Copies have been distributed to highway and transportation agencies and are available to other interested persons from the Program Director, NCHRP, Transportation Research Board, 2101 Constitution Avenue, N. W., Washington, DC 20418. A listing of these items is contained in Appendix K of *NCHRP Report 224*.

Although the art of pavement recycling continues to evolve, the guidelines for the planning, design, and construction of recycling projects are suitable for immediate implementation. They are based on extensive field experience and contain procedures for selecting from among recycling alternatives, construction and energy information, material requirements, and model specifications. Additional information is needed on long-range performance of recycled pavements. The report contains suggestions for data collection and analysis to fill this need and provide for improved pavement rehabilitation guidelines.

CONTENTS

ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 1-17 by the Texas Transportation Institute, Texas A&M University. The principal investigator for the Texas Transportation Institute was Jon A. Epps, Research Engineer and Professor of Civil Engineering. The other authors of the report are Dallas N. Little, Assistant Research Engineer and Assistant Professor of Civil Engineering, Texas Transportation Institute; Richard J. Holmgreen, Engineering Research Associate, Texas Transportation Institute; Ronald L. Terrel, Professor of Civil Engineering, University of Washington; and William B. Ledbetter, Research Engineer and Professor of Civil Engineering, Texas A&M University. Bob M. Gallaway provided overall administration and technical supervision of the project for the Texas Transportation Institute.

Technical guidance for the investigation was provided by the following consultants: Fred N. Finn, Consultant, Ben Lomond, California; R. G. Hicks, Professor of Civil Engineering, Oregon State University; L. C. Krchma, Consultant, Kansas City, Missouri; and Ronald L. Terrel, Professor of Civil Engineering, University of Washington.

Grateful acknowledgment is extended to the following States, counties, and cities that assisted in obtaining pavement deflection readings or supplied materials from recycling projects. Cooperating state agencies included state highway departments in Arizona, California, Iowa, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Nevada, Oklahoma, Oregon, Texas, Utah, Virginia, Washington, and Wyoming. Cooperating counties included Elkhart County, Ind.; Fresno County, Calif.; Kings County, Calif.; Kossuth County, Iowa; and Washoe County, Nev. Cooperating cities included Amarillo, Tex.; Beverly Hills, Calif.; Glendale, Calif.; and Lemoore, Calif.

The following companies supplied samples of recycling modifiers for testing: Ashland Petroleum Company, AMOCO Oil Company, Chevron USA, Douglas Oil Company, Kerr-McGee Corporation, Lion Oil Company, Mobil Oil Corporation, Pax International, Phillips Petroleum Company, Shell Oil Company, and Witco Chemical Company.

Member companies and individuals from the following institutes, associations, and groups contributed to the study through their review of recycling guidelines or by supplying reference information: American Concrete Paving Association, Asphalt Emulsion Manufacturers Association, Asphalt Recycling and Reclaiming Association, The Asphalt Institute, National Asphalt Pavement Association, Portland Cement Association, and West Coast User-Producer Group on Asphalt Specifications.

GUIDELINES FOR RECYCLING PAVEMENT MATERIALS

SUMMARY

Rehabilitation and maintenance of the present transportation system is costly, time consuming, and material intensive. Reuse or recycling of the existing pavement materials for rehabilitation and maintenance purposes offers several advantages over the use of conventional materials and techniques. Among the major benefits are conservation of aggregates, binders, and energy as well as preservation of the environment and existing highway geometrics.

Because recycling appeared to be an attractive alternative for pavement rehabilitation and maintenance, the National Cooperative Highway Research Program synthesized available data on recycling and published the information as *NCHRP Synthesis of Highway Practice 54*. In order to provide information for implementation of recycling technology, NCHRP Project 1-17 was initiated to develop realistic guidelines for the recycling of pavement materials. Results of this project are documented herein.

The guidelines for recycling pavement materials have been developed in this project based on existing literature, personal conversations and correspondence, and a laboratory and field testing program. These guidelines are intended to provide to the practicing engineer the following information:

1. Point out the potential advantages of recycling.
2. Assist both in making a preliminary analysis of recycling as a pavement rehabilitation alternative and in identifying a suitable methodology.
3. Provide guidance and criteria for making a detailed analysis of cost, energy, materials design, structural design, construction specifications, and quality control.
4. Recommend a methodology for evaluating project results so that recycling alternatives can be compared with conventional methods of rehabilitation.

The laboratory testing program conducted on pavement modifiers, recycled asphalt mixtures, and recycled portland cement concrete mixtures resulted in the following findings:

1. Testing techniques must be carefully controlled when asphalt modifying agents are evaluated.
2. Laboratory evaluation tests must be performed on a project by project basis.
3. Existing methods to predict asphalt modifier contents are sufficiently accurate to allow the engineer to estimate required modifier quantities.
4. The temperature susceptibility of modifier–asphalt blends is dependent on the type of modifier used. The amount of modifier (within reasonable limits) does not greatly alter the temperature susceptibility.
5. The compatibility of asphalt modifiers and old recycled asphalts needs to be defined more accurately.
6. The resilient modulus value indicates the ability of a modifier to alter the properties of the old recycled asphalt.
7. High Marshall flow values are often associated with recycled mixtures.
8. Recycled and conventional mixtures with acceptable Marshall stabilities may not have adequate Hveem stability.

9. Recycled mixtures may be water susceptible. Modifier type apparently does not affect water susceptibility.

10. The water susceptibility test recommended by Lottman (*40*) is more severe than vacuum saturation and soak procedures used routinely at Texas A&M University.

11. Recycled pavements need to be sampled at several locations in order that project variation can be considered.

12. Portland cement concrete made with recycled portland cement concrete or combinations of recycled portland cement concrete and asphaltic concrete can be designed such that acceptable strength characteristics in both compression and tension can be obtained. Increased water contents will normally be required when crushed recycled aggregates are used to produce the desired workability. Higher shrinkage and poorer durability can be expected for recycled aggregate portland cement concrete. Increased water content and the fact that old portland cement concrete used as an aggregate is not air entrained may contribute to the observed lower durability.

13. Suitable econocrete mixtures can be made with recycled portland cement concrete or combinations of recycled portland cement concrete and asphaltic concrete. Increased water contents will normally be required to produce the desired workability when crushed recycled aggregates are used. Lower strength, poorer durability, and higher shrinkage can be expected for recycled aggregate econocrete mixtures.

The structural evaluation of recycled asphaltic concrete material led to the following conclusions:

1. Hot recycled asphaltic concrete is generally structurally comparable to conventional asphaltic concrete.

2. Hot recycled asphaltic concrete used as a base course is potentially very effective in either maintaining or increasing the structural capability of a pavement section.

3. Hot recycled asphaltic concrete surfaces are slightly stiffer than conventional asphaltic concrete surfaces. As a consequence their fatigue characteristics require careful study.

4. In-place recycled asphaltic concrete materials used as base courses have successfully employed stabilizers including asphalt cement, emulsified asphalt, lime, and cement.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

The concept of recycling pavement materials has been available and has been used for many years in a limited manner. In recent years, because of more interest in such factors as energy and materials conservation recycling has become a more attractive alternative to rehabilitating pavements. This report is intended to serve as a guide to the engineer and provide assistance in determining when recycling is viable and how to perform the recycling operation from a design and construction standpoint.

Specifically, the guidelines contained herein are intended to do the following:

1. Point out the potential advantages of recycling.
2. Assist both in making a preliminary analysis of recycling as a pavement rehabilitation alternative and in identifying a suitable methodology.
3. Provide guidance and criteria for making a detailed analysis of cost, energy, materials design, structural design, construction specifications, and quality control.
4. Recommend a methodology for evaluating project results so that recycling alternatives can be compared with conventional methods of rehabilitation.

Figure 1 shows an overview of the guidelines.

BACKGROUND

Federal, state, and local agencies including city and county governing bodies responsible for transportation facilities are faced with a number of problems including the following:

1. A reduction in available funds for transportation facilities caused by inflation, decline in tax base, reduction or leveling in revenue from fuel tax, and fiscal demands of other programs among other factors.
2. Materials supply problems resulting from depletion of sources near the point of use; unavailability due to zoning laws; increased haul distances and associated transportation costs; strict environmental codes limiting production in certain areas and requiring major expenditures for air and water quality, noise control and pit and quarry restoration; and use of construction materials for other than construction purposes.
3. Equipment availability problems resulting from reduced budgets, high cost of new equipment, and other factors.
4. Manpower problems resulting from fiscal constraints on wages, which often create a deficiency of trained equipment operators and qualified engineering-oriented employees, labor-management problems, and need to increase production to provide for an economical operation.
5. Energy problems associated with fuel availability, cost, and urgent need to reduce energy consumption.

Because of these problems and others, there is an urgent need to optimize the use of aggregates, binders, equipment, manpower, energy, and funds from planning, design, construction, rehabilitation, and maintenance standpoints.

One solution to some of the transportation problems outlined is to reuse or recycle existing materials for construction, rehabilitation, and maintenance purposes. Recycling of pavement materials (such as asphaltic concrete and portland cement concrete) offers several advantages over the use of conventional materials. Among the major benefits are conservation of aggregates, binders, and energy and preservation of the environment and existing highway geometrics.

Conservation of aggregate and binder is important. Although the United States has an abundant supply of source materials for production of quality aggregates for the foreseeable future (*1*, *2*), distribution of these sources does not always coincide with location of need. Thus, it has become necessary to haul aggregates over large distances. This has escalated the cost and the energy consumed in constructing transportation facilities. Recycling the aggregate in the old pavement for reconstruction, for rehabilitation, or for maintenance purposes will decrease aggregate demand and extend the supply of construction aggregate at a time when sources (particularly near urban areas) are being depleted because of high use, mining restrictions, environmental protection regulations, and appreciating land values.

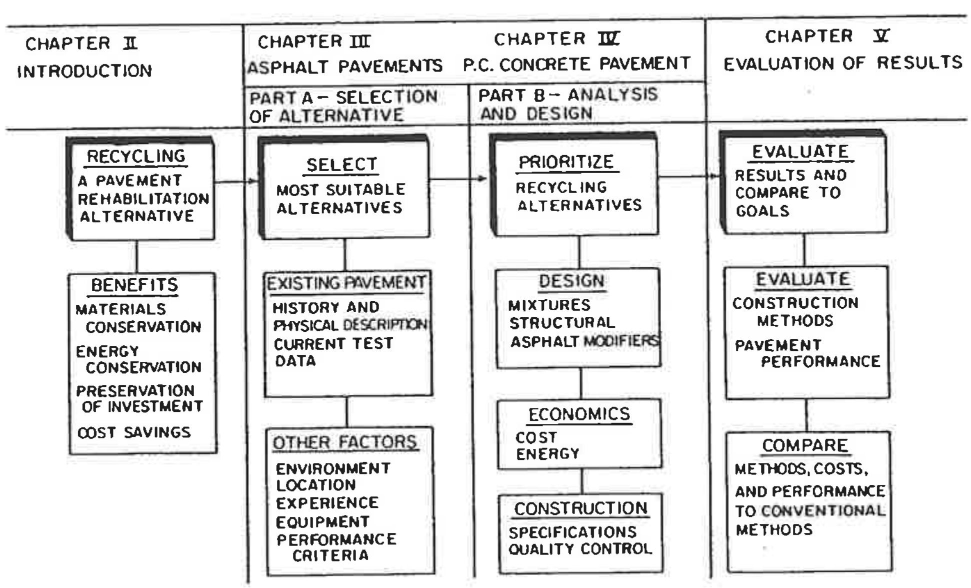


Figure 1. Overview of guidelines for recycling pavements.

Conservation of binders is another important advantage accorded by recycling. For example, pulverization and re-use of asphaltic concrete normally requires about 1 to 3 percent additional asphalt, whereas a new asphaltic concrete mixture requires about 6 percent. This saving of about 10 gal of asphalt per ton (0.04 l/kg) of asphaltic concrete can contribute to the national fuel conservation program. Asphalt can be used directly as fuel for electrical power plants, for utilities at refineries, or can be converted to other hydrocarbons for use in aircraft, automobile, and steel manufacturing.

The conservation of energy is apparent in recycling operations if one considers the reduced hauling required for aggregates and the reduced hauling and production energy required for the binder in recycled pavement materials. Energy savings of recycling operations, however, should be determined on a job-to-job basis.

Recycling can contribute to environmental preservation by reducing the amount of new materials required for highway use. Thus, a corresponding reduction is possible in environmental problems of mining the new material and manufacturing the products, in addition to avoiding the problems associated with disposition of the old pavement.

The maintenance of highway geometrics can be achieved relatively easily by pavement recycling. For multilane facilities, only the distressed lane need be recycled. Full width overlays are not required to promote drainage. Vertical clearance problems caused by overlays at bridges, signs, and tunnels can be overcome by strengthening the existing surfaces, base, or subgrade. Vertical control problems with drainage facilities, such as gutter flow lines, curb height, inlet capacity, and manholes, are reduced when recycling operations are used instead of overlays.

Because the benefits of recycling appear promising from a wide variety of viewpoints, a number of agencies including the National Cooperative Highway Research Program (NCHRP) have sponsored research. *NCHRP Synthesis of Highway Practice 54,* "Recycling Materials for Highways," was the first comprehensive summary of recycling information (*3*). Federal Highway Administration sponsored programs include Demonstration Project No. 39 (*4, 5*); Demonstration Project No. 47 (*6*); National Experimental and Evaluation Program (NEEP) Project No. 22 (*7*); Implementation Package 75-5 (*8*); Office of Research studies on "Softening or Rejuvenating Agents for Recycled Bituminous Binders," "Tests for Efficiency of Mixing Recycling Asphalt Pavements," "Data Bank for Recycled Bituminous Concrete Pavement," and "Materials Characterization of Recycled Bituminous Paving Mixtures"; and HPR and special state studies (*9, 10*). Other government sponsored studies have been performed by the Corps of Engineers (*11*) and the Navy (*12*).

Associations and institutes that have contributed to the collection and distribution of recycling information include the American Concrete Paving Association, Asphalt Emulsion Manufacturers Association, Asphalt Reclaiming and Recycling Association, The Asphalt Institute (*13*), National Asphalt Pavement Association (*14, 15*), Portland Cement Association (*16*) and West Coast User-Producer Group on Asphalt Specifications (*17*). In addition, conference sessions and symposiums have been held on pavement recycling at the Transportation Research Board, American Society for Testing and Materials (*18*), and Association of Asphalt Paving Technologists.

Because recycling has become an attractive alternative for pavement rehabilitation and because of the large amount of developing technology that has become recently available, NCHRP formulated a research project (NCHRP Project 1-17) to develop realistic guidelines for the recycling of pavement materials. The investigation performed under NCHRP Project 1-17 for the development of guidelines for pavement recycling is described herein.

RESEARCH OBJECTIVE AND APPROACH

The overall objective of this project (NCHRP Project 1-17) was to develop realistic guidelines for the recycling of pavement materials for the rehabilitation and reconstruction of existing pavements.

The general research approach used to accomplish this objective consisted of reviews of the existing literature, performance of laboratory and field tests, together with analysis of the data and evaluation of the practicality of the guidelines. Specifically the following tasks and subtasks were performed:

Task 1—Develop guidelines for recycling pavement materials

1. Conduct literature review.
2. Define recycling approaches.
3. Define conditions under which recycling is a feasible rehabilitation alternative.
4. Define laboratory and field tests suitable for evaluating materials to be recycled.
5. Define preliminary pavement design methods.
6. Determine costs of various recycling alternatives and define a method for life-cycle analysis.
7. Determine a process for selecting the most promising recycling alternatives for a given project.
8. Define laboratory and field tests suitable for the design of recycled mixtures.
9. Define detailed pavement design methods.
10. Determine energy requirements for various recycling approaches.
11. Develop specifications for major recycling approaches.
12. Prepare interim guidelines for pavement recycling.

Task 2—Evaluate practicality of guidelines

1. Identify guideline problem areas.
2. Perform laboratory and field testing and analysis programs to resolve identified problem areas.
3. Refine interim recycling guidelines.

The "Interim Guidelines for Recycling Pavement Materials" was prepared and copies of the report were distributed to state highway and transportation agencies.

Laboratory and field test programs were conducted to provide a basis for improvement in specific portions of the interim guidelines. Studies were performed to provide information for the following purposes:

1. Preparation of specifications for asphalt recycling modifiers.
2. Preparation of mixture design methods for recycling asphalt and portland cement concrete recycled pavements.
3. Definition of mixture characteristics of recycled asphalt and portland cement concrete recycled mixtures.
4. Structural coefficients for recycled mixtures.
5. Performance of recycled pavements.
6. Evaluation of the practicality of the developed recycling guidelines.

On the basis of the comments received and the laboratory and field test programs, the interim guidelines were revised. These revised guidelines are issued in this report (*NCHRP Report 224*). Full details of the laboratory and field test results and more complete discussions of design criteria for selecting pavement recycling alternatives are contained in the Volumes 2 and 3 appendixes of the agency's final report as submitted to the sponsors. For the availability of these materials, the reader is referred to the "Foreword" in this report. For the convenience of qualified researchers, the contents of this appendix material are listed here in Appendix K.

USE OF THE REPORT

Figure 2 shows the overall concept of pavement rehabilitation and the fact that recycling is only one of several rehabilitation alternatives the selection of which depends on the observed pavement distress, the establishment of the probable causes of distress based on field and laboratory study, and design input information such as the history of pavement maintenance requirements and costs, history of pavement performance, horizontal and vertical geometric controls, environmental factors, and traffic.

Once recycling has been selected as a possible rehabilitation alternative, the guidelines can be used to select the most promising recycling option. Chapter Three should be used if an asphalt pavement is to be recycled; Chapter Four should be used if a portland cement concrete pavement is to be recycled.

Chapters Three and Four describe the limited laboratory and field tests that should be performed to establish the material resources available in the pavement and the types of possible stabilizers that can be used with the materials. From this preliminary information, recycling alternatives can be selected. Chapters Three and Four also cover a more detailed evaluation of the promising recycling alternatives. Detailed laboratory tests are described that determine stabilizer contents, the need for recycling agents, and the pavement structural requirements. (The term recycling agent has been defined by the Pacific Coast User-Producer Group as a "hydrocarbon product with physical characteristics selected to restore aged asphalt to requirements of current asphalt specifications." It should be noted that soft asphalt cements as well as specialty products can be classified as recycling modifiers or agents. The terms asphalt modifier, softening agent, and reclaiming agent have also been used to describe this product.) Energy requirements for the recycling alternatives are outlined as well as construction specifications.

Chapter Five is devoted to a description of methods to determine the performance of recycled pavements. Both field and laboratory testing programs are outlined. These data are suggested for use as feedback from which the engineer can select future pavement rehabilitation alternatives.

Chapter six contains example problems that illustrate the methodology used in the guidelines to define a recycling method suitable for a particular pavement. It should be realized that more than one recycling approach will likely be suitable for a given pavement. In addition, the engineer must consider life-cycle cost and energies associated with both recycling and conventional rehabilitation alternatives.

Appendixes have been prepared to provide the detail necessary for the engineer to successfully use the guidelines.

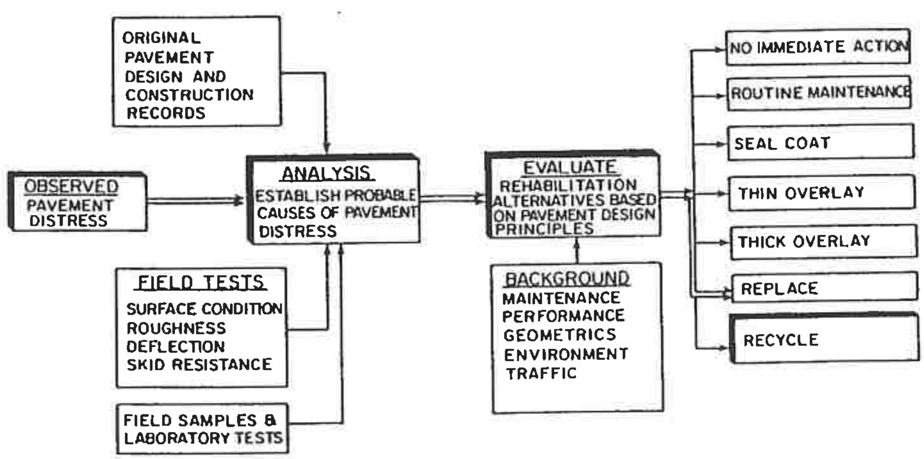


Figure 2. Recycling as a rehabilitation alternative.

CHAPTER TWO

FINDINGS—STATE-OF-THE-ART AND LABORATORY AND FIELD TEST SUMMARIES

RECYCLING ALTERNATIVES

Recycling or reuse of existing pavement materials for pavement rehabilitation, reconstruction, and maintenance is not a new concept. A wide variety of recycling approaches has emerged since 1915 (*19*). Categorization of recycling approaches is usually based on (1) the recycling procedure used, (2) the type of paving materials to be recycled and the end products they are to produce, or (3) the structural benefit to be gained from the recycling approach. Each of these categories has its own merit in describing the purpose and applicability of a given type of recycling. A categorization based on the recycling procedure has been used in this report.

Definitions for recycling categories have been prepared by the Federal Highway Administration Demonstration Project No. 39 Technical Advisory Committee (*4*), a joint National Asphalt Pavement Association–Asphalt Institute Committee (*20*), Asphalt Recycling and Reclaiming Association (*21*), National Cooperative Highway Research Program (*3*), U.S. Army Engineers Waterways Experiment Station (*11*), and Navy Civil Engineering Laboratory (*12*). For convenience, pavement recycling alternatives have been divided into several general categories:

1. *Surface recycling*—reworking of the surface of a pavement to a depth of less than about 1 in. (25 mm) by heater-planer, heater-scarifier, hot-milling, cold-planing, or cold-milling devices. This operation is a continuous, single-pass, multistep process that may involve use of new materials, including aggregate, modifiers, or mixtures.
2. *In-place surface and base recycling*—in-place pulverization to a depth greater than about 1 in. (25 mm), followed by reshaping and compaction. This operation may be performed with or without the addition of a stabilizer.
3. *Central-plant recycling*—scarification of the pavement material, removal of the pavement from the roadway prior to or after pulverization, processing of material with or without the addition of a stabilizer or modifier, and laydown and compaction to desired grade. This operation may involve additional heat, depending on the type of material recycled and the stabilizer used.

Surface Recycling

Surface recycling differs from the other broad categories of recycling in that it involves reworking the surface of a pavement to a depth of less than 1 in. (25 mm) (unless multiple passes are made). Thus, surface recycling has a limited effectiveness in repairing rough riding or severely rutted roads or in significantly increasing the load-carrying capacity of the roadway. However, surface recycling is presently the most popular form of recycling because it can treat a wide variety of pavement distress, including raveling, rutting, flushing, and corrugations at a reasonable cost. Additionally, data illustrate the usefulness of heater scarification plus an overlay to reduce reflection cracking. Other advantages of surface recycling appear to be its ability to promote a bond between the old roadway and a thin overlay and to provide a transition between the new overlay and existing gutters, bridges, pavements, and so forth. The material removed by planing and milling can be reused in stabilized or unstabilized bases and shoulders and in stabilized surfaces.

The evolution of surface recycling equipment is not well documented; however, literature indicates that three of the original heater-planer units were developed in California in the 1930's (*22*). One early unit was a heater, towed as a semitrailer behind a truck trailer, followed by an independent grader. A second unit was a combined heater and planer. A third unit was a heater mounted on a grader. The grader blade on this unit was replaced by a planer blade. The diesel oil-fired heater was pulled by the scarifier arms, and the solid rubber tires were cooled by water dripping from a front-mounted water tank. The blade could be rotated to deliver the cuttings inside the rear wheels on either side. The cuttings were picked up by a front-end loader (*22*).

The first surface recycling machine that did not use heat apparently dates to about 1936 (*22*). This device used chisels to cut the cold roadway. Since the early days of cold surface recycling, techniques have been developed to grind the pavement with rotating drums equipped with cutting teeth.

Since 1930, a wide variety of recycling equipment has been developed and a number of innovative techniques established. For discussion purposes, this equipment and the associated techniques have been categorized into heater planers, heater scarifiers, hot millers, cold planers, and cold millers.

Heater Planing

Heater planing has been used primarily for maintaining pavement longitudinal grade and transverse cross slope. Other uses include removing pavement from bridges to reduce the dead weight; maintaining proper clearances in tunnels, at underpasses, and at sign bridges; removing improperly designed or constructed chip or slurry seals; and removing surface irregularities from rough pavements caused by instability, swelling clays and/or repeated maintenance activities such as crack sealing, and the like.

It is a common practice to heat and plane a pavement prior to overlay. This activity will correct rutting problems, remove some of the pavement roughness, and provide a header cut, gutter cut, or keyway to prevent feathering of the hot mix. Any material that is removed from the roadway can be reused.

A unique application of the heater planer is to use the heating units to aid in a corrective maintenance activity. For pavements with poor skid resistance, a layer of polish-resistance aggregate is spread on the surface with a conventional seal-coat spreader. The heating unit then heats the pavement and is followed by a steel-wheel roller to embed the aggregate into the old pavement surface. This activity is particularly effective where flushing or bleeding is a problem.

Heater Scarifying

Recycling operations using the heater-scarifying approach take many forms. The basic operations consist of preparing, heating, and scarifying the surface; adding additional materials if required; compacting; making final adjustments to manholes and drainage structures; and opening the facility to traffic.

Heater scarifiers have also been used to remove pavement surface irregularities. Use of these units immediately before making an asphaltic concrete overlay offers some advantages. Pavement surface roughness can be removed to provide a smooth surface for a new wearing course and thereby eliminate or reduce the amount of leveling course required. The bond between the old pavement and a new asphaltic concrete overlay is also improved by use of the heater scarifier or heater planer immediately before an overlay.

Reflection cracking, which is a major consideration in overlay design, may be reduced by use of heater scarifying prior to overlaying asphaltic concrete pavements. Documentation illustrates this advantage in the southwest.

Hot Milling

Hot-milling has not been extensively used in the United States. The process is limited to aspalt-surfaced roadways and is performed for the same general purposes as given in the section on cold milling.

Cold Planing

Cold-planing operations are commonly performed in the summer on asphalt-surfaced roadways. The primary purposes of cold planing are to remove corrugations and other stability failures, to reduce the amount of rutting, and to remove improperly designed or constructed chip seals or slurry seals. The appearance and performance of cold planing are not as satisfactory in most cases as the heater-planer technique.

Equipment normally used for cold planing by city and county governments is a motor grader with hardened steel blades. The operation is normally considered to be maintenance, and the removed material is often reused.

Cold Milling

Cold milling has been performed on both asphalt-surfaced and portland cement concrete-surfaced roadways. The major purpose of cold milling is removal of surface deterioration.

Millings can be used for unstabilized base courses or stabilized base and surface courses. The millings can be treated either in-place or at a central plant.

The types of pavement distress that can be treated by cold milling include rutting, raveling, flushing, and corrugations of asphalt-surfaced pavements; and rutting, raveling, scaling, faulting, and spalling of portland cement concrete-surfaced pavements. The success of cold milling depends on the nature and extent of the distress, among other factors.

Additional applications of cold milling include repairing a rough-riding road, improving skid resistance, and preparing an asphaltic concrete or portland cement concrete surface to receive an overlay. Automated grade control features on many cold-milling machines afford the opportunity to improve ride quality.

Most milling operations improve the surface texture of the roadway and crush the exposed surface of the aggregate. Both the improved surface texture (macrotexture) and the crushed aggregate (microtexture) promote skid resistance. The improvement in skid resistance may, however, be temporary if the aggregate is polish susceptible. The improved pavement surface texture will also increase the bond or shear strength between the old surface and a new overlay. This bond strength is particularly important for portland cement concrete overlays such as those used on bridge decks.

In-place Surface and Base Recycling

In-place recycling of old asphaltic concrete and portland cement concrete pavement is not a new concept. Almost every state has used conventional construction equipment such as bulldozers, vibratory compactors, rollers, and the like, to crush old pavement and combine it with a portion of the existing base or subbase to form a reconstituted structural layer. The development of pulverizing equipment and processing techniques are among the more important recent refinements of in-place recycling.

Stabilizers such as lime, cement, asphalt, and other chemicals have been used in these processes. Use of cement as stabilizers for recycled bases and surfaces dates to 1942 (*23*). Use of asphalt with recycled material probably dates to the early 1940's, although the most recent work indicates 1966 (*24*). States that have performed in-place recycling of the type described include Arkansas, California, Florida, Illinois, Indiana, Kansas, Kentucky, Louisiana, Maine, Michigan, Nebraska, Nevada, New Jersey, New York, Pennsylvania, Tennessee, Texas, and Washington. Probably all states have recycled existing bases and surfaces without the addition of a stabilizer.

Two basic approaches can be used for in-place recycling, depending on the thickness of the pavement to be treated and the thickness of the asphaltic concrete surface. If the asphaltic concrete surface is about 5 in. (125 mm) thick or less, specially designed pulverization equipment can be used without preliminary ripping and breaking. For asphaltic concrete surfaces thicker than about 5 in. (125 mm), motor graders with scarifiers or dozers with ripper teeth are usually used for the initial breakup. Heavy equipment (dozers, rollers, compactors) can be used if additional breakdown is required prior to pulverization.

A major advantage of in-place recycling is the ability to significantly improve the load-carrying capability of the pavement without changes in the horizontal and vertical geometry of the roadway. Other advantages include the ability to treat almost all types of pavement distress in asphalt-surfaced roadways, to reduce or eliminate reflection cracking, to reduce frost susceptibility of the recycled material, and to improve skid resistance and the ride quality of the roadway.

Among the disadvantages are the following: quality control is not as good as that of central-plant operations, pulverization can not be easily performed on portland cement concrete-surface roadways, proper curing conditions are often required for strength gain, and cost and traffic disruption may be relatively high.

Central-Plant Recycling

Central-plant surface and base recycling has been practiced for a number of years. Pavement and building rubble has been crushed and used as both unstabilized and stabilized base course in Washington, D.C.; Los Angeles; Minnesota; and San Francisco. The recycling of portland cement concrete back into portland cement concrete has been investigated briefly in the laboratory, and only the State of Iowa has placed experimental projects (*25*). Recycling of asphalt paving surfaces into asphaltic concrete using central-plant operations had an early history with Warren Brothers in 1915 (*19*), but very little experimentation was conducted from that time until 1974 (*25*).

Processes involving use of additional heat in central plants and recycling agents as the stabilizer have a tremendous future. It is anticipated that about 10 percent of the asphaltic concrete hot-mix market will be supplied by hot central-plant recycling operations in the next 3 to 5 years (*26*). Thus, 30 to 35 million tons (27 to 32 Tg) will be produced. The plants will be either new plants or existing plants (numbering in excess of 4,700), which will be altered to solve pollution problems that arise when asphalt mixtures are recycled.

Increased interest in central-plant recycling has led to development of new techniques for heating the reused materials and new concepts for pavement removal and sizing.

Two approaches have been used to size the material prior to recycling in a central plant. The pavement can be reduced in size in-place and then hauled to the central plant, or the pavement can be removed from the site and sizing can be performed with equipment normally associated with aggregate processing. In-place sizing equipment includes hot- and cold-milling machines, heater-planing equipment, and on-grade pulverizers.

Central-plant sizing can be performed with conventional, fixed, and portable crushing and screening equipment. The pavement is normally ripped and broken to a size suitable to be received by the primary crusher prior to loading onto the haul units. In some instances, it is economical to use grid rollers and other types of construction equipment to produce a suitably sized material on the roadway prior to hauling to the central plant. Jaw and roll crushers have proven to be satisfactory.

Equipment to centrally process recycled material is commercially available and for convenience can be separated into at least four general categories: (1) direct flame heating, (2) indirect flame heating, (3) superheated aggregate, and (4) without heat. Details of the type of equipment presently used can be found in *NCHRP Synthesis of Highway Practice 54* (*3*).

RECYCLING MODIFIERS

Asphalt binders present in recycling pavements often have physical or chemical properties that make the "old" asphalt undesirable for reuse without modification. Materials have been developed to restore these old binders to a condition suitable for reuse. This concept is not new and has been the subject of a number of studies during the last several years (*9, 12, 17, 29, 30, 31, 32, 33, 34, 35*).

Materials used to alter properties of asphalt cements have been called softening agents, reclaiming agents, modifiers, recycling agents, fluxing oils, extender oils, and aromatic oils.

The term "modifier" will be used to designate this type of material in the report and originates from ASTM Subcommittee D 4.37 (Modifier Agents for Bitumen in Pavements and Paving Mixtures). The general definition of a modifier is "a material when added to asphalt cement will alter the physical-chemical properties of the resulting binder" (*29*). A more specific definition has been developed by the Pacific Coast User-Producer Group for the term "recycling agent." A recycling agent is a hydrocarbon product with physical characteristics selected to restore aged asphalt to requirements of current asphalt specifications. It should be noted that soft asphalt cements, as well as specialty products can be classified as recycling modifiers or agents.

The purpose of the modifier in asphalt pavement recycling is to:

1. Restore the recycled or "old" asphalt characteristics to a consistency level appropriate for construction purposes and for the end use of the mixture.
2. Restore the recycled asphalt to its optimal chemical characteristics for durability.
3. Provide sufficient additional binder to coat any new aggregate that is added to the recycled mixing.
4. Provide sufficient additional binder to satisfy mixture design requirements.

Properties of Modifiers

Modifier properties of interest to the engineer are those that can be used for specification purposes to ensure that the modifier will perform the following functions:

1. Be easy to disperse in recycled mixture (*17, 32*).

2. Alter viscosity of old recycled asphalt cement to the desired level (*17, 30, 32, 33*).

3. Be compatible with the old recycled asphalt to ensure that syneresis (exudation of paraffins from asphalts) will not occur (*17, 30*).

4. Have the ability to redisperse the asphaltenes in the old recycled asphalt (*33*).

5. Improve the life expectancy of the recycled asphalt mixture (*17, 30, 32, 33*).

6. Be uniform in properties from batch to batch (*32*).

7. Be resistant to smoking and flashing if used in hot mix operations (*17, 30, 32, 33*).

Tests that have been investigated by various groups for inclusion in specifications are as follows:

1. Viscosity at 100, 140, 210, 275 F (38, 60, 99, 135 C), ASTM D2170, D2171 (*9, 17, 30, 32, 33*).
2. Flash point, ASTM D92 (*9, 12, 17, 30, 32, 33*).
3. Volatility, ASTM D1160 (*30, 35*).
4. RTF-C residue (weight loss, viscosity change, ductility, penetration), AASHTO T240 (*17, 32*).
5. Rostler parameters (compatibility, chemical composition), ASTM D2006 (*9, 12, 17, 30, 35*).
6. Clay-gel absorption chromatograph, ASTM D2007 (*33*).
7. Mixed analine point (*9, 36*).
8. Refractive index (*9, 36*).
9. Fire point (*9*).
10. Smoke Point (*9*).
11. Solubility parameter (*33*).
12. Specific gravity, ASTM D70 (*9, 17, 30*).
13. Viscosity-gravity constant (*36*).
14. Spot test (*17*).

A review of the references cited indicates that materials of a wide range of viscosity, as well as other properties, are available. For example, the viscosity as measured at 140 F (60 C) ranges from 2.4 to 64,000 centistokes (0.0024 to 64 Pa · s), flash points range from 190 to 658 F (88 to 348 C), asphaltenes content ranges from a trace amount to 51 percent, nitrogen bases range from 1.2 to 41.2 percent, paraffins range from 0.2 to 43.5 percent, and specific gravity ranges from 0.891 to 1.148.

Blends of Modifiers and Aged Asphalts

It is sometimes assumed that the field mixing process together with a reaction time (of unknown length) will allow the modifier and the "old" recycled asphalt to be completely mixed. If this supposition is accepted, the problem of blending old asphalts and modifiers is greatly simplified. The basic laboratory steps consist of extraction and recovery of the old asphalt followed by mixing various percentages of modifier until the desired consistency is obtained. This process is basically a trial and error procedure; however, methods of predicting modifier contents to produce desired viscosities have been developed and published by Arizona (*31*), Chevron (*32*), Dunning (*33*), Navy (*12*), Pacific Coast User Producer Group (*17*), and Witco (*30*). The basis for all of these methods is basically the same in that the viscosity of a blend of asphalts of different viscosity can be characterized by equations of the following form:

$$\log(\nu) = a + bp \text{ (Refs. 12, 31)} \qquad (1a)$$

$$\log - \log(\nu) = a + bp \text{ (Refs. 17, 30, 32)} \qquad (1b)$$

$$\log - \log(\nu) = a + b(\log p) \text{ (Ref. 33)} \qquad (1c)$$

where ν is the viscosity of the blend (normally measured at 140 F (60 C) in centistokes, p is the volume percent modifier in the blend, and a and b are constants. If no modifier is used, the viscosity is that of the old asphalt. If 100 percent modifier is used, the viscosity is that of the modifier. Hence, the constants a and b must be determined for each old asphalt-modifier blend.

A procedure suitable for use in the recycling guidelines has been developed by the Pacific Coast User-Producer Group (*17*). Charts developed by Chevron (*32*) and Witco (*30*) are for proprietary products. Detailed data on laboratory blends, field blends, and mixtures of modifiers and recycled pavement materials are given in Appendix C of Volume 2 of the agency report (see App. K for further details).

In brief, the laboratory and field tests performed in this study consisted of the following.

From the original 36 modifiers tested, seven were selected for blending with a laboratory-aged asphalt. Modifiers were selected primarily to provide a wide range of viscosity as measured at 140 F (60 C). Emulsions were not used because hot mix operations were used in all mixture laboratory work.

Modifier 1 was commercially produced for recycling of asphalt pavements. Modifier 2 was a reclaimed motor oil from the Texas A&M University Transportation Center. Modifier 3 was commercially produced as a lube stock. Modifiers 4 and 5 were AC-5 asphalt cement. Modifier 5 had higher paraffin content than modifier 4. Modifier 6 was a commercially available slurry oil and Modifier 7 was a roofing asphalt flux. The laboratory-aged asphalt was a specially prepared air-blown Los Angeles basin asphalt cement prepared by Dougals Oil Company.

Modifier concentrations were selected to produce a viscosity of 1,000 ± 200 poises (100 ± 20 Pa · s) at 140 F (60 C) (requirements for AC = 10 asphalt cement). It is interesting to note that although the viscosity at 140 F (60 C) was controlled over a fairly narrow range, the penetration at 77 F (25 C) for all blends conforming to AC-10 requirements ranged from a penetration of 42 to a penetration of 142, while penetrations at 60 F (15.6 C) ranged from 10 to 70 and viscosities at 210 F (98.8 C) from 14.7 to 24.8 poises (1.47 to 2.48 Pa · s). In the case of modifier 7, an asphalt cement was produced that did not meet the AC-10 requirements for penetration at 77 F (25 C) (ASTM D3381). Thus, temperature susceptibility of an asphalt blend is a function of the modifier selected.

A limited laboratory program was undertaken to determine if modifier content also affected temperature susceptibility. The results indicate that temperature susceptibility is not greatly affected by the amount of modifier.

From the seven modifiers selected for study with the laboratory-aged asphalt, four (modifiers 1–4) were selected for blending with asphalts extracted and recovered from pavements located near Rye Grass, Wash., Woodburn, Ore., and Abilene, Tex. These pavements were used in hot mix recycling projects. The three projects produced a range in viscosity and temperature typical of many in-service pavements.

Blends of materials from location 3 of the Rye Grass, Wash., project consistently gave low viscosity and high penetrations as compared to other locations. This can be explained by the relative soft nature of the extracted and recovered field-aged asphalt from location 3. Similar behavior was noted on results of location 5 blends where the field-aged asphalt had a relatively low viscosity. Blends of modifier 2 result in the largest variation among locations.

Asphalts extracted from the various locations of the Woodburn, Ore., project were more consistent in their properties. However, viscosity measured at 140 F (60 C) varies in excess of ±100 poises (±10 Pa · s) among locations.

Temperature susceptibility of blended field asphalts is a function of the type of modifier used. A relatively high penetration asphalt is produced when modifier 4 is used with the asphalt extracted and recovered from the Rye Grass, Wash. and the Abilene, Tex., projects. Review of data from the Woodburn, Ore., projects indicates that a relatively low penetration material will be produced with modifier 4.

Extraction and recovery tests performed on mixtures after laboratory mixing, compacting, and Marshall testing, show that the mixtures in which modifier 4 was used hardened more during the mixing and compaction operations than did mixtures with the other modifiers. Mixtures containing modifier 1 exhibited the lowest amount of hardening during mixing and compaction.

Penetration-ductility test results obtained after 150 days of curing at 140 F (60 C) indicate that all modifier-project combinations meet the established criteria. That is, the blended asphalts can be expected to produce a paving mixture with satisfactory performance.

Mixtuers of Modifiers and Recycled Pavement Materials

Pavement materials from the three recycling projects (Woodburn, Ore.; Abilene, Tex.; and Rye Grass, Wash.) were obtained and used to prepare laboratory mixtures for property characterization.

Mixture proportions were determined by laboratory testing; Chevron (*32*), Pacific Coast User-Producer Group (*17*), and Witco (*30*) mixture design procedures were used as a starting point. CKE, oil equivalencies, and surface areas were determined on the aggregates so that these methods could be used. The materials used for the laboratory mixtures contained 30 percent laboratory standard crushed limestone and 70 percent recycled material. The amount of modifier selected was that required to soften the old asphalt in the recycled mixture to a viscosity of about 1,000 poises (100 Pa · s) at 140 F (60 C). AC-10 asphalt cement was added as needed to control air voids. Results of the test program illustrate the property variation that can be expected between sample locations for a given project and a given modifier.

Modifier 4 could not be added in sufficient quantities to soften the old asphalt in the Rye Grass and Woodburn projects to the desired viscosity while maintaining an acceptable air void content in the mixture.

Values of resilient modulus are within ranges normally associated with asphaltic concrete mixtures. Marshall properties are typical of recycled mixtures in that high stabilities and relatively high flow values are obtained.

Hveem stability values for the Rye Grass and Woodburn projects are relatively low. Acceptable Hveem stabilities were obtained on the Abilene project. Marshall stability values for the three projects with modifiers 1, 2, and 3 are generally in the range from 800 to 1,000. These values are in general acceptable for base courses and some types of surface courses. Thus, these data present an interesting anomaly, in that, the Rye Grass and Woodburn mixtures are acceptable from a Marshall stability standpoint, but not from Hveem stability criteria. As stated in the literature, a correlation does not exist between Marshall and Hveem stabilities.

It is interesting to note that the resilient modulus of samples fabricated from materials at location 3 of the Rye Grass project is low, indicating a softer field-aged asphalt. The low resilient modulus at Woodburn locations 2 and 6 can not be as readily explained. However, modifier 1 has a more pronounced softening effect at location 2 than on other locations in the Woodburn project.

A careful examination of the data results obtained from laboratory samples cured at 32, 77, 140, and 275 F (0, 25, 60, and 135 C) for various lengths of time, removed from the curing room, placed in a 77 F (25 C) room for 3 hours, and then tested to determine their resilient modulus indicates that the rate of change in resilient modulus and asphalt hardening is not only a function of curing temperature and modifier type but also a function of the field-aged asphalt. Thus it is imperative that detailed tests be performed on each project to be recycled.

Samples subjected to water susceptibility tests (Lottman's procedure (*40*) and a vacuum saturation and 7-day soak procedure developed after work performed by Schmidt at Chevron Research) indicate the following:

1. The type of modifier has little effect on the water sensitivity of recycled mixtures provided adequate mixing and the desired viscosity are obtained.
2. The Lottman water susceptibility test is more severe than the vacuum saturation and soak test.
3. The ratio of the retained "strength" varies, depending on the type of test performed (resilient modulus, stability, tensile strength).
4. The mixtures prepared from recycled asphaltic concrete from Abilene are the most water susceptible.

STRUCTURAL EVALUATION OF RECYCLED MATERIALS

A review of the literature has suggested that little information is available which defines the load-carrying ability of recycled materials. Therefore a laboratory and field testing program was initiated to define these properties. The structural evaluation program consisted of two major efforts: (1) an evaluation of the AASHTO structural layer coefficients of various recycled materials used as surfaces and/or bases, and (2) an in-situ, nondestructive evaluation of recycled materials.

The basic data used to determine the AASHTO coefficients were the laboratory-measured resilient moduli values obtained over the range of temperatures that the AASHO Road Test pavement experienced during its life. The in-situ, nondestructive evaluation program compared the properties of the recycled material with that of a reference or control layer in an adjoining pavement section. The reference section was of conventional construction and usually had an asphaltic concrete surface course. The Dynaflect was selected as the method by which to evaluate the in-situ recycled pavements.

Complete details of this work can be found in the Volume 2 appendixes of the agency report (see App. K for further information). The results are summarized as follows.

Laboratory-derived material properties such as Hveem and Marshall stabilities, indirect tensile strengths, moisture susceptibility, and resilient moduli indicated that recycled asphaltic concrete could be expected to replace conventional asphaltic concrete in the pavement structure with satisfactory results.

Recycled asphaltic concrete used as both surface and base courses appears to be able to function as well as conventional materials based on a comparison with the standard paving materials used at the AASHO Road Test. This comparison was made using the structural layer coefficents calculated for the recycled material and compared with the structural coefficients developed at the Road Test. Although there are obvious limitations in comparing materials only in this way, the structural coefficient is based on the most thorough study of pavement performance available and is believed to give a realistic first approximation of the performance of recycled materials.

The greater stiffness of the recycled materials studied is evident. The effective thicknesses (based on stiffness) of most recycled materials were greater than the conventional layer used for comparison. Here, the pavement engineer should always exercise caution when using a layer equivalency, structural coefficient, or thickness ratio. The authors wish to point out the fallacy of a single, unique structural coefficient or thickness equivalency factor for any material. Indeed, the factors are highly sensitive to the material characteristics of the surrounding layers, the thickness of the various layers, and the entire structural pavement interaction. However, it is reasonable to infer that the recycled pavements, which have functioned successfully for as many as 7 years and which maintain a stiffness comparable to, or greater than, the conventional layer evaluated against, are structurally as sound as conventional materials. Of course, this must be verified by more thorough laboratory fatigue, creep, and permanent deformation testing. Such characterization should be evaluated in both layered elastic and viscoelastic structural pavement analyses.

FIELD CORE STUDY

The field core study was initiated to determine the mechanical properties of field-recycled mixtures. These data were used as input for determination of the AASHTO structural coefficients. Comparisons of these data with laboratory-molded and conventional field-produced materials were also made.

Two cores were taken at each of nine locations for Minnesota, Iowa, Kansas, Nevada, and Utah. These cores were obtained from 1,000 ft (305 m) of pavement section. Resilient modulus values were obtained at −13 F (−25 C), 32 F (0 C), 68 F (20 C), 77 F (25 C), and 104 F (40 C).

Before-and-After Recycling Comparisons

Cores from both the recycled section and the old pavement prior to recycling were obtained from the Rye Grass (Wash.), Abilene (Tex.) and Woodburn (Ore.) projects. Material property comparisons between the after- and the before-recycling cores are summarized in the following.

Rye Grass, Washington Project

Data obtained on this project indicate the following:

1. The resilient moduli at various temperatures are slightly lower on recycling due, in part, to the addition of a softener or asphalt cement modifier in this project. The slope of the resilient modulus–temperature curve is about the same for both the recycled and prior to recycling core data, indicating similar temperature sensitivity.
2. Neither the recycled nor the before-recycled cores were moisture susceptible based on resilient moduli tests.
3. Hveem stabilities were below 30 for both recycled cores and before-recycling cores. The recycled cores have a larger stability and are somewhat less sensitive to moisture effects because they showed no appreciable stability loss due to Lottman conditioning.
4. Marshall stabilities and flow showed little change due to recycling. No moisture damage effects were detected in the recycled cores by the Marshall test.
5. Indirect tension testing also revealed that the before-and-after cores were not susceptible to moisture effects.

Abilene, Texas Project

Data obtained on this project indicate the following:

1. Resilient moduli of recycled materials and before-recycled materials are very similar both in the magnitude of the moduli and in the susceptibility of these moduli to temperature at 77 F (25 C) and below. Significant difference exists at 100 F.
2. The recycled material was significantly more susceptible to moisture effects as measured by the change in resilient modulus than the unrecycled material. However, this must be tempered by the fact that the recycled layer, used as a base, was a combination of old AC surface and old base material.
3. Marshall stabilities were considerably lower after recycling. The stability values indicate that moisture damages both the after and the before-recycled materials.
4. Hveem stability values of the recycled mixture are below 30. The stability values indicate that moisture damages both the after- and the before-recycled materials.
5. Cores from the recycled pavement indicated a significant susceptibility to water as measured by the indirect tensile test.
6. Resilient modulus, Marshall stability, Hveem stability, and indirect tensile test results indicate that the recycled mixture is water susceptible.

Woodburn, Oregon Project

Data obtained on this project indicate the following:

1. The resilient moduli at temperatures above −10 F (−23 C) are significantly higher after recycling. The slope of the resilient modulus–temperature curve is nearly identical for both the recycled and the before-recycling core data. These data indicate similar temperature susceptibility.

2. The percent loss in resilient modulus as measured by the Schmidt test after Lottman water exposure is about equal for both the after- and the before-recycled cores.

3. The Marshall stabilities after recycling increased by 35 percent. Stabilities of the recycled and unrecycled cores were comparable after Lottman conditioning. Large Marshall flows were experienced on Lottman-conditioned after-recycling cores.

4. The Hveem stabilities remained about the same after recycling as before recycling. However, the loss in Hveem stability due to Lottman water exposure was lower for the recycled cores than for the cores prior to recycling.

5. The indirect tension test showed a significant strength increase for the recycled material. Although the strength loss after Lottman conditioning was greater for the recycled material, the absolute value of strength was greater than that for the before-recycled cores. Tensile strain and failure decreased upon recycling.

Laboratory and Field Compacted Property Comparisons

Samples of loose mixtures were obtained after recycling from the Rye Grass, Abilene, and Woodburn projects. These mixtures were compacted and subjected to a test program. Results are summarized as follows:

1. The air void content of field-compacted cores of recycled mixtures is typically larger than the laboratory-compacted field-mixed recycled materials. For example, the air void content of the field cores from Rye Grass averaged 5.1 percent, while laboratory-compacted samples averaged about 1 percent. Comparisons for the Abilene project are 10.4 percent versus 4 percent, and for the Woodburn project 7.7 percent versus 2.8 percent.

2. Resilient modulus values measured at 77 F (25 C) for field core samples are typically lower than the laboratory-compacted field-mixed recycled materials. For example, the resilient modulus of the field cores from Rye Grass averaged 222,000 psi (1.54×10^6 kPa), while laboratory-compacted samples averaged about 600,000 psi (4.14×10^6 kPa). Comparisons for the Abilene project are 438,000 psi (3.02×10^6 kPa) versus 996,000 psi (6.8×10^6 kPa); and, for the Woodburn project, 371,000 psi (2.56×10^6 kPa) versus 875,000 psi (6.03×10^6 kPa). The resilient modulus is dependent on air void content. High air void content mixtures will normally have a lower resilient modulus than identical mixtures with low air void contents.

3. Marshall and Hveem stability values for field core samples are typically lower than those for the laboratory-compacted field-mixed recycled materials. For example, the Marshall and Hveem stabilities of the field cores from Rye Grass averaged 1,183 and 29, respectively. Laboratory-compacted samples averaged about 2,350 and 30, respectively. Comparisons for the Abilene project for Marshall and Hveem stabilities are 1,090 and 26 versus 2,400 and 20. Comparisons for the Woodburn project are 1,760 and 23 versus 2,660 and 40. Stability values are affected by the air void content.

4. Tensile strength values for field core samples are typically lower than the laboratory-compacted field-mixed recycled materials. For example, the tensile strength of the field cores from Abilene averaged 57 psi (393 kPa), while laboratory-compacted samples averaged 183 psi (1,261 kPa). Comparisons for the Woodburn are 99 psi (682 kPa) versus 228 psi (1,571 kPa). Tensile strains at failure are similar for the laboratory- and the field-compacted samples.

Comparison of Field Mixtures With and Without Modifier

The major portion of the Abilene project was recycled without the addition of a low viscosity modifier. However, a low viscosity modifier (below RA 5) was used on a portion of the project. Loose mixture samples were obtained after recycling and subjected to tests. Results are summarized as follows:

1. The air void content of samples were 2.9 percent with modifiers and 4.1 percent without modifiers.

2. Resilient modulus values measured at 77 F (25 C) for samples containing a modifier were 454,000 psi (3.13×10^6 kPa) and 996,000 psi (6.87×10^6 kPa) without a modifier.

3. Marshall stability values were 2,070 with a modifier and 2,400 without a modifier. Flow values were nearly identical.

4. Hveem stability values were 16 with a modifier and 20 without a modifier.

5. Tensile strengths were 130 psi (896 kPa) with a modifier and 183 psi (1,262 kPa) without a modifier.

Comparisons of Asphaltic Concrete and Recycled Mixture

New asphaltic concrete and recycled asphaltic concrete were placed in the same project on Interstate 8 near Gila Bend, Ariz. Cores were obtained from this project and subjected to a test program. Results are summarized as follows:

1. Resilient modulus testing revealed a great similarity in the magnitude and temperature susceptibility of resilient modulus for the recycled cores and the conventional asphaltic concrete cores. Resilient modulus after Lottman conditioning is lower for the conventional material. This indicates a moisture susceptibility improvement due to recycling.

2. Hveem stabilities prior to, and after, Lottman conditioning were comparable for the conventional and recycled materials.

3. Marshall stabilities were significantly higher for the recycled material, and the effects of Lottman conditioning were substantially less for the recycled material as measured by the Marshall stability.

4. The indirect tension data also reflected the superiority of the recycled material in terms of water susceptibility.

Property Variation Within a Project

Samples of loose field-mixed recycled materials were obtained from five locations within the Rye Grass project. Twelve samples were molded at each location and subjected to a test program. Results are summarized as follows. The average resilient modulus, as measured on 12 molded samples from each location, is 560,000 psi (3.86 kPa), 593,000 psi (4.09×10^6 kPa), 515,000 psi (3.55×10^6 kPa), 679,000 psi (4.68×10^6 kPa), and 729,000 psi (5.03×10^6 kPa). Marshall and Hveem stabilities and indirect tension tests were performed on three samples from each of the five locations. The average Marshall stability values for the five locations are 2,410, 2,340, 2,310, 2,530, and 2,470; flow values are 20, 20, 21, 19, and 20. Hveem stability values recorded for the five locations are 31, 26, 21, 29, and 40. Tensile strengths were 184 psi (1,270 kPa), 184 psi (1,270 kPa), 179 psi (1,230 kPa), 197 psi (1,360 kPa), and 191 psi (1,320 kPa) for the five locations.

GENERAL CONCLUSIONS

The foregoing review of the literature and experimental studies has provided the background information necessary to define recycling procedures, processes, and approaches. Twenty-four alternatives have been identified for recycling asphaltic concrete pavements. Eight alternatives have been defined for recycling portland cement concrete pavement. Detailed descriptions of these operations are contained in Chapters Three and Four. Major advantages and disadvantages of surface, in-place, and central plant recycling are given in Table 1.

TABLE 1

MAJOR ADVANTAGES AND DISADVANTAGES OF RECYCLING TECHNIQUES

Recycling Techniques	Advantages	Disadvantages
Surface	• Reduces frequency of reflection cracking • Promotes bond between old pavement and thin overlay • Provides a transition between new overlay and existing gutter, bridge, pavement, etc. that is resistant to raveling (eliminates feathering) • Reduces localized roughness due to compaction • Treats a variety of types of pavement distress (raveling, flushing, corrugations, rutting, oxidized pavement, faulting) at a reasonable initial cost • Improved skid resistance	• Limited structural improvement • Heater-scarification and heater-planing has limited effectiveness on rough pavement without multiple passes of equipment • Limited repair of severely flushed or unstable pavements • Some air quality problems • Vegetation close to roadway may be damaged • Mixtures with maximum size aggregates greater than 1-inch cannot be treated with some equipment
In-Place	• Significant structural improvements • Treats all types and degrees of pavement distress • Reflection cracking can be eliminated • Frost susceptibility may be improved • Improve skid resistance	• Quality control not as good as central plant • Traffic disruption • Pulverization equipment in need of frequent repair • Pavements cannot be rejected in place
Central	• Significant structural improvements • Improved quality control • Treats all types and degrees of pavement distress • Reflection cracking can be eliminated • Improve skid resistance • Frost susceptibility may be improved • Geometrics can be more easily altered • Improved quality control if addition binder and/or aggregates must be used • Improve ride quality	• Increased disruption • Potential air quality problems at plant site • Traffic disruption

CHAPTER THREE

FINDINGS—GUIDELINES FOR RECYCLING ASPHALT PAVEMENT

This chapter contains guidelines for recycling asphalt pavements. Asphalt pavements are considered to be those pavements surfaced with bituminous bound materials. Composite pavements containing portland cement concrete that have been overlaid with an asphalt pavement are considered in this chapter, unless the recycled material is to be used as econocrete or portland cement concrete. Recycled composite pavements used as econocrete or portland cement concrete are considered in Chapter Four.

Once the pavement engineer has determined that recycling is a reasonable approach to rehabilitation he must decide which recycling method is most suited for the particular project under consideration. The analysis techniques described herein are guidelines for the engineer to follow during this decision process. For convenience, the analysis technique has been divided into two major sections. The first section, Part A, is a preliminary analysis identifying the few recycling methods that appear to be most suitable. The second section, Part B, is a more detailed analysis based on laboratory and field data, cost and energy projections, and results in a prioritized list of alternatives with appropriate mixture and structural designs and construction specifications. The overall view of this preliminary analysis, which results in a selection of recycling alternatives (Part A) is shown in Figure 3.

PART A—SELECTION OF ALTERNATIVES

This part of the report contains guidelines that allow the engineer to select a few of the many recycling alternatives available for a particular project. Twenty-four recycling alternatives have been identified as feasible for recycling of asphalt pavements. Table 2 gives the recycling alternatives available. A brief definition of these alternatives follows. Detailed descriptions of the methods are contained in Part B of this chapter.

Definitions

Surface Recycling

Heater Planer Without Additional Aggregates (A1). This operation involves the heating and shearing or planing of the asphalt surface together with appropriate cleaning and traffic control operations. Multiple passes may be necessary because a single pass is normally limited to ¾-in. removal.

Heater Planer with Additional Aggregates (A2). This operation may or may not involve the heating and shearing or planing of the asphalt surface prior to the even distribution of a skid resistant aggregate. The skid resistant aggregate is spread on the pavement surface at a rate of approximately 1 cu yd of aggregate to 250 sq yd of pavement surface area. Following aggregate distribution a heating unit is used to heat the aggregate and the existing pavement surface to a depth sufficient to embed the aggregate. The heating unit is immediately followed by compaction to press the crushed rock chips into the heated surface.

Heater Scarify (A3). This operation involves the heating and scarification of an asphalt surface. The operation may include the addition of asphalt and/or a modifier. A number of variations are possible which are shown in Figure 4. Scarification is usually limited to ¾ in. to 1 in. in a single pass.

Heater Scarify Plus Thin Overlay or Aggregate (A4). This operation involves the scarification of an asphalt surface followed by the addition of a skid resistant aggregate, a slurry seal, a chip seal, or an asphaltic concrete mixture. This operation may involve the mixing of the recycled asphaltic concrete with the new asphaltic concrete and/or aggregate and/or recycling agent. A number of variations are possible which are shown in Figure 4.

Heater Scarify Plus Thick Overlay (A5). This operation involves the scarification of an asphalt surface followed by the addition of an asphaltic concrete mix. The operation may involve the mixing of the recycled asphaltic concrete with the new asphaltic concrete and/or aggregate and/or recycling agent. A number of variations are possible which are shown in Figure 4.

Surface Milling (A6). This operation involves the removal of the surface of a pavement by a hot milling, cold milling, or cold planing machine. The depth of removal is variable and may be as great as 4 in. in a single pass. The millings or shavings are removed from the construction site.

Surface Milling Plus Thin Overlay (A7). This operation involves the removal of the surface of a pavement by a hot milling, cold milling, or cold planing machine and the addition of a slurry seal, chip seal, or asphaltic concrete thin overlay material. The material used for the overlay may be a new asphaltic concrete or a mixture prepared from the millings or shavings.

Surface Milling Plus Thick Overlay (A8). This operation involves the removal of the surface of a pavement by a hot milling, cold milling, or cold planing machine and the addition of a thick overlay. The material used for the overlay may be new asphaltic concrete or a mixture prepared from the millings or shavings.

In-Place Recycling

Minor Structural Improvement Without New Binder (B1). This operation involves the cold planing or crush-

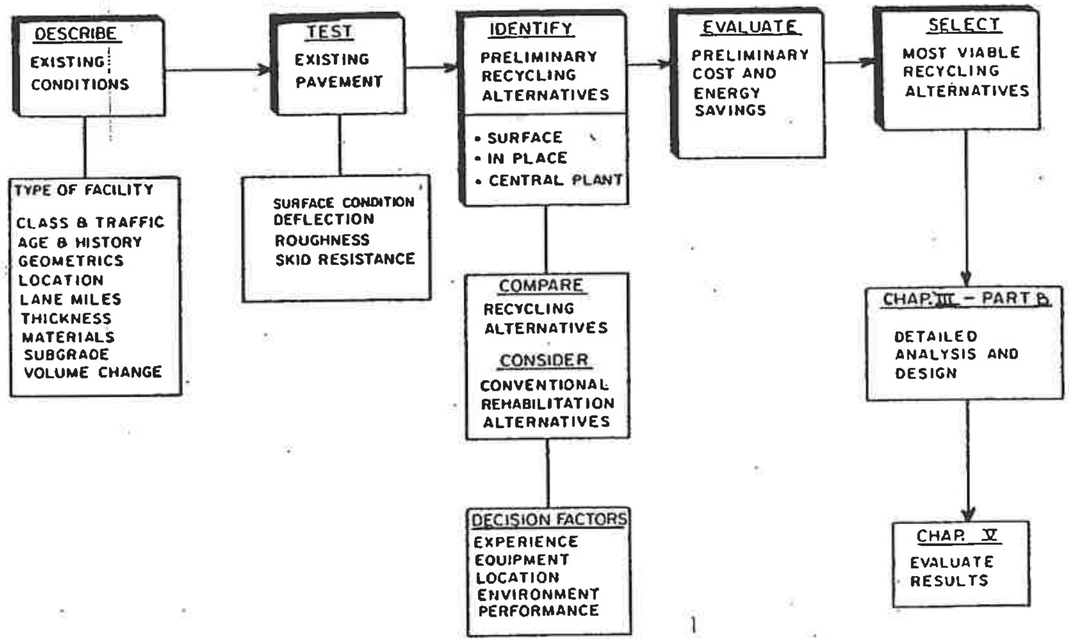


Figure 3. Preliminary analysis and selection of most suitable alternatives.

TABLE 2
OPTIONS FOR BITUMINOUS PAVEMENT RECYCLING

Category	Method	Description	Code
Surface	Heater Planer	Without additional aggregate	A1
		With additional aggregate	A2
	Heater scarify	Heater scarify only	A3
		Heater scarify plus thin overlay or aggregate	A4
		Heater scarify plus thick overlay	A5
	Surface milling or grinding	Surface milling only	A6
		Surface milling plus thin overlay	A7
		Surface milling plus thick overlay	A8
In Place	Asphalt concrete surface less than 5 inches	Minor structural improvement without new binder	B1
		Minor strctural improvement with binder	B2
		Major structural improvement without new binder	B3
		Major structural improvement with new binder	B4
	Asphalt concrete surface greater 5 inches	Minor structural improvement without new binder	B5
		Minor structural improvement with new binder	B6
		Major structural improvement without new binder	B7
		Major structural improvement with new binder	B8
Central Plant	Cold mix process	Minor structural improvement without new binder	C1
		Minor structural improvement with new binder	C2
		Major structural improvement without new binder	C3
		Major structural improvement with new binder	C4
	Hot mix process	Minor structural improvement without new binder	C5
		Minor structural improvement with new binder	C6
		Major structural improvement without new binder	C7
		Major structural improvement with new binder	C8

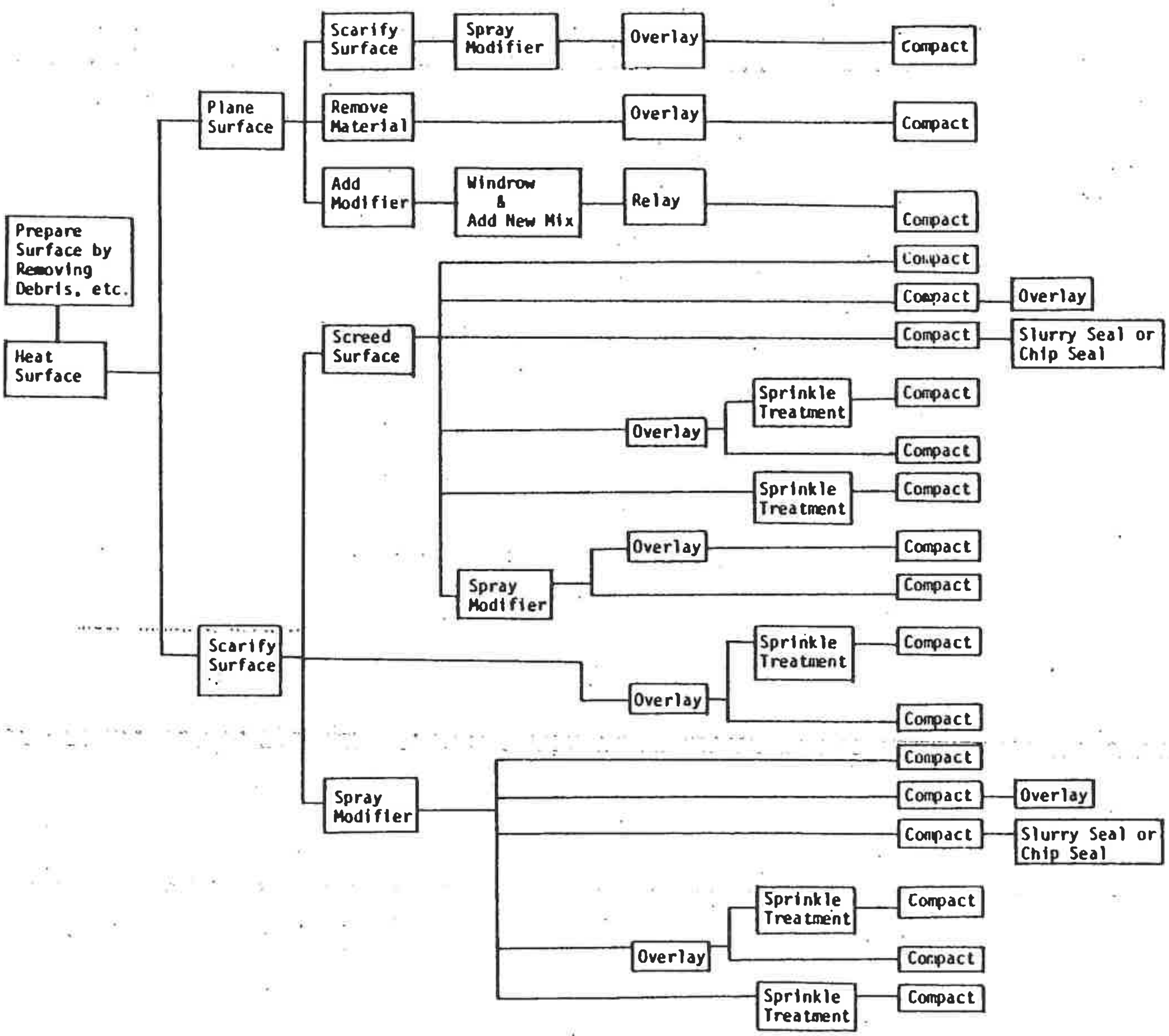


Figure 4. Recycling using heater planer and heater scarifier.

ing and pulverizing of old asphalt surfaced pavements (asphalt bound materials less than 5 in. thick) and recombining with the existing base and/or subbase to form a reconstituted layer. Pulverization of the thinner asphalt pavements need not be preceded by ripping and breaking and can be adequately accomplished by using a specialized traveling pulverizer.

Minor Structural Improvement with New Binder (B2). This operation involves the crushing and pulverizing of old asphalt pavements (less than 5 in. thick), followed by addition of new binders and/or recycling agents and recombining with the existing base and/or subbase. Stabilizers such as lime, cement, asphalt, and fly ash may be used to ameliorate or strengthen this reconstituted layer. Pulverization of the thinner asphalt pavements need not be preceded by ripping and breaking and can be adequaely accomplished by using a specialized traveling pulverizer.

Major Structural Improvement Without New Binder (B3). This operation involves the crushing and pulverizing of old asphalt pavements (less than 5 in. thick) and recombining with the existing base and/or subbase to form a reconstituted layer. Pulverization of the thinner asphalt pavement need not be preceded by ripping and breaking and can be adequately accomplished by using a specialized traveling pulverizer. Major structural improvement can be gained by increasing the thickness of the reconstituted layer or by means of an overlay.

Major Structural Improvement with New Binder (B4). This operation involves the crushing and pulverizing of old asphalt pavements (less than 5 in. thick) and adding new binders and/or modifiers and recombining with the existing base and/or subbase. Stabilizers such as lime, cement, asphalt, and fly ash may also be used to ameliorate or strengthen the reconstituted layer. Pulverization of the thinner asphalt pavement need not be preceded by ripping and breaking and can be adequately accomplished by using a specialized traveling pulverizer. Major structural improvement can be gained by increasing the thickness of the reconstituted layer through stabilization or by means of an overlay.

Minor Structural Improvement Without New Binder (B5). This operation involves the crushing and pulverization of old asphalt pavements (greater than 5 in. thick) and recombining with the existing base or subbase to form a reconstituted layer. Ripping and breaking of the thick pavement prior to pulverization are normally required.

Minor Structural Improvement with New Binder (B6). This operation involves the crushing of old asphalt pavements (greater than 5 in. thick), adding new binders and/or modifiers and recombining with the existing base and/or subbase. Stabilizers such as lime, cement, asphalt, and fly ash may be used to ameliorate or strengthen the reconstituted layer. Ripping and breaking of the thick pavement prior to pulverization are normally required.

Major Structural Improvement Without New Binder (B7). This operation involves the crushing and pulverization of old asphalt pavements (greater than 5 in. thick) and recombining with the existing base or subbase to form a reconstituted layer. Ripping and breaking of the thick pavement prior to pulverization are normally required. Major structural improvement can be gained by increasing the thickness of the reconstituted layer or by means of an overlay.

Major Structural Improvement with New Binder (B8). This operation involves the crushing of old asphalt pavements (greater than 5 in. thick), adding new binders and/or modifiers, and recombining with the existing base and/or subbase. Stabilizers such as lime, cement, asphalt, and fly ash may be used to ameliorate or strengthen this reconstituted layer. Ripping and breaking of the thick pavement prior to pulverization are normally required.

Central Plant Recycling

Minor Structural Improvement Without New Binder (C1). This is a cold mix operation. The existing asphalt pavement is ripped and broken at the job site. Crushing can be performed on the job site, but most commonly the old pavement material is hauled to the central plant and crushed, screened, sized, and stockpiled. The sized material is blended to provide the proper mixture.

Minor Structural Improvement with New Binder (C2). This is a cold mix operation. The existing asphalt pavement is ripped and broken at the job site. Crushing can be performed on the job site, but most commonly the old pavement material is hauled to the central plant and crushed, screened, sized, and stockpiled. The material is then blended with a stabilizer generally by using a pugmill as the primary mixer. Stabilizers such as lime, cement, asphalt, and fly ash may be used to ameliorate or strengthen the reconstituted material.

Major Structural Improvement Without New Binder (C3). This is a cold mix operation. The existing asphalt pavement is ripped and broken at the job site. Crushing can be performed on the job site, but most commonly the old pavement material is hauled to the central plant and crushed, screened, sized, and stockpiled. Major structural benefit is obtained by increasing the depth of the reconstituted layer or by means of an overlay.

Major Structural Improvement with New Binder (C4). This is a cold mix operation. The existing asphalt pavement is ripped and broken at the job site. Crushing can be performed on the job site, but most commonly the old pavement material is hauled to the central plant and crushed, screened, sized, and stockpiled. The material is then blended with a stabilizer generally by using a pugmill as the primary mixer. Stabilizers such as lime, cement, asphalt, and fly ash may be used to ameliorate or strengthen the reconstituted material. Major structural benefit is obtained by increasing the depth of the reconstituted layer or by means of an overlay.

Minor Structural Improvement Without New Binder (C5). This is a hot mix operation. The existing asphalt pavement is ripped and broken at the job site. Crushing can be performed on the job site, but most commonly the old pavement material is hauled to the central plant and crushed, screened, sized, and stockpiled. The recycled material may or may not be blended with new aggregate prior to heating and mixing. Direct flame, indirect flame, or superheated aggregate hot recycling processes are used.

Minor Structural Improvement with New Binder (C6). This is a hot mix operation. The existing asphalt pavement is ripped and broken at the job site. Crushing can be performed on the job site, but most commonly the old pavement material is hauled to the central plant and crushed, screened, sized, and stockpiled. The recycled material may or may not be blended with new aggregate prior to heating and mixing. The addition of asphalt and/or a recycling agent is an integral part of the operation. Direct flame, indirect flame, or superheated aggregate hot recycling processes are used.

Major Structural Improvement Without New Binder (C7). This is a hot mix operation. The existing asphalt pavement is ripped and broken at the job site. Crushing can be performed on the job site, but most commonly the old pavement material is hauled to the central plant and crushed, screened, sized, and stockpiled. The recycled material may or may not be blended with new aggregate prior to heating and mixing. Direct flame, indirect flame, or superheated aggregate hot recycling processes are used. Major structural benefit is obtained by increasing the depth of the reconstituted layer or by means of an overlay.

Major Structural Improvement with New Binder (C8). This is a hot mix operation. The existing asphalt pavement is ripped and broken at the job site. Crushing can be performed on the job site, but most commonly the old pavement material is hauled to the central plant and crushed, screened, sized, and stockpiled. The recycled material may or may not be blended with new aggregate prior to heating and mixing. The addition of asphalt and/or a recycling agent is an integral part of the operation. Direct flame, indirect flame, or superheated aggregate hot recycling processes are used.

From a review of the foregoing definitions it is apparent that the type of equipment, degree of structural improvement, the thickness of the existing asphalt bound material, and the use of heat in the recycling process are key factors used to define the recycling approaches. It is important that the engineer be familiar with the recycling operations previously defined prior to reading the remainder of the guidelines.

Selection of Recycling Alternatives

If the engineer is to select the most appropriate recycling alternative for a particular project, he must describe or characterize the conditions of the existing facility. Aside from historical facts and known conditions, the present condition must be measured on some rational basis and compared to standard criteria. Key factors that influence the decision include the following: (1) surface conditions, (2) structural conditions, (3) roughness, and (4) skid resistance. These factors together with a summary of key data describing the existing facility are discussed in the following.

TABLE 3

SUMMARY OF EXISTING PAVEMENT CONDITIONS

FEATURE	VALUE	COMMENT
Location		
Size of Project (lane-miles)		
Class of Roadway		
Existing Pavement Cross Section (Include date, thickness and type of original pavement layers; date, thickness and type of subsequent rehabilitation and maintenance activities)		
Geometrics (Number of lanes, width, vertical clearance, other constraints)		
Traffic Characteristics ADT Average daily eq. 18 kip axle loads		
Subgrade Characteristics		
Surface Condition (Pavement Rating Score, PRS)		
Structural Condition (Deflection, 0.001 inch overlay required)		
Roughness (Serviceability Index)		
Skid Resistance (SN_{40})		
Other Factors (Distance to aggregate and binder source, available equipment and contractor experience)		

Existing Facility

Particular data are required to describe adequately the existing facility for the purposes of rehabilitation decision-making. These factors are summarized in Table 3 in a form for easy reference. Specific items noted are as follows: (1) location and size of project, (2) roadway class, (3) existing pavement cross section, (4) geometrics, (5) traffic, and (6) subgrade characteristics. The contribution of the factors, in terms of a selection process for recycling, are briefly described next.

Location and Size of Project. The location and size of a project may be such that only certain techniques would be cost effective. For example, projects located in remote areas will have to be large in size to justify the transportation of the equipment associated with central plant recycling. In-place recycling is a cost effective approach for pavement rehabilitation in remote areas where small projects with low traffic volumes are under consideration.

Roadway Class. Generally, the roadways can be classed in broad categories as: Interstate and Urban Freeway, Rural Primary (U.S. and state signed routes), Rural Secondary (farm and ranch-to-market, park roads, etc.), and Urban Streets (arterial, collector, local). Roadway class dictates criteria for determining the need for pavement rehabilitation as well as general criteria for selection of an appropriate recycling alternative.

Existing Pavement Cross Section. The date of original construction together with a listing of the thickness and types of materials used will be important in judging the general serviceability of the pavement. Subsequent history of rehabilitation and maintenance activities, such as seal coats, overlays, patching, crack sealing, etc., will influence the determination of a viable recycling alternative. Thickness of each layer of different material, as well as the type of material and its condition, should be obtained from project records. Reliance on memory for the information is often risky. A few carefully located core samples will provide confidence in the information.

The type or nature of the existing materials will influence the recycling method selected for a given project. If the bound materials, such as multilayers of seal coats and overlays are variable, both vertically and horizontally, it may be difficult to make a uniform recycled mixture without adding large quantities of aggregate and/or binder to dilute these undesirables. Asphalt modifiers and/or additional asphalt may also be needed. If the structural strength of the pavement must be increased, several options exist that include removing the pavement materials and stabilizing the subgrade before remixing and replacing the pavement, or using all existing pavement materials stabilized as a base course and then overlaying.

Geometrics. The geometric features of a roadway, such as horizontal and vertical alignment, are often constraints to conventional rehabilitation techniques such as asphalt overlays. For example, the drainage line at curbs and gutters can not be altered without considerable expense. Therefore, an overlay must be constructed at the appropriate thickness in the driving lanes and then tapered to near zero thickness at the gutter. Multiple overlays can cause havoc, resulting in excessively high crowns at the centerline and steep cross slopes. Other features such as drainage inlets and manholes also cause problems of a similar nature. Recycling of existing pavement materials offers a solution to some of these problems.

Vertical clearance for trucks and other special vehicles at bridges and overhead signals and signs is often critical and can not be reduced as would be the case if overlays were used. Recycling offers a further benefit here.

On multilane highways, the truck or travel lane often deteriorates before the passing lane. Overlaying only one of the lanes would be impractical, but recycling of that lane alone or to strengthen it before adding a general overlay would provide a more acceptable solution. Similarly, superelevation could be preserved or altered as needed without disturbing adjacent lanes.

Changing the horizontal alignment or adding new features, such as shoulder widening or a new shoulder and lane widening or a new lane, may also be opportunities to use recycling techniques. Often, these features may not need the full design strength of adjoining lanes and could be stabilized in-place, or the existing aggregate base could be used to make asphaltic concrete without the need for new materials or for wasting existing materials.

Traffic Characteristics. The speed and volume of traffic, to a large extent, determine the traffic control problems associated with pavement rehabilitation activities. The use of recycling on high traffic volume urban facilities should be geared toward those activities that can provide low roadway occupancy time, can be performed with single lane blockage, and can use materials with rapid strength gain after placement.

The volume and axle weight distribution of traffic are important from a pavement design standpoint. For pavement design purposes, traffic should be converted to average daily equivalent 18,000-lb axle-load repetitions that are representative for the design period. It is suggested that the AASHTO procedures be used for this conversion.

Subgrade Characteristics. Pavement failures due to factors outside the pavement layers often need to be considered. For example, a subgrade that contains a swelling clay may need to be improved before recycling the pavement materials would be effective. Another environmentally influenced problem related to volume change is frost heave. For both of these problems, recycling may offer a reasonable solution in that the pavement materials would need to be removed in any event in order to remove or improve the poor subgrade. While removing the materials, they could be reprocessed and replaced after the subgrade has been prepared. (See App. K for further details.)

In summary, all known information about the pavement materials and background needs to be summarized and used in the decision process. Surprises at the time of construction can be avoided usually by proper testing, evaluation, planning, and design.

Surface Condition

Each potential recycling project should be surveyed for surface defects that can be used not only to assess the cause of distress but perhaps to also suggest corrective action. Several agencies have devised methods to estimate pavement distress and one such approach is discussed in Appendix A, Volume 3, of the agency's report (see App. K for further information). Once the survey is made, the results can be summarized and entered on the first line of Table 4. This table has all the usual types of distress displayed across the top and major recycling alternatives listed along the left margin. In order to use this table, the engineer should systematically look at each distress marked on the first line and estimate which recycling methods would correct that distress, and indicate this assessment by placing a check mark in the appropriate box. Note that a number of boxes are shaded; this indicates that these recycling options would not be appropriate. For example, a pavement with severe alligator cracking over 30 percent of the area would not be improved by using a heater planer (A1) alone. Similarly, other surface methods would not be applicable unless a thick overlay followed the operation. Further, one can note on Table 4 that some methods of in-place recycling and central plant recycling would also not be particularly beneficial for certain types of distress.

Once the viable recycling alternatives for improving surface condition are identified, they can be summarized in Table 7.

Structural Condition

The structural adequacy or structural condition of the roadway under consideration is determined by the thickness of the overlay required. Overlay requirements should be determined by an appropriate deflection-based procedure (see App. K). Certain recycling alternatives defined in this report can be eliminated, depending on the thickness of the overlay required (Table 5). For example, if the overlay required is greater than 2 in., only those recycling alternatives providing a major structural improvement would be considered adequate (A5, A8, B3, B7, C3, and C8). For overlay requirements less than 2 in., those recycling alternatives providing minor structural improvements are suggested for use (Table 5). Those recycling alternatives identified as appropriate for improving the pavement from a structural adequacy standpoint should be entered in Table 7.

Roughness

The smoothness of ride may be a deciding factor for rehabilitation of many roadways. Occasionally, a rough surface may be the only significant problem and surface recycling would be the solution. If a pavement is rough, but also has other deficiencies that require more extensive reworking, the roughness should be taken care of automatically in that operation. Therefore, the need for surface recycling based on ride measurements (serviceability index, SI) can be estimated as noted in Table 6. As in previous discussion, some methods would not be appropriate and have been blocked out. For example, it is not recommended that very rough primary highway (SI less than 2.4) be surface recycled without an appropriate overlay (methods A1, A2, A3, A4, and A6). Those methods that are considered appropriate should be noted on Table 6 and the

TABLE 4

SELECTION OF RECYCLING TECHNIQUES BASED ON ROADWAY CONDITIONS

	RECYCLING METHODS / CONDITION OF EXISTING PAVEMENT →	
SURFACE	HEATER PLANER WITHOUT ADDITIONAL AGGREGATE	A1
	HEATER PLANER WITH ADDITIONAL AGGREGATE	A2
	HEATER SCARIFY	A3
	HEATER SCARIFY + THIN OVERLAY	A4
	HEATER SCARIFY + THICK OVERLAY	A5
	SURFACE MILLING	A6
	SURFACE MILLING + THIN OVERLAY	A7
	SURFACE MILLING + THICK OVERLAY	A8
IN PLACE	THIN ASPHALT CONCRETE-MINOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	B1
	THIN ASPHALT CONCRETE-MINOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	B2
	THIN ASPHALT CONCRETE-MAJOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	B3
	THIN ASPHALT CONCRETE-MAJOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	B4
	THICK ASPHALT CONCRETE-MINOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	B5
	THICK ASPHALT CONCRETE-MINOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	B6
	THICK ASPHALT CONCRETE-MAJOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	B7
	THICK ASPHALT CONCRETE-MAJOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	B8
CENTRAL PLANT	COLD PROCESS-MINOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	C1
	COLD PROCESS-MINOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	C2
	COLD PROCESS-MAJOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	C3
	COLD PROCESS-MAJOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	C4
	HOT PROCESS-MINOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	C5
	HOT PROCESS-MINOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	C6
	HOT PROCESS-MAJOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	C7
	HOT PROCESS-MAJOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	C8

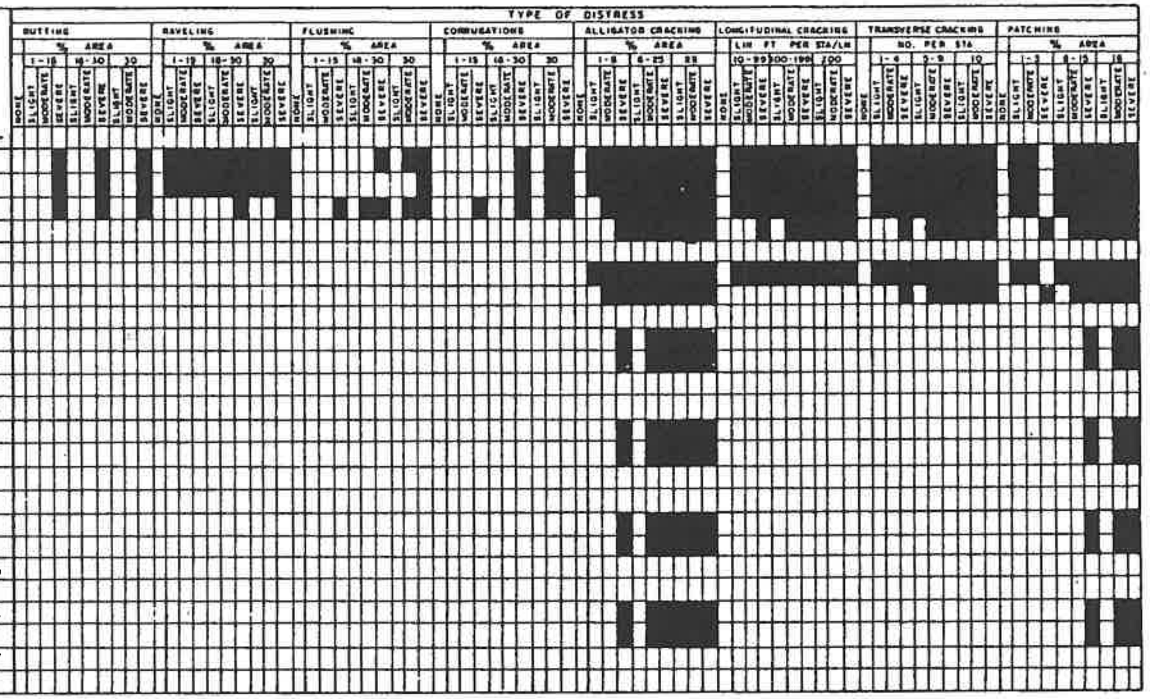


TABLE 5

SELECTION OF RECYCLING TECHNIQUES TO IMPROVE STRUCTURAL STRENGTH BASED ON PAVEMENT DEFLECTION

Recycling Methods			Thickness of Required Overlay		
			None	Less Than 2 inches	Greater Than 2 inches
Heater Planer	A1	Without additional aggregate			
	A2	With additional aggregate			
Heater scarify	A3	Heater scarify only			
	A4	Heater scarify plus thin overlay or aggregate			
	A5	Heater scarify plus thick overlay			
Surface milling or grinding	A6	Surface milling only			
	A7	Surface milling plus thin overlay			
	A8	Surface milling plus thick overlay			
Asphalt concrete surface less than 5 inches	B1	Minor structural improvement without new binder			
	B2	Minor structural improvement with new binder			
	B3	Major structural improvement without new binder			
	B4	Major structural improvement with new binder			
Asphalt concrete surface greater than 5 inches	B5	Minor structural improvement without new binder			
	B6	Minor structural improvement with new binder			
	B7	Major structural improvement without new binder			
	B8	Major structural improvement with new binder			
Cold mix process	C1	Minor structural improvement without new binder			
	C2	Minor structural improvement with new binder			
	C3	Major structural improvement without new binder			
	C4	Major structural improvement with new binder			
Hot mix process	C5	Minor structural improvement without new binder			
	C6	Minor structural improvement with new binder			
	C7	Major structural improvement without new binder			
	C8	Major structural improvement with new binder			

TABLE 6

SELECTION OF SURFACE RECYCLING TECHNIQUES BASED ON ROAD ROUGHNESS

Type of Facility		Interstate Urban Freeway				Primary				Secondary				Urban Streets			
Recycling Methods \ Serviceability Index		+3.0	2.5-2.9	2.0-2.4	-2.0	+3.0	2.5-2.9	2.0-2.4	-2.0	+3.0	2.5-2.9	2.0-2.4	-2.0	+3.0	2.5-2.9	2.0-2.4	-2.0
Heater Planer Without Additional Aggregate	A1																
Heater Planer With Additional Aggregate	A2																
Heater Scarify	A3																
Heater Scarify and Thin Overlay	A4																
Heater Scarify and Thick Overlay	A5																
Surface Milling	A6																
Surface Milling and Thin Overlay	A7																
Surface Milling and Thick Overlay	A8																

results summarized in Table 7. (See App. K for further details.)

Skid Resistance

Many pavements may perform adequately from a structural standpoint, but simply be deficient in skid resistance because of excess asphalt cement or perhaps because of polishing aggregate. As part of the overall pavement testing scheme, skid resistance can be measured by using any one of several test methods, but preferably by the so-called ASTM skid trailer (App. K). It is noted that all recycling methods are appropriate for improving skid resistance with the possible exception of the heater planer without additional aggregate (A1) or heater scarifier only (A3). The acceptable recycling methods to improve skid resistance should be entered in Table 7.

Steps in Determining Preliminary Recycling Alternatives

As discussed earlier, the goal in this chapter is to select several reasonable viable alternatives to recycle asphalt pavements. Referring to Figure 3, one can note that after all preliminary information is collected, the potentially successful approaches can be analyzed with respect to cost and energy savings and the most viable survivors determined. The steps required to reach these conclusions are summarized as follows:

1. List available information on existing roadway (Table 3).
2. Test existing pavement:
   a. Surface condition (Table 4)
   b. Structural condition (Table 5)
   c. Roughness (Table 6)
   d. Skid resistance (App. K)
3. Evaluate other decision factors unique to the particular project.
4. Make preliminary cost analysis of remaining options and rank accordingly (Table 8).
5. Consider alternatives that appear most viable and continue evaluation (Chap. Three, Part B).

PART B—DETAILED ANALYSIS AND DESIGN

This part of the report will provide guidance and an outline for making a detailed analysis of a recycling approach. Cost, energy, mixture design, structural design, construction specifications, and quality control requirements are included for surface, in-plate, and central plant recycling. Use of this part will allow the engineer to prioritize the preliminary recycling alternatives selected earlier in this chapter under Part A.

Surface Recycling

As discussed in Part A, surface recycling techniques are different from the other broad categories of recycling in that they rework the surface of a pavement to a depth of approximately 1 in. (unless multiple passes are made). Heater-planing and heater-scarification equipment have single pass capabilities of the order of ¾ in., whereas certain cold-milling machines can remove up to 5 in. in a single pass. Therefore, to repair rough riding roads or severely rutted roads, multiple passes will have to be made with certain types of equipment. Significant increases in the load carrying ability of the roadway are not possible without the addition of an overlay or rebinding the pulverized material in an in-place recycling operation.

Equipment and methods, application of surface recycling techniques, mixture design, structural design, construction specifications, and quality control guidelines are presented in the following.

Equipment and Methods

Surface recycling equipment, first developed in the 1930's, can be categorized into five basic types of equipment: (1) heater planers, (2) heater scarifiers, (3) hot millers, (4) cold planers, and (5) cold millers. The recycling techniques that have been developed for the use of this equipment are items A1 to A8 as identified in this chapter under Part A. More detailed descriptions of these operations follow.

Heater Planer (A1, A2). The heater-planer operation consists of a mobile heating unit followed by a planing device. The heating and planing devices may be contained in one mobile unit, such as that shown in Figure 5(a), or may be two pieces of equipment. Auxiliary clean-up equipment is also required.

Heater-planer operations using additional aggregates have a sequence of operations such as that shown in Figure 5(b). The operation consists of separate mobile units for heating and planing the pavement followed by aggregate distribution, heating, and rolling. Auxiliary clean-up equipment is also required. The application of aggregate followed by heating and rolling without a planing operation can provide a skid resistant surface under certain conditions.

Heater Scarification (A3, A4, A5). The wide variety of heater-scarification operations, with and without overlay, are shown in Figure 4. Three typical operations using additional asphalt and/or recycling agent and an asphaltic concrete overlay are shown in Figure 6. As noted, single pass units are available to heat, scarify, and add new asphalt and/or modifier and new asphaltic concrete.

In most instances the heater-scarification–overlay procedure may be diagrammed as follows: (1) A large, mobile combustion chamber is used to heat the pavement to soften the asphalt binder. (2) Closely spaced scarifier teeth are then used to plow continuous shallow furrows in the softened materials. (3) The pavement is recompacted. (4) A liquid recycling agent is applied to the recompacted pavement surface. (5) An asphalt overlay is placed. (6) The overlay is compacted to firmly bond the new overlay to the older pavement structure.

Frequently, there is delay of several days between steps 4 and 5. Also, there is an alternative procedure in which step 3 is omitted. This alternative procedure has an advantage in that omission of recompaction after scarification means that the pavement is in a roughened and hot condition when the overlay is placed. This further ensures a tight bond between the existing pavement and the overlay.

Surface Milling and Grinding (A6, A7, A8). Surface

TABLE 7

SUMMARY OF PRELIMINARY RECYCLING ALTERNATIVES

Recycling Methods				Surface Condition	Deflection	Roughness	Skid Resistance
Surface	Heater Planer	Without additional aggregate	A1				
		With additional aggregate	A2				
	Heater scarify	Heater scarify only	A3				
		Heater scarify plus thin overlay or aggregate	A4				
		Heater scarify plus thick overlay	A5				
	Surface milling or grinding	Surface milling only	A6				
		Surface milling plus thin overlay	A7				
		Surface milling plus thick overlay	A8				
In Place	Asphalt concrete surface less than 5 inches	Minor structural improvement without new binder	B1				
		Minor structural improvement with new binder	B2				
		Major structural improvement without new binder	B3				
		Major structural improvement with new binder	B4				
	Asphalt concrete surface greater than 5 inches	Minor structural improvement without new binder	B5				
		Minor structural improvement with new binder	B6				
		Major structural improvement without new binder	B7				
		Major structural improvement with new binder	B8				
Central Plant	Cold mix process	Minor structural improvement without new binder	C1				
		Minor structural improvement with new binder	C2				
		Major structural improvement without new binder.	C3				
		Major structural improvement with new binder	C4				
	Hot mix process	Minor structural improvement without new binder	C5				
		Minor structural improvement with new binder	C6				
		Major structural improvement without new binder	C7				
		Major structural improvement with new binder	C8				

milling and grinding equipment is capable of removing pavement to a depth greater than 1-in. Thus this type of equipment can be used to provide pulverized material for in-place and central plant recycling operations as well as for surface recycling. Equipment is available that can mill to a depth of about 5-in. in widths from a few inches to 12 ft. Some of the units heat the pavement prior to milling, while most cold mill or plane the pavement. Asphalt overlays can be added after the milling operations.

The guidelines established earlier under Part A have indicated that surface recycling techniques without the addition of an overlay offer little increase in the load carrying ability of the pavement. In fact, if a substantial portion of the pavement is removed, a decrease in load carrying ability will result.

Application of Surface Recycling Techniques

Heater-planer techniques are best suited for (1) removal of localized instability problems; (2) correction of slight and, perhaps, moderate rutting problems; (3) corrections of bleeding surfaces where additional aggregates can be used; (4) removal of localized severe surface undulations caused by swelling clays, frost heave, etc.; and (5) removal of asphalt mixture prior to overlays along gutters, at bridge approaches, and at other areas where a feathered edge of asphaltic concrete is likely to abrade.

Heater-scarification techniques are best suited for (1) removal of localized instability and skid problems provided additional aggregate is used; (2) correction of slight and, perhaps, moderate rutting problems; (3) temporary sealing and rejuvenation of raveled and/or oxidized pavements

TABLE 6

REPRESENTATIVE COSTS FOR ASPHALT PAVEMENT RECYCLING OPERATIONS

Category	Method	Description	Code	Representative Costs per Sq.Yd. Average	Range	Assumptions
A. Surface	Heater Planer	Without additional aggregate	A1	0.50	0.35 - 0.90	Heat, plane, clean-up, haul, traffic control
		With additional aggregate	A2	0.45	0.30 - 0.80	Spread aggregate, heat, roll, traffic control and clean-up
	Heater Scarify	Heater scarify only	A3	0.33	0.25 - 0.80	Heat, scarify, recompact, traffic control (3/4 inch scarification)
		Heater scarify plus thin overlay of asphalt concrete	A4	1.10	0.80 - 1.40	Heat, scarify, recompact, add 50 lbs of asphalt concrete per square yard, compact, traffic control (3/4 inch scarification)
		Heater scarify plus chip seal or slurry seal	A4	0.75	0.60 - 1.00	Heat, scarify, recompact, place slurry seal or chip seal and traffic control (3/4 inch scarification)
		Heater scarify plus thick overlay	A5	3.30	2.60 - 4.00	Heat, scarify, recompact, add 300 lbs of asphalt concrete per square yard, compact, traffic control (3/4 inch scarification)
	Surface Milling or Grinding	Surface milling only	A6	0.60	0.35 - 1.20	Milling, cleaning, hauling, traffic control (1 inch removal)
		Surface milling plus thin overlay	A7	2.60	2.00 - 3.00	Milling, cleaning, hauling, 200 lbs of asphalt concrete, traffic control (1 inch removal)
		Surface milling plus thick overlay	A8	4.60	3.75 - 5.75	Milling, cleaning, hauling 400 lbs of asphalt concrete, traffic control (1 inch removal)
B. In-Place	Asphalt Concrete Surface Less Than 5 In.	Minor structural improvement without new binder	B1	2.80	2.20 - 3.40	Rip, pulverize and remix to 4 inch depth with 2 inches of asphalt concrete, traffic control
		Minor structural improvement with new binder	B2	2.40	1.90 - 2.90	Rip, pulverize and remix with stabilizer to 4 inches depth with 1 inch of asphalt concrete, traffic control
		Major structural improvement without new binder	B3	5.20	4.10 - 6.30	Rip, pulverize and remix to 6 inch depth with 4 inches of asphalt concrete, traffic control
		Major structural improvement with new binder	B4	4.10	3.30 - 4.90	Rip, pulverize and remix with stabilizer to 6 inch depth with 2 inches of asphalt concrete, traffic control
		Minor structural improvement without new binder	B5	3.00	2.40 - 3.60	Rip, pulverize and remix to 4 inch depth with 2 inches of asphalt concrete, traffic control

TABLE 8 (*Continued*)

Category	Method	Description	Code	Representative Costs per Sq.Yd. Average	Range	Assumptions
B. In-Place	Asphalt Concrete Surface Greater Than 5 In.	Minor structural improvement with new binder	B6	2.60	2.10 - 3.10	Rip, pulverize and remix with stabilizer to 4 inch depth with 1 inch of asphalt concrete, traffic control
		Major structural improvement without new binder	B7	5.50	4.40 - 6.60	Rip, pulverize and remix to 6 inch depth with 4 inches of asphalt concrete, traffic control
		Major structural improvement with new binder	B8	4.40	3.50 - 5.30	Rip, pulverize and remix with stabilizer to 6 inch depth with 2 inches of asphalt concrete, traffic control
C. Central Plant	Cold Mix Process	Minor structural improvement without new binder	C1	3.60	2.90 - 4.30	Remove, crush, and replace to 4 inch depth with 2 inches of asphalt concrete, traffic control
		Minor structural improvement with new binder	C2	3.00	2.40 - 3.60	Remove, crush, mix, and replace to 4 inch depth with 1 inch of asphalt concrete, traffic control
		Major structural improvement without new binder	C3	6.40	5.10 - 7.70	Remove, crush and replace to 6 inch depth with 4 inches of asphalt concrete, traffic control
		Major structural improvement with new binder	C4	5.00	4.00 - 6.00	Remove, crush, mix and replace to 6 inch depth with 2 inches of asphalt concrete, traffic control
	Hot Process	Minor structural improvement without new binder	C5	3.90	3.10 - 4.70	Remove, crush, and replace to 4 inch depth with 1.5 inches of asphalt concrete, traffic control
	Hot Mix Process	Minor structural improvement with new binder	C6	3.30	2.60 - 4.00	Remove, crush, mix and replace to 4 inch depth with 1/2 inch of asphalt concrete, traffic control
		Major structural improvement without new binder	C7	6.60	5.30 - 7.90	Remove, crush and replace to 6 inch depth with 3 inches of asphalt concrete, traffic control
		Major structural improvement with new binder	C8	5.20	4.20 - 6.20	Remove, crush, mix and replace to 6 inch depth with 1 inch of asphalt concrete

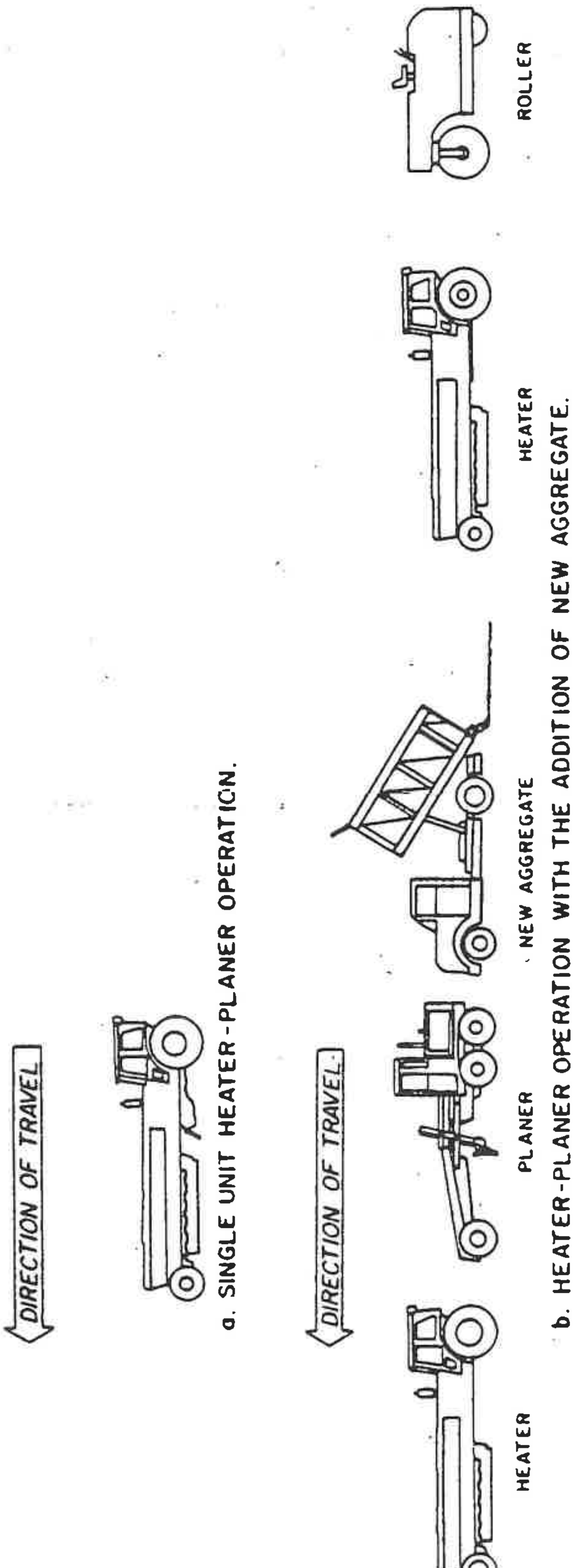


Figure 5. Heater-planer operations.

with and without transverse and longitudinal cracks (reduces rate of reflection cracking); and (4) establishing a strong bond between an old pavement and a new asphaltic concrete overlay. Evidence exists that a properly heater-scarified and modified pavement will act as a stress relieving interface between an old pavement and new overlay. However, experience does not show that a heater-scarified pavement will increase the load carrying ability of the pavement.

Surface milling operations are best suited for (1) removal of instability problems, (2) correction of certain types of skid problems including bleeding, cross slopes, and macrotexture; (3) removal of surface undulations caused by swelling clays, frost heave, etc.; (4) removal of asphaltic concrete and portland cement concrete prior to overlay along gutters, at bridge approaches, and at other areas where weathered edge of asphaltic concrete is likely to abrade; and (5) promotion of bond between an old pavement and a new overlay and for general removal for central plant recycling.

Mixture Design

The design of mixtures associated with surface recycling techniques is limited by the nature of the operation. Heater-planer and heater-scarification operations may use additional aggregates sprinkled on the surface to provide skid resistance. These aggregates should be subjected to standard aggregate tests and a test to ensure that the aggregate will not polish under the action of the imposed traffic. (See App. K.)

Heater-scarification operations should be carefully evaluated to ensure that the mixture produced from this operation has the properties desired. During the evaluation of each heater-scarification job, several questions should be answered: Should additional aggregate be used? Should additional asphalt be used? Should a recycling agent be used? Should additional asphaltic concrete be added? The answers to these questions normally can be determined only by a detailed laboratory testing program. Samples of the asphalt surface prior to recycling should be obtained and subjected to a series of tests as outlined in Appendix A. If the asphalt needs to be softened, an asphalt and/or recycling agent may have to be added. If stability is a problem or if the amount of additional asphalt or recycling agent required is excessive, additional aggregate may have to be added.

The question of adding additional asphaltic concrete is one based on the amount of load carrying ability that must be achieved and the amount of additional mixture that will be necessary to provide a smooth riding surface. The additional asphaltic concrete may also improve the stability and/or other desirable properties of the heater-scarified pavement. When additional asphaltic concrete is used, standard mix design procedures are suggested for use that are outlined in Appendix A.

Surface milling and grinding operations do not require mix design considerations unless an asphaltic concrete overlay is to be used or the millings are to be reused. Standard mix design methods should be used for the asphaltic concrete overlay and designs in Appendixes A, B, and C should be used for mixtures containing the millings.

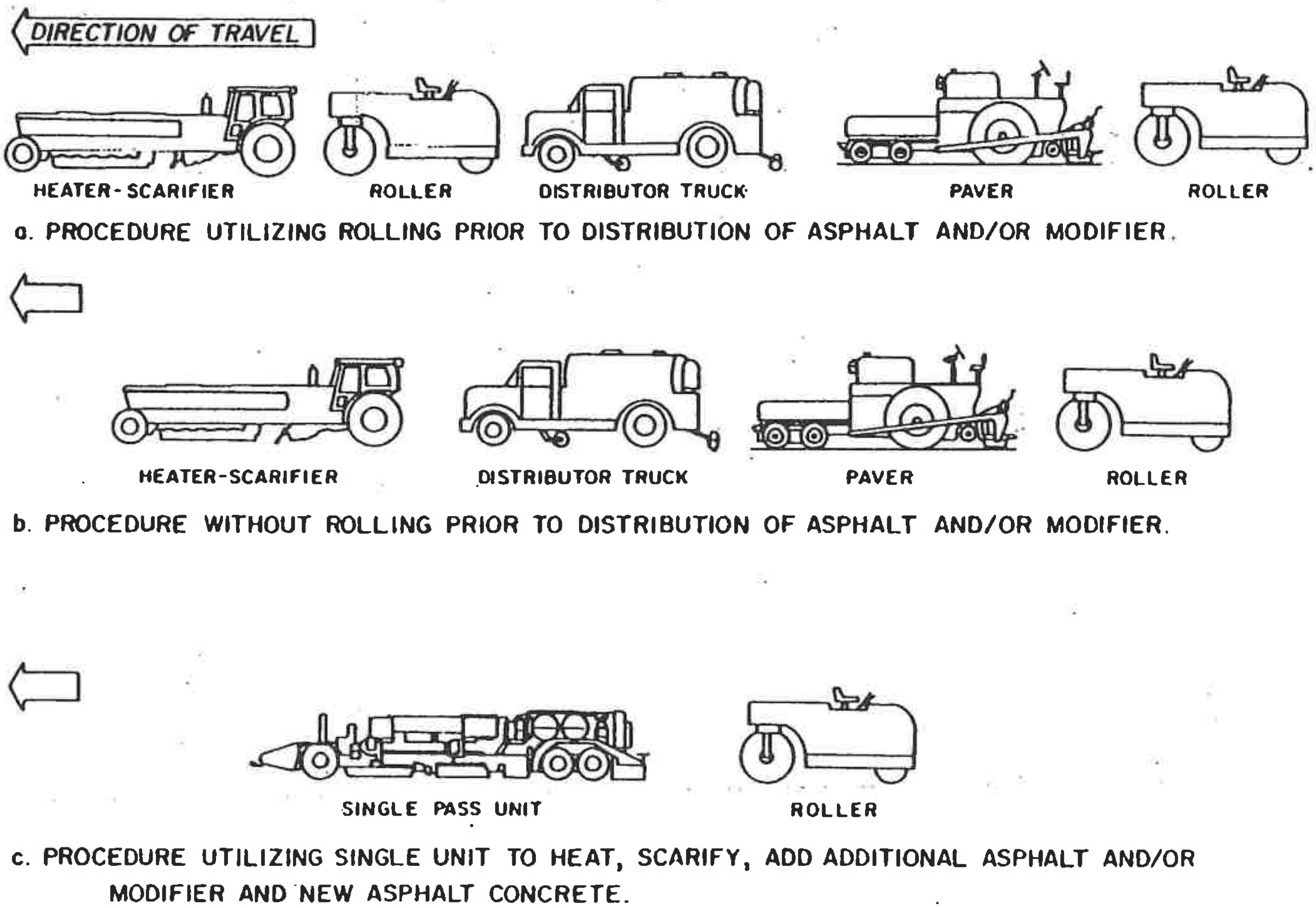


Figure 6. Heater-scarification operations.

Structural Design

Structural design considerations associated with surface recycling are limited to the thickness of overlay required to prevent failure due to traffic and reflection cracking. A satisfactory design method has not been developed to consider reflection cracking. However, evidence exists in the southwest that illustrates the advantage of using heater scarification prior to overlays to delay the occurrence of reflection cracking. Up to 6 years of satisfactory performance have been obtained with ¾-in. depth of heater scarification followed by a thin overlay of asphaltic concrete.

Economics and Energy

The costs associated with surface recycling operations are given in Tables F-1 and F-2. Detailed cost information of materials used in various operations (Fig. 4) associated with surface recycling are also included in Appendix F. The energy associated with surface recycling operations is included in Appendix G. Little data have been developed to date to define the energy data consumption for the various recycling operations; however, sufficient data do exist in Appendix G to calculate representative energy requirements for each of the surface recycling options shown in Figure 4.

Costs and energy comparisons should be made on a life-cycle basis. A 20- to 30-year period is suggested for the analysis period. Details of the methodology involved in this analysis are given in Appendix J.

Construction Specifications

Specifications for heater-planing, heater-scarification, and heater remixing operations are included in Appendix H. Specifications for asphaltic concrete used with these techniques should be those commonly used by the contracting agency.

Quality Control

Methods of testing for quality control purposes are covered in Appendix I, or methods commonly used by the contracting agency can be substituted.

In-Place Recycling

As discussed earlier in Part A, in-place recycling techniques are different from the other broad categories of recycling in that all construction operations are performed on-grade or in-place. Additional aggregate, stabilizing binder, and/or a recycling agent may be added to the pulverized old pavement material prior to reshaping and compaction. These characteristic construction operations create some quality control problems.

Equipment and methods, application of in-place recycling techniques, mixture design, structural design, construction specifications, and quality control guidelines are presented in the following.

Equipment and Methods

Many agencies have recycled existing unstabilized bases together with their surfaces without the addition of a stabilizer. Recently, equipment has become available to pulverize stabilized bases and surfaces and to use the reprocessed material with a binder such as lime, cement, or asphalt for a quality base course material.

The types of equipment used for in-place recycling are very similar to that used for on-grade stabilization with lime, cement, or asphalt. In general, the only specialized equipment is that used to properly size bound materials prior to restabilization. Specially designed pulverizers, hammer mills, or cold-milling machines have been developed for this purpose. The pulverizers and hammer mills that are presently used require more power and more wear resistant parts than are presently available on soil stabilization equipment.

The recycling techniques that have been identified for the use of this equipment are items B1 to B8 as identified earlier in this chapter under Part A. Basic differences in these techniques are: (1) the thickness of the stabilized material to be recycled, the use of a new binder, and the degree of structural improvement.

The basic sequence of operations for in-place surface and base stabilization are shown in Figure 7. As noted, the initial separation of techniques is based on the thickness of the surface course (thickness of stabilized material). When the thickness of the stabilized material is about 5 in. or less, pulverization can be performed without a ripping and breaking operation. Recycling methods B1, B2, B3, and B4 are approximates for pavements with 5 in. or less of stabilized materials; while methods B5, B6, B7, and B8 are approximates for pavements with 5 in. or more of stabilized surfacing materials.

The second separation of in-place recycling techniques shown in Figure 7 is based on the use of stabilizing agents. Recycling methods B2, B4, B6, and B8 use a binder such as lime, cement, or asphalt.

Two typical in-place recycling operations are shown in Figures 8 and 9. The operations are those required when the existing asphalt stabilized surface material is greater than 5 in., and a preliminary ripping and breaking operation is required prior to pulverization. The type and thickness of the new wearing course will depend on the structural capacity required by traffic.

The sequence of operations shown in Figure 9 is for a situation where both a modifier and additional asphalt material is to be added to the pulverized material. In general, it is preferable to add the modifier prior to addition of the existing binder. If cement and/or lime is to be used as the new binder, steps 5, 6, and 7 of the sequence are replaced with a step to apply the cement or lime.

Application of In-Place Recycling Techniques

There are several advantages of in-place processing. Equipment required for the process is minimal and processing in-place affords the opportunity to correct structural and material problems quickly and, therefore, without pro-

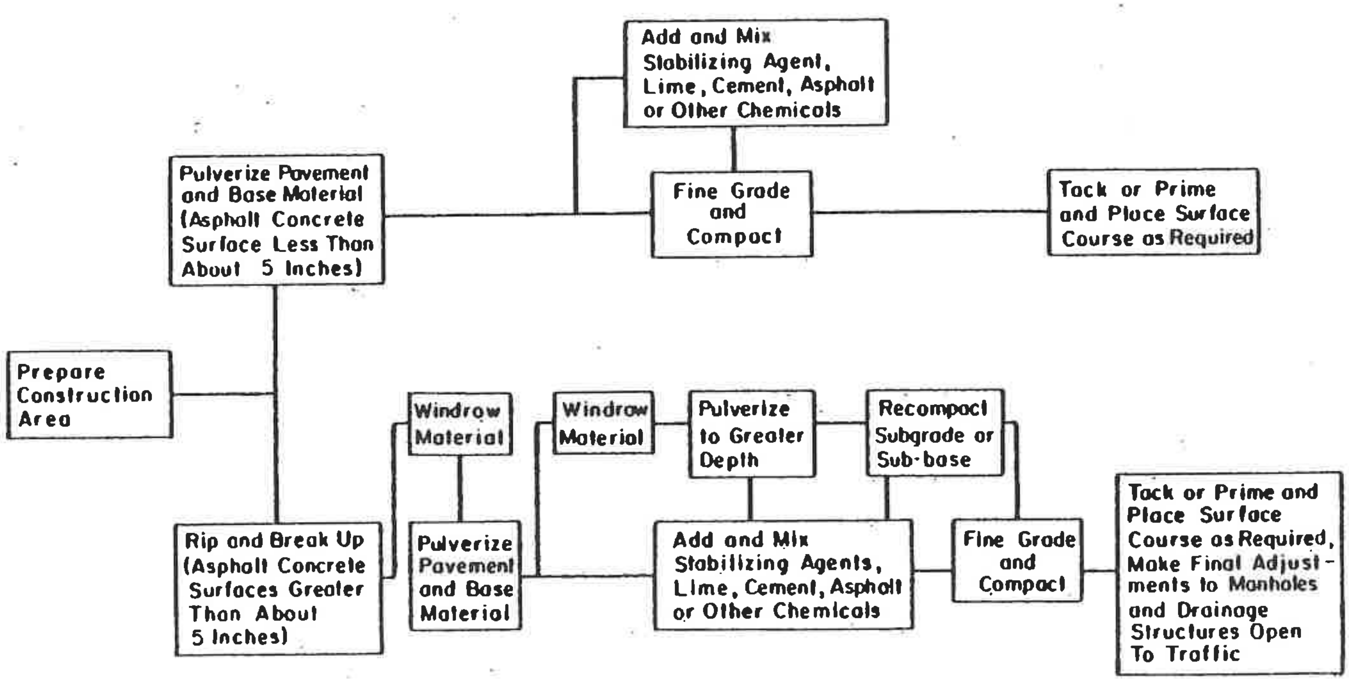


Figure 7. In-place surface and base recycling operations.

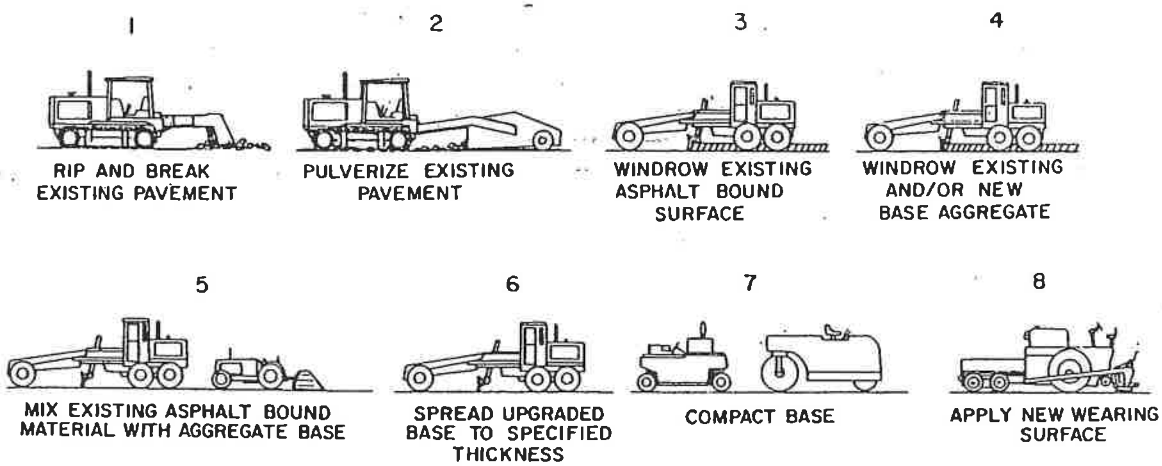


Figure 8. Typical in-place recycling operation without restabilization.

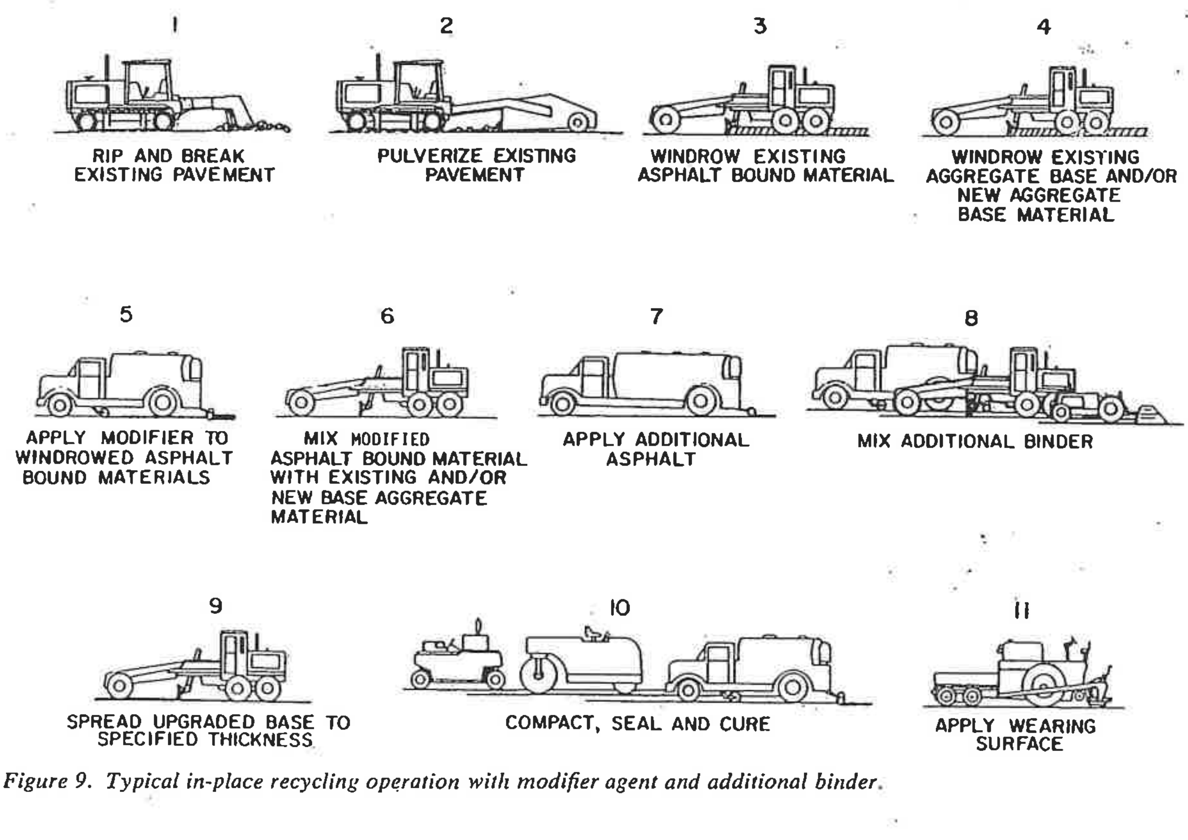


Figure 9. Typical in-place recycling operation with modifier agent and additional binder.

longed disruption of traffic. Where an existing asphaltic concrete course is pulverized and mixed together with the existing aggregate base, the residual asphalt acts as an excellent binder to help make the recycled base waterproof and less frost susceptible. The addition of new binder or chemical stabilizer, such as lime or cement, may further up-grade the recycled base by reducing swell potential where active clays are present in the base, by reducing freeze-thaw potential, by waterproofing the base aggregate, and/or by increasing the load-carrying capacity of the pavement structure.

With an increased load-carrying capacity in the base course, the pavement structure may be constructed thinner. A thinner pavement structure could mean less total materials required and, therefore, a savings of "virgin," select materials. Another advantage is that any material generated as waste due to grade requirement of the new surface course can be sold or stockpiled for future use.

Generally the equipment required for in-place recycling is of the basic road building type and is, therefore, available at almost any location. Furthermore, because in-place recycling is quite versatile in terms of the equipment required and the construction sequence, the engineer can tailor the operation to handle any peculiarities of the project. Inasmuch as the equipment required is widely used, equipment operators are readily available.

The binders most widely used to upgrade the existing base aggregate (i.e., liquid asphalt, lime, cement, and fly ash) are usually acquired economically. In addition, the agencies associated with these products (The Asphalt Institute, the National Lime Association, the Portland Cement Association) provide detailed construction procedures and suggestions for optimizing the benefits from the use of these binders.

The ultimate decision as to the application of in-place recycling is based on a total evaluation considering user utility, structural requirements, energy expenditures, and cost.

Construction Procedures

For detailed construction procedures for use of lime, cement, or bituminous stabilizer, refer to Appendix H.

Mixture Design

The mixture design process for in-place recycling requires the determination of both the type and amount of stabilizer to be used. If asphalt is to be the stabilizer, the engineer should consult Appendix A to determine the need for a recycling agent and/or the quantity of bituminous material. Guidelines for selecting stabilizers other than asphalt (such as lime and portland cement) are given elsewhere (see App. K for further details).

Structural Design

The AASHO Interim Guide, 1972, procedure for pavement structural design is suggested for use because layer coefficients, *a*, for in-place, upgraded materials either are published in the Guide or can be obtained from other agencies that have employed these guides for design (i.e., the Forest Service) (see App. D). Layer coefficients for selected recycled materials have been developed as a part of this NCHRP project and are also given in Appendix D.

Economics and Energy

The costs associated with in-place recycling are given in Tables F-1 and F-2. Energy data may be obtained from Appendix G.

Costs and energy comparisons should be made on a life-cycle basis. A 20- to 30-year period is suggested for the analysis period. Details of the methodology involved in this analysis are given in Appendix J.

Construction Specifications

Appendix H contains specifications for in-place recycling of existing asphalt courses with existing base and/or subbase (lime stabilization, cement stabilization, and asphalt stabilization).

Quality Control

Methods of testing for quality control puropses are covered in Appendix I, or methods commonly used by the contracting agencies can be substituted.

Central Plant Recycling

As previously discussed in Part A, central plant recycling techniques are different from the other methods of recycling in that the material is removed from the roadway and mixed either cold or hot at a central location. Additional asphalt, recycling agents, cement, lime, aggregate, or other materials may be added at the plant to enhance the overall properties. These recycling operations, although maintaining good quality control, are often costly.

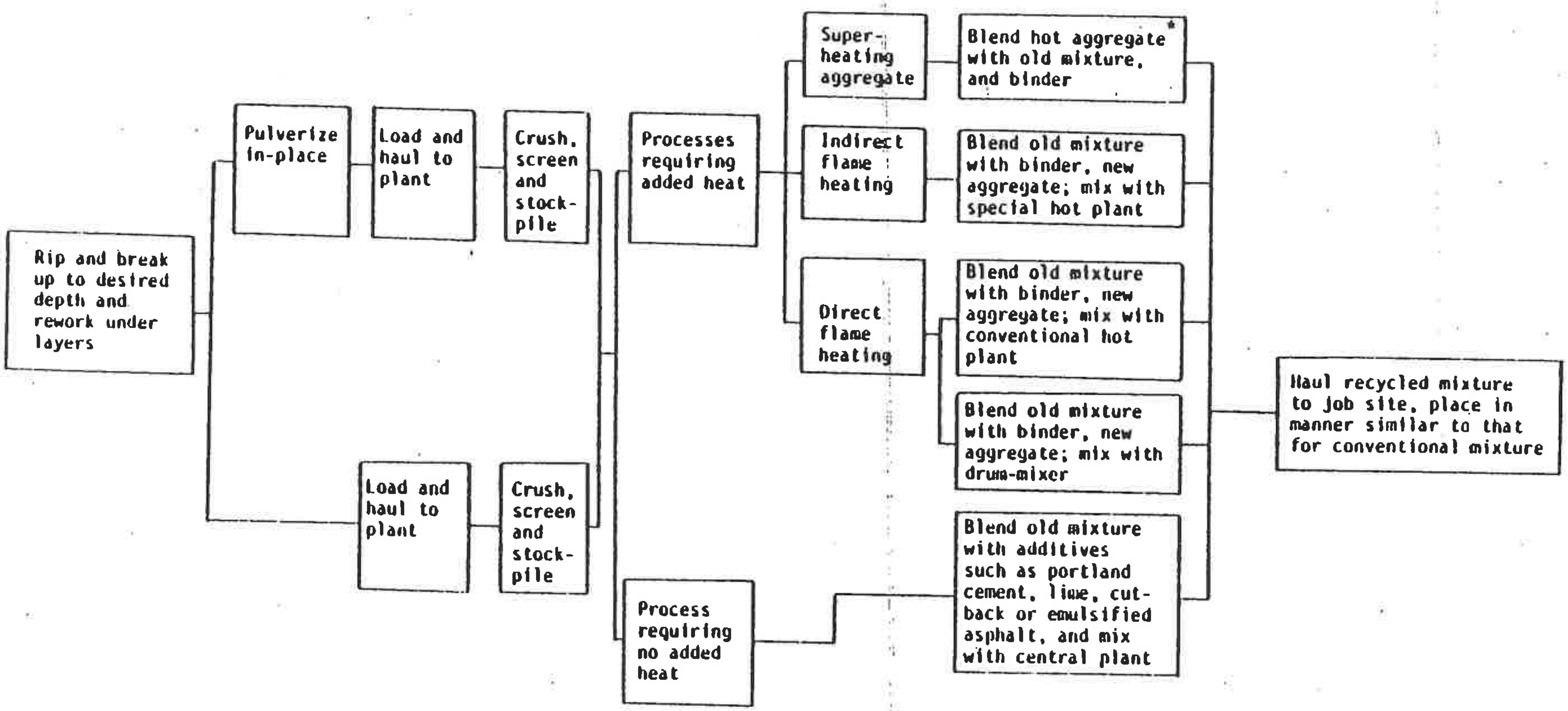
Equipment and methods, application of central plant recycling techniques, mixture design, structural design, construction specifications, and quality control guidelines are discussed in the following.

Equipment and Methods

Recycling of asphalt pavements using central plants is not a new concept. Recycling plants utilizing heat were in existence in 1915, and large tonnages of recycled materials were produced in the Pittsburgh area in the 1950's and 1960's. A widespread rebirth of central plant recycling occurred in 1973 because of the rapid increase in the price of asphalt cement and increased costs of other construction materials and equipment. This increased interest has led to the development of new techniques for heating and reusing materials, as well as of new concepts for pavement removal and sizing. Techniques developed are shown in Figure 10.

Pavement Removal and Sizing Operations. Two approaches have been used to size the material prior to recycling in a central plant. The pavement can be reduced in size in-place and then hauled to the central plant, or the pavement can be removed from the site and crushed at the central plant. In-place or on-grade removal and sizing can be performed with equipment normally associated with surface and in-place recycling—specifically, hot- and cold-milling machines, heater-planing equipment, and on-grade pulverizers.

Central plant sizing can be performed with conventional fixed and portable crushing and screening equipment. The pavement is normally ripped and broken up prior to loading in a size suitable to be received by the primary crusher. In some instances it is economical to use grid rollers and other types of construction equipment to produce a suitably sized material on the roadway prior to hauling to the central plant. Jaw and roll crushers have proven to be satisfactory.



Binder may include with or without recycling agent new aggregate may be used as required to correct mix design.

Figure 10. Central plant recycling techniques.

Central Plant Equipment. Equipment to centrally hot process the recycled material is available and for convenience can be separated into at least three general categories (Fig. 10): direct flame heating, indirect flame heating, and superheated aggregate. The concepts of superheated aggregate and direct flame overlap in several existing methods are discussed next.

Direct flame heating is typically performed with a drum mixer wherein all materials are mixed simultaneously in a revolving drum with a flame at one end. The standard drum mixer plant, as shown in Figure 11, has been used on several experimental jobs. Problems with air quality have led to several modifications, such as the addition of heat shields, split feeds, and the like.

The use of the drum mixer with a heat dispersion shield has been developed (Fig. 12). The heat shield and additional cooling air are used to reduce the hot gasses to a temperature below about 800 to 1200 F and thus reduce the amount of blue smoke formation. This type of equipment can recycle successfully mixtures containing up to about 70 percent recycled asphaltic concrete.

The concept of a drum within a drum has been used in Iowa (Fig. 13). This process is based on a small diameter drum that is inserted in the charging end of a conventional drum mix unit. New or virgin aggregate is introduced into the inner drum where it is superheated to 300 to 500 F. Reclaimed materials are introduced into the outer drum through a second charging chute. The reclaimed material and the heated virgin material meet at the discharge point of the inner drum where heat transfer occurs. This type of equipment can recycle successfully mixtures containing up to about 50 to 60 percent recycled bituminous materials.

Split feed drum mixers were first used in 1976 (Fig. 14). New aggregate is introduced at the flame end of the drum where it is superheated to 300 to 500 F. At about the midpoint of the drum the recycled bituminous material is introduced and is heated by the hot gasses as well as by heat transfer from the superheated new aggregate. This type of equipment can recycle successfully mixtures containing up to about 60 to 70 percent recycled bituminous materials.

Indirect flame heating has been performed with special drum mixer exchanger tubes (Fig. 15). These tubes, which transfer the gasses, prevent the mixtures from coming into direct contact with the flame and extremely high temperatures. These plants can recycle up to 100 percent recycled materials.

Superheated aggregate can be used to heat recycled bituminous material. Two of the direct flame methods previously noted make use of this concept to partially heat the recycled material. Figures 16, 17, and 18 show these methods which make use of superheating new or virgin aggregate. This superheated aggregate is then used to heat the recycled or old mixture. Standard plants can be used for this approach. Figures 16 and 17 show different locations of blending the new aggregate and the recycled bituminous materal.

Tandem drum mixers can also be used. The first drum or aggregate drier can be used to superheat new aggregate. The second drum or drier can be used either to heat the recycled mixture (Fig. 18) or to mix and heat the new and recycled materials. It is possible to use exhaust gasses from the first drier as a heat source for the second drier unit.

The central plant recycling technique using superheated aggregate is limited to about 50 percent recycled bituminous materials.

The final revision of central plant recycling, as shown in Figure 19, is without the addition of heat. High production rates can be obtained with this type of plant using lime, cement, or asphalt as a binder. This cold central plant recycling operation can use up to about 100 percent recycled bituminous materials.

The recycling techniques identified for the use of this equipment are items C1 to C8, as identified in this chapter, Part A. Basic differences in these techniques are: type of process (hot or cold), use of new binder, and degree of structural improvement.

Techniques C1, C2, C3, and C4 are cold processes; techniques C5, C6, C7, and C8 are hot processes. Techniques C2, C4, C6, and C8 use new binder; techniques C3, C4, C7, and C8 provide major structural improvement.

Applications of Central Plant Recycling Technique

There are several advantages of central plant operations. Excellent quality control can be obtained in terms of particle sizing, recycling agent content, binder content, blending percentages of new and recycled aggregate, and mixture homogeneity. Processes involving the use of heat generally produce mixtures that do not have to be cured before obtaining near maximum strength.

Other advantages of central plant operations include the ability of the process to repair nearly all types of pavement

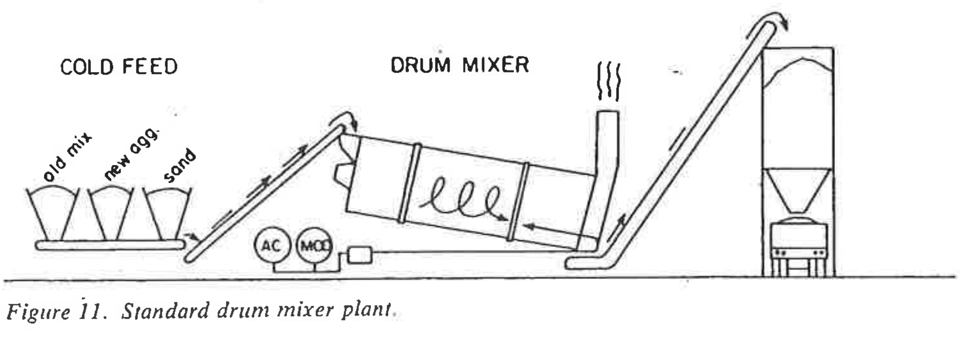


Figure 11. Standard drum mixer plant.

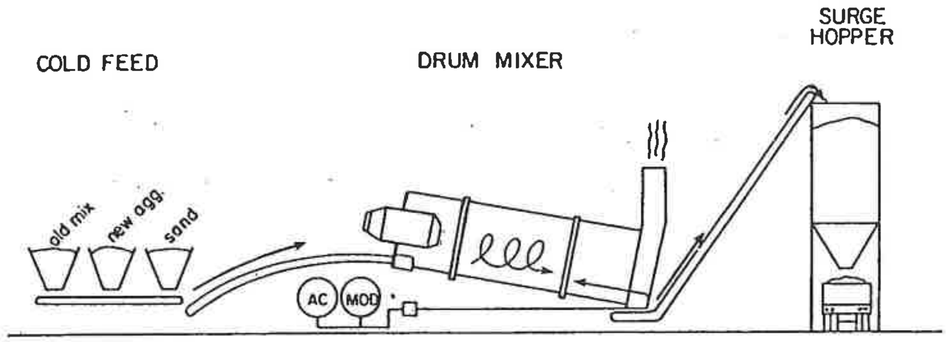


Figure 12. Drum mixer with heat dispersion shield.

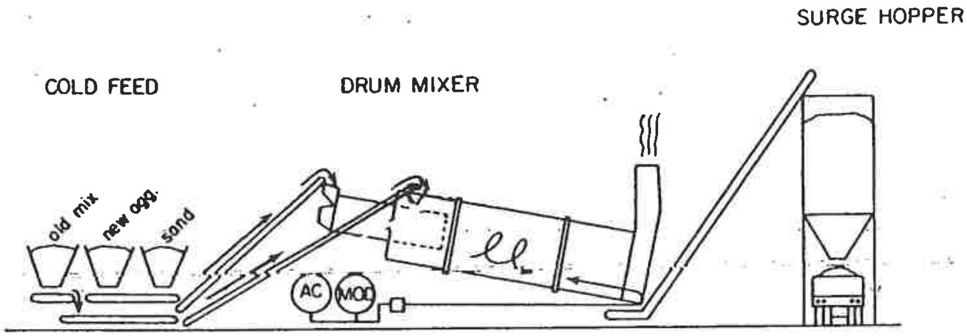


Figure 13. Drum within a drum plant.

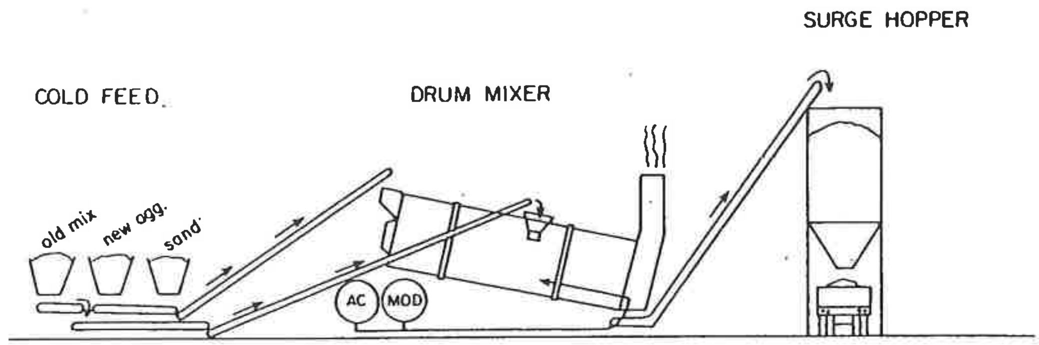


Figure 14. Drum mixer with split feed.

distress and to produce significant structural improvement. Skid resistance problems can also be corrected by proper mixture design, including the addition of a nonpolishing coarse aggregate. Reflection cracking can be eliminated provided the entire stabilized section of the pavement is removed and recycled.

Selection of central plant recycling operations over other recycling approaches will be most dependent on the availability of plant equipment, the need for structural improvement, and the distance of haul to new aggregate and existing plants. Central plant recycling appears most promising when major structural improvements are required on fairly

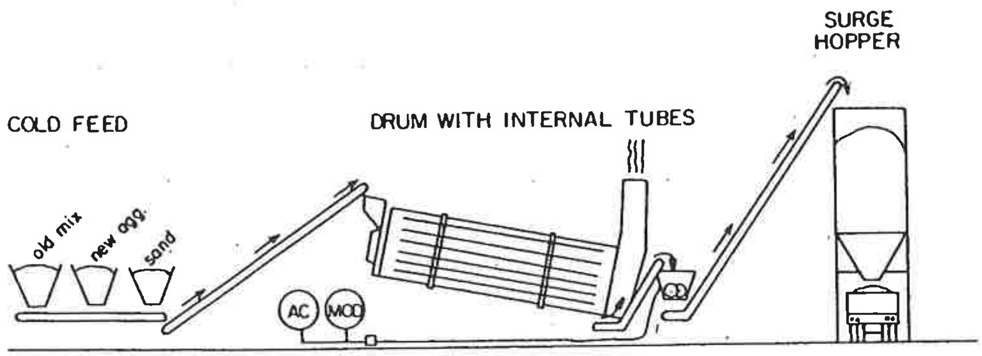


Figure 15. Special drum mixer with heat exchanger tubes.

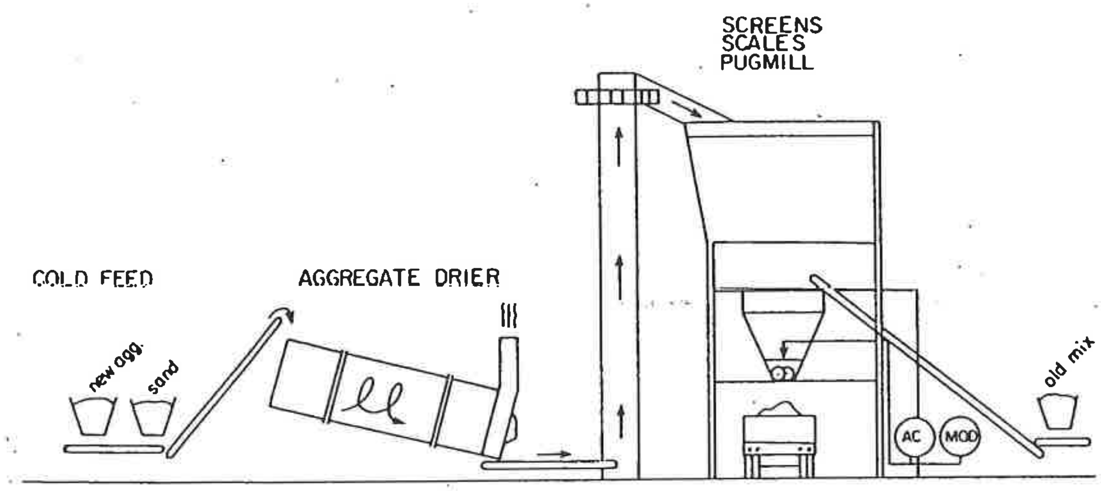


Figure 16. Standard batch plant with old mix added to superheated aggregates at the pug mill.

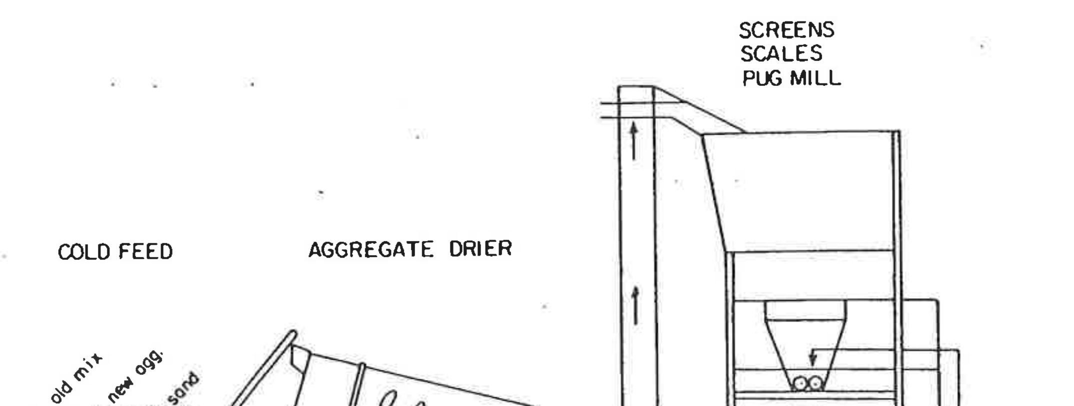


Figure 17. Standard batch plant with old mix added to superheated aggregate at drier discharge.

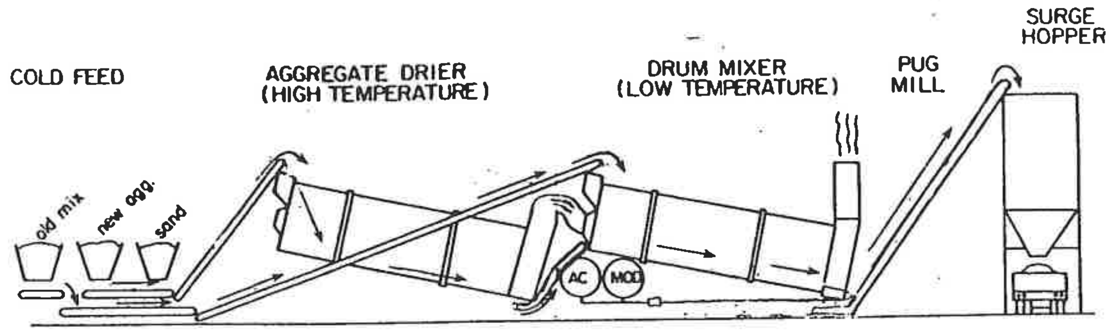


Figure 18. Tandem drum mixers—one heating aggregate only, the other heating old mix, blended in pug mill with binder.

high traffic volume facilities. With proper scheduling, it is possible to remove a section of pavement and replace that same section of pavement the same day. Recycled mixture made with aggregate from the previous day's removal operation can be used.

Construction Procedures

For detailed construction procedures for use of lime, cement, or bituminous stabilizers, refer to Appendix H (see also App. K).

Mixture Design

The mixture design process for central plant recycling requires the determination of both the type and amount of binder to be used. If asphalt is to be the binder, the engineer should consult Appendix A to determine the need for a modifier recycling agent and/or the quantity of bituminous material. Guidelines for selecting stabilizers other than asphalt (such as lime and portland cement) are given elsewhere (see App. K for further details).

Structural Design

The AASHO Interim Guide, 1972, procedure for pavement structural design is suggested for use because layer coefficients, *a*, for upgraded materials either are published in the Guide or can be obtained from other agencies that have employed these guides for design (i.e. the U.S. Forest Service) (see App. D). Layer coefficients for recycled materials have been developed as a part of this NCHRP project and are also given in Appendix D.

Economics and Energy

The costs associated with central plant recycling are given in Tables F-1 and F-2. Energy data may be obtained from Appendix G. A 20- to 30-year period is suggested for the analysis period. Details of the methodology involved in this analysis are given in Appendix J.

Construction Specifications

Because of the wide variations of conditions surrounding

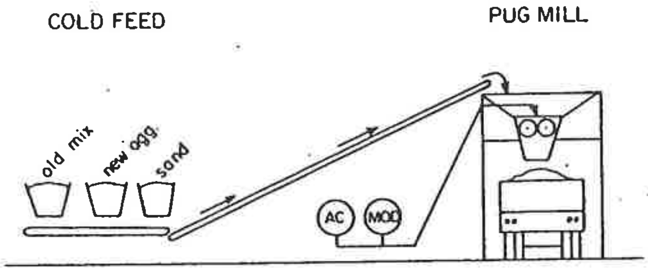


Figure 19. Cold mix plant.

a recycling project, a guide specification must necessarily be somewhat general. Most aspects of evaluation and design are covered elsewhere in this report. Once various test data are developed and the engineer is satisfied that recycling is a reasonable alternative to other methods of rehabilitation, he must then be able to tell the contractor what he wants. One approach has been to prepare the usual construction specifications for reconstruction or asphalt overlay; additionally, another set of specifications is prepared for the most suitable recycling method. Then, both alternate procedures are presented in the call for bids and the potential contractors are asked to submit cost proposals for one or both construction methods. The owner agency can thus evaluate them to determine the most cost effective approach.

Instead of attempting to cover all types and options within the central plant area, a typical, or model, specification has been adapted from The Asphalt Institute literature and is included in Appendix H. This particular specification is primarily for hot mix types of materials, but can be modified for other plant mix operations. During the early periods of an agency's utilization of recycling pavement materials, existing specifications probably will be revised to meet one's needs. After more experience has provided confidence, a new special specification likely will be developed. A particularly useful procedure is to quote the standard specification and then modify it to meet special requirements with "Notes to the Engineer."

Quality Control

Methods of testing for quality control purposes can be found in Appendix I, or methods commonly used by the contracting agencies can be substituted.

CHAPTER FOUR

FINDINGS—GUIDELINES FOR RECYCLING PORTLAND CEMENT CONCRETE PAVEMENT

This chapter contains guidelines associated with recycling portland cement concrete pavements. Portland cement concrete pavements are considered to be those pavements surfaced with portland cement bound materials. Composite pavements containing portland cement concrete that have been overlaid with an asphalt pavement were covered in Chapter Three, unless the recycled material was to be used as econocrete or portland cement concrete. Recycled composite pavements used as econocrete or portland cement concrete are considered in this chapter.

Once the pavement engineer has determined that recycling is a reasonable approach to rehabilitation, he must decide which recycling method is most suited for the particular project under consideration. The analysis techniques described herein are guidelines for the engineer to follow during this decision process. For convenience, the analysis techniques have been divided into two major sections. The first section, Part A, is a preliminary analysis identifying the few recycling methods that appear to be most suitable. The second section, Part B, is a more detailed analysis based on laboratory and field data, cost and energy projections, and results in a prioritized list of alternatives with appropriate mixture and structural designs and construction specifications. The overall view of this preliminary analysis, which results in a selection of recycling alternatives (Part A) is shown in Figure 20.

PART A—SELECTION OF ALTERNATIVES

This part of the report contains guidelines that allow the engineer to select a few of the many recycling alternatives available for a particular project. Eight recycling alternatives have been identified as feasible for recycling portland cement concrete pavements. Table 9 gives the recycling alternatives available. A brief definition of these alternatives follows. Detailed descriptions of the methods are contained in Part B of this chapter.

Definitions

Surface Recycling

Surface Milling (A9). This operation involves the removal of the surface of a pavement by a cold-milling or cold-planing machine. The depth of removal is variable and may be as much as 2 in. in a single pass. The millings or shavings are removed from the construction site.

Surface Milling Plus Thin Overlay (A10). This operation involves the removal of the surface of a pavement by a cold-milling or cold-planing machine and the addition of a thin overlay. The material used for the overlay may be a new asphaltic concrete or portland cement concrete or a mixture prepared from the millings or shavings.

Surface Milling Plus Thick Overlay (A11). This operation involves the removal of the surface of a pavement by a cold-milling or cold-planing machine and the addition of a thick overlay. The material used for the overlay may be a new asphaltic concrete or portland cement concrete or a mixture prepared from the millings or shavings.

Central Plant Recycling

Cold Mix Process Without Binder (C9). This operation involves the breaking of the old concrete pavement on-grade, loading, hauling, crushing at a central plant, blending the produced aggregate and mix aggregate as required to meet the desired gradation, hauling, placing and compacting.

Cold Mix Process with Binder (C10). This operation involves the breaking of the old concrete pavement on-grade, loading, hauling, crushing at a central plant, blending the produced recycled aggregate and new aggregate as required to meet the desired gradation, mixing with a binder such as portland cement or emulsified asphalt, hauling, placing, compacting, and curing.

Cold Mix Process—Econocrete (C11). This operation involves the breaking of the old concrete pavement on-grade, loading, hauling, crushing at a central plant, blending the produced recycled aggregate and new aggregate as required to meet the desired gradation, mixing with portland cement to produce econocrete (a fluid, low cement content portland cement concrete), hauling, placing, consolidating, and curing.

Cold Mix Process—Portland Cement Concrete (C12). This operation involves the breaking of the old concrete

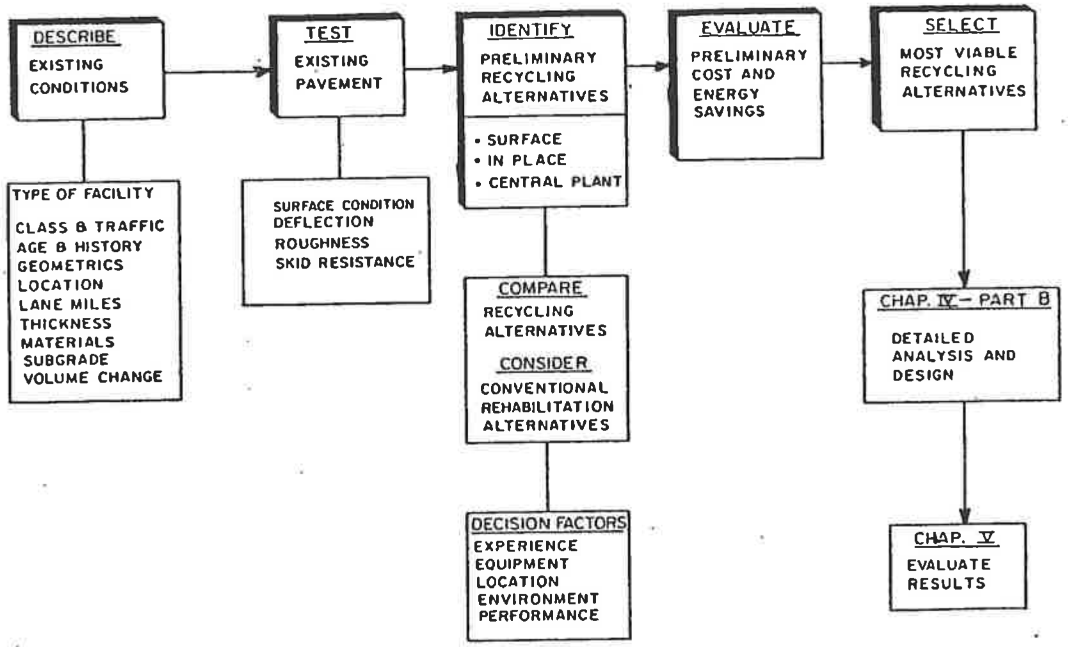


Figure 20. Preliminary analysis and selection of most suitable alternatives.

pavement on-grade, loading, hauling, crushing at a central plant, blending the produced recycled aggregate and new aggregate as required to meet the desired gradation, mixing with portland cement to produce portland cement concrete, hauling, placing, consolidating, and curing.

Hot Mix Process with Binder (C13). This operation involves the breaking of the old concrete pavement on-grade, loading, hauling, crushing at a central plant, blending the produced recycled aggregate and new aggregate as required to meet the desired gradation, mixing the heated aggregate with asphalt cement or emulsified asphalt to produce asphaltic concrete or asphalt-treated base, hauling, placing, and compacting.

From a review of the foregoing definitions it is apparent that the type of equipment, degree of structural improvement, and the use of a binder are key factors used to define the recycling approaches. It is important that the engineer be familiar with the recycling operations previously defined prior to reading the remainder of the guidelines.

Selection of Recycling Alternatives

If the engineer is to select the most appropriate recycling alternative for a particular project, he must describe or characterize the condition of the existing facility. Aside from historical facts and known conditions, the present condition must be measured on some rational basis and compared to standard criteria. Key factors that influence the decision include the following as a minimum: (1) surface condition, (2) structural capacity, (3) roughness, and (4) skid resistance.

These factors together with a summary of key data describing the existing facility are discussed in the following.

TABLE 9

OPTIONS FOR PORTLAND CEMENT CONCRETE PAVEMENT

Category	Method	Description	Code
SURFACE	Surface milling, grinding or planing	Surface milling only	A9
		Surface milling plus thin overlay	A10
		Surface milling plus thick overlay	A11
CENTRAL	Cold mix process	Without binder	C9
		With binder	C10
		Econocrete	C11
		Portland Cement Concrete	C12
	Hot mix process	With binder	C13

Existing Facility

Particular data are required to describe adequately the existing facility for the purposes of rehabilitation decision-making. These factors are summarized in Table 10 in a form for easy reference. Specific items noted are as follows: (1) location and size of project, (2) roadway class, (3) existing pavement cross section, (4) geometrics, (5) traffic, and (6) subgrade characteristics.

Location and Size of Project. The location and size of a project may be such that only certain techniques would be cost effective. For example, projects located in remote

TABLE 10

SUMMARY OF EXISTING PAVEMENT CONDITIONS

FEATURE	VALUE	COMMENT
Location		
Size of Project (lane-miles)		
Class of Roadway		
Existing Pavement Cross Section (Include date, thickness and type of original pavement layers; date, thickness and type of subsequent rehabilitation and maintenance activities)		
Geometrics (Number of lanes, width, vertical clearance, other constraints)		
Traffic Characteristics ADT Average daily eq. 18 kip axle loads		
Subgrade Characteristics		
Surface Condition (Pavement Rating Score, PRS)		
Structural Condition (Deflection, 0.001 inch overlay required)		
Roughness (Serviceability Index)		
Skid Resistance (SN_{40})		
Other Factors (Distance to aggregate and binder source, available equipment and contractor experience)		

areas will have to be large in size to justify the transportation of the equipment associated with central plant recycling.

Roadway Class. Generally, the roadways can be classed in broad categories as: Interstate and Urban Freeway, Rural Primary (U.S. and state signed routes), Rural Secondary (farm and ranch-to-market, park roads, etc.), and Urban Streets (arterial, collector, local). Roadway class dictates criteria for determining the need for pavement rehabilitation as well as general criteria for selection of an appropriate recycling alternative.

Existing Pavement Cross Section. The date of original construction together with a listing of the thickness and types of materials used will be important in judging the general serviceabilty of the pavement. Subsequent history of rehabilitation and maintenance activities, such as seal coats, overlays, patching, crack sealing, etc., will influence the determination of a viable recycling alternative. Thickness of each layer of different material, as well as the type of material and its condition, should be obtained from project records. Reliance on memory for the information is often risky. A few carefully located core samples will provide confidence in the information.

The type or nature of the existing materials will influence the recycling method selected for a given project. If the bound materials are variable, both vertically and horizontally, it may be difficult to make a uniform recycled mixture without adding large quantities of aggregate and/or binder to dilute these undesirables. If the structural strength of the pavement must be increased, several options exist that include removing the pavement materials and stabilizing the subgrade before remixing and replacing the pavement, or using all existing pavement materials stabilized as a base course and then overlaying.

Geometrics. The geometric features of a roadway, such as horizontal and vertical alignment, are often constraints to conventional rehabilitation techniques such as portland cement concrete or asphalt overlays. For example, the drainage line at curbs and gutters can not be altered without considerable expense. Therefore, an overlay must be constructed at the appropriate thickness in the driving lanes and then tapered to near zero thickness at the gutter. Mulipie overlays can cause havoc, resulting in excessively high crowns at the centerline and steep cross slopes. Other features such as drainage inlets and manholes also cause problems of a similar nature. Recycling of existing pavement materials offers a solution to some of these problems.

Vertical clearance for trucks and other special vehicles at bridges and overhead signals and signs is often critical and can not be reduced as would be the case if overlays were used. Recycling offers a further benefit here.

On multilane highways the truck or travel lane often deteriorates before the passing lane. Overlaying only one of the lanes would be impractical, but recycling of that lane alone or to strengthen it before adding a general overlay would provide a more acceptable solution. Similarly, superelevation could be preserved or altered as needed without disturbing adjacent lanes.

Changing the horizontal alignment or adding new features, such as shoulder widening or a new shoulder and lane widening or a new lane, may also be opportunities to use recycling techniques. Often, these features may not need the full design strength of adjoining lanes and could be stabilized in place or the existing aggregate base could be used to make asphaltic concrete without the need for new materials or for wasting existing materials.

Traffic Characteristics. The speed and volume of traffic, to a large extent, determine the traffic control problems associated with pavement rehabilitation activities. The use of recycling on high traffic volume urban facilities should be geared toward those activities that can provide low roadway occupancy time, can be performed with single lane blockage, and can use materials with rapid strength gain after placement.

The volume and axle weight distribution of traffic are important from a pavement design standpoint. For pavement design purposes, traffic should be converted to average daily equivalent 18,000-lb axle-load repetitions that are representative for the design period. It is suggested that the AASHTO procedures be used for this conversion.

Subgrade Characteristic. Pavement failures due to factors outside the pavement layers often need to be considered. For example, a subgrade that contains a swelling clay may need to be improved before recycling the pavement materials would be effective. Another environmentally influenced problem related to volume change is frost heave. For both of these problems, recycling may offer a reasonable solution in that the pavement materials would need to be removed in any event in order to remove or improve the poor subgrade. While removing the materials, they could be reprocessed and replaced after the subgrade has been prepared. (See App. K for further details.)

In summary, all known information about the pavement materials and background needs to be summarized and used in the decision process. Surprises at the time of construction can be avoided usually by proper testing, evaluation, planning, and design.

Surface Condition

Each potential recycling project should be surveyed for surface defects that can be used not only to assess the cause of distress but perhaps to also suggest corrective action. Several agencies have devised methods to estimate pavement distress and one such approach is discussed in Appendix A, Volume 3, of the agency's report (see App. K for further information). Once this survey is made, the results can be summarized and entered on the first line of Table 11. The engineer should systematically look at each distress marked on the first line in this table and estimate which recycling methods would correct that distress, and indicate this assessment by placing a check mark in the appropriate box. Note that a number of boxes are shaded; this indicates that these recycling options would not be appropriate. For example, the central plant operations are not suitable for recycling continuously reinforced concrete pavements (CRCP). Similarly, surface milling by itself is unsuitable for treating several types of distress such as severely spalled joints.

Once all the viable recycling alternatives for improving surface conditions are determined, they can be summarized in Table 14. If the portland cement concrete pavement has been previously overlaid with asphaltic concrete, a condition survey should be used and recycling options, as given in Table 2, should be considered as well as those recycling alternatives specific to portland cement concrete.

Structural Condition

The structural adequacy or structural condition of the roadway under consideration is determined by the thickness of the overlay required. The Corps of Engineers procedure for flexible overlays over rigid pavements or the Illinois Department of Transportation method is suggested for use. The equation used in the Corps of Engineers method is as follows:

$$t = 2.5\,(F h_d - c h) \qquad (2)$$

in which:

t = thickness of the overlay, in.;
F = factor related to the subgrade modulus;
h_d = required thickness determined using a conventional portland cement concrete pavement thickness method, in.;
h = existing pavement thickness, in.; and
c = coefficient depending on the condition of the existing slab ($c = 1$ when the existing pavement is in good overall structural condition, $c = 0.75$ when the existing pavement has initial joint and corner

TABLE 11

SELECTION OF RECYCLING TECHNIQUES BASED ON SURFACE CONDITION OF PCC PAVEMENTS

	RECYCLING METHODS	Pumping: Slight	Pumping: Moderate	Pumping: Severe	Surface Deterioration, % Area, <15: Slight	Surface Deterioration, % Area, <15: Moderate	Surface Deterioration, % Area, <15: Severe	Surface Deterioration, % Area, 16-50: Slight	Surface Deterioration, % Area, 16-50: Moderate	Surface Deterioration, % Area, 16-50: Severe	Surface Deterioration, % Area, >50: Slight	Surface Deterioration, % Area, >50: Moderate	Surface Deterioration, % Area, >50: Severe	Spalling, % Joints, Cracks, <15: Slight	Spalling, % Joints, Cracks, <15: Moderate	Spalling, % Joints, Cracks, <15: Severe	Spalling, % Joints, Cracks, 16-50: Slight	Spalling, % Joints, Cracks, 16-50: Moderate	Spalling, % Joints, Cracks, 16-50: Severe	Spalling, % Joints, Cracks, >50: Slight	Spalling, % Joints, Cracks, >50: Moderate	Spalling, % Joints, Cracks, >50: Severe	Longitudinal Cracking, Lin. Ft per Sta., 10-99: Slight	Longitudinal Cracking, Lin. Ft per Sta., 10-99: Moderate	Longitudinal Cracking, Lin. Ft per Sta., 10-99: Severe	Longitudinal Cracking, Lin. Ft per Sta., 100-199: Slight	Longitudinal Cracking, Lin. Ft per Sta., 100-199: Moderate	Longitudinal Cracking, Lin. Ft per Sta., 100-199: Severe	Longitudinal Cracking, Lin. Ft per Sta., >200: Slight	Longitudinal Cracking, Lin. Ft per Sta., >200: Moderate	Longitudinal Cracking, Lin. Ft per Sta., >200: Severe	Patching, % Area, 1-5: Good	Patching, % Area, 1-5: Fair	Patching, % Area, 1-5: Poor	Patching, % Area, 6-15: Good	Patching, % Area, 6-15: Fair	Patching, % Area, 6-15: Poor	Patching, % Area, >15: Good	Patching, % Area, >15: Fair	Patching, % Area, >15: Poor	Faulting, % Joints, <10: Moderate	Faulting, % Joints, <10: Severe	Faulting, % Joints, >10: Moderate	Faulting, % Joints, >10: Severe	CRCP Only: Crack Spacing, Ft., 5-10: Closed	CRCP Only: Crack Spacing, Ft., 5-10: Open	CRCP Only: Crack Spacing, Ft., Other: Closed	CRCP Only: Crack Spacing, Ft., Other: Open	CRCP Only: Intersecting Cracks, %, <10: Moderate	CRCP Only: Intersecting Cracks, %, <10: Severe	CRCP Only: Intersecting Cracks, %, >10: Moderate	CRCP Only: Intersecting Cracks, %, >10: Severe	Jointed Only: Joint Spacing, Ft, <20: Sawed	Jointed Only: Joint Spacing, Ft, <20: Constructed	Jointed Only: Joint Spacing, Ft, >20: Sawed	Jointed Only: Joint Spacing, Ft, >20: Constructed	Jointed Only: Transverse Cracking, No. per Panel, 1-4: Slight	Jointed Only: Transverse Cracking, No. per Panel, 1-4: Moderate	Jointed Only: Transverse Cracking, No. per Panel, 1-4: Severe	Jointed Only: Transverse Cracking, No. per Panel, 5-9: Slight	Jointed Only: Transverse Cracking, No. per Panel, 5-9: Moderate	Jointed Only: Transverse Cracking, No. per Panel, 5-9: Severe	Jointed Only: Transverse Cracking, No. per Panel, >10: Slight	Jointed Only: Transverse Cracking, No. per Panel, >10: Moderate	Jointed Only: Transverse Cracking, No. per Panel, >10: Severe
	CONDITION OF EXISTING PAVEMENT																																																																
SURFACE	SURFACE MILLING ONLY																																																																
SURFACE	SURFACE MILLING PLUS THIN OVERLAY																																																																
SURFACE	SURFACE MILLING PLUS THICK OVERLAY																																																																
CENTRAL	COLD MIX PROCESS WITHOUT BINDER																																																																
CENTRAL	COLD MIX PROCESS WITH BINDER																																																																
CENTRAL	COLD MIX PROCESS - ECONOCRETE																																																																
CENTRAL	COLD MIX PROCESS - PORTLAND CEMENT CONCRETE																																																																
CENTRAL	HOT MIX PROCESS WITH BINDER																																																																

cracks due to loading but no progressive structural distress or recent cracking, and $c = 0.35$ when the existing pavement is badly cracked or shattered structurally).

Determination of the factor h_d in the equation can be accomplished by any number of thickness design methods—AASHO Interim Guide, Portland Cement Association method, American Concrete Institute method, United States Steel method, Continuously Reinforced Pavement Group method, and methods presently used by the various states. Additional details can be obtained in Appendix E.

If the portland cement concrete has been overlaid with asphaltic concrete, the overlay design procedure developed by Illinois should be used.

Selection of recycling alternatives based on structural improvement is based on the required thickness of overlay as determined by these methods. For example, if the thickness for overlay is greater than 2 in., surface milling by itself and surface milling with thin overlay will not be an acceptable recycling alternative (Table 12). Central plant operations should not be scheduled unless an overlay greater than 2 in. is required (Table 12). Those recycling alternatives identified as appropriate for improving the pavement from a structural adequacy standpoint should be entered in Table 14.

As previously noted, the criteria used for selecting the recycling alternative is based on the thickness of asphaltic concrete overlay required. It is not the intent of this criterion to eliminate the consideration of a portland cement concrete overlay. The use of a portland cement concrete overlay is one of several rehabilitation alternatives that should be considered in addition to the recycling options contained in these guidelines.

Roughness

The smoothness of ride may be a deciding factor for rehabilitation of many roadways. Occasionally, a rough surface may be the only significant problem and surface recycling would be the solution. If a pavement is rough, but also has other deficiencies that require more extensive reworking, the roughness may be taken care of automatically in that operation. Therefore, the need for surface recycling based on ride measurements (serviceability index, SI) can be estimated as noted in Table 13. As in previous discussions, some methods would not be appropriate and have been blocked out. For example, it is not recommended that rough Interstate and primary highways be recycled without an appropriate overlay. Those methods that are considered appropriate should be checked off in Table 13 and the results summarized in Table 14. (See App. K for further details.)

Skid Resistance

Many pavements perform adequately from a structural standpoint, but are deficient in skid resistance because of loss of surface texture or perhaps because of polishing aggregates. As part of the overall pavement testing scheme, skid resistance can be measured by using any one of several standard test methods, but preferably the so-called ASTM skid trailer (see App. K). It is noted that all recycling methods are appropriate for improving skid resistance. The acceptable recycling methods to improve skid resistance should be entered in Table 14.

Steps in Determining Preliminary Recycling Alternatives

As discussed earlier, the goal in this chapter is to select several reasonable viable alternatives to recycle portland cement concrete pavements. Referring to Figure 20, one can note that after all preliminary information is collected, the potentially successful approaches can be analyzed with respect to cost and energy savings and the most viable survivors determined. The steps required in order to reach these conclusions are summarized as follows:

1. List available information on existing roadway (Table 10).
2. Test existing pavement:
   a. Surface condition (Table 11)
   b. Structural condition (Table 12)
   c. Roughness (Table 13)
   d. Skid resistance (App. K)
3. Evaluate other decision factors unique to the particular project.
4. Make preliminary cost analysis of remaining options and rank accordingly (Table 15).
5. Consider alternatives that appear most viable and continue evaluation (Chap. Four, Part B).

PART B—DETAILED ANALYSIS AND DESIGN

This part of the report will provide guidance and an outline for making a detailed analysis of a recycling approach. Cost, energy, mixture design, structural design, construction specifications, and quality control requirements are included for surface and central plant recycling. Use of this part will allow the engineer to prioritize the preliminary recycling alternatives selected earlier in this chapter under Part A.

TABLE 12

SELECTION OF RECYCLING TECHNIQUES TO IMPROVE STRUCTURAL STRENGTH

Recycling Method		Thickness of Required Overlay		
		None	Less Than 2 Inches	Greater Than 2 Inches
Surface	Surface milling only			
	Surface milling plus thin overlay			
	Surface milling plus thick overlay			
Central	Cold mix process without binder			
	Cold mix process with binder			
	Cold mix process - Econocrete			
	Cold mix process - portland cement concrete			
	Hot Mix process with binder			

TABLE 13

SELECTION OF RECYCLING TECHNIQUES BASED ON ROAD ROUGHNESS

	Recycling Method \ Type of Facility / Serviceability Index	Interstate or Urban Freeway				Primary				Secondary				Urban Street			
		+ 3.0	2.5 - 2.9	2.0 - 2.4	- 2.0	+ 3.0	2.5 - 2.9	2.0 - 2.4	- 2.0	+ 3.0	2.5 - 2.9	2.0 - 2.4	- 2.0	+ 3.0	2.5 - 2.9	2.0 - 2.4	- 2.0
Surface	Surface milling only			(shaded)	(shaded)				(shaded)								(shaded)
Surface	Surface milling plus thin overlay				(shaded)												
Surface	Surface milling plus thick overlay																
Central	Cold mix process without binder																
Central	Cold mix process with binder																
Central	Cold mix process - Econocrete																
Central	Hot mix process with binder																

Surface Recycling

Surface recycling techniques used on rigid pavements involve the use of cold-milling or cold-planing machines. This type of equipment is capable of removing up to about 2 in. of portland cement concrete in a single pass. Asphaltic concrete overlays are often placed after milling. Portland cement concrete overlays could also be used.

Milling obtained from the pavement has been used for unstabilized base courses and has the potential to be used as stabilized bases and surface courses.

A number of pavements have been milled to improve skid resistance. Surface texture, drainage, and skid number are improved; however, the immediate increase in skid number may be temporary if the old concrete contains a polishing aggregate.

Equipment and methods, applications of surface recycling techniques, structural design, construction specifications, and quality control guidelines are presented in the following.

Equipment and Methods

Surface milling and grinding on portland cement concrete was first performed by attachments on motor patrol equipment. These units were 30 in. wide and had relatively little production capability as compared to existing equipment that can remove a 12-ft pavement in a single pass. The sequence of operations involving surface recycling is as follows: (1) establishing desirable grade line; (2) milling, grinding, or planing the pavement to the desired depth; (3) clean-up involving rotary broom and vacuum equipment; and (4) disposal or recycling of the millings.

Surface recycling operations involving overlays use the sequence of operations as described, with the addition of a tack coat and an asphaltic concrete overlay. Portland cement concrete overlays could also be used. Recycling techniques identified in these guidelines and using this equipment are methods A9, A10, and A11.

The guidelines established in Part A have indicated that surface recycling techniques without the addition of an overlay offer little increase in the load carrying ability of the pavement. In fact, if a substantial portion of the pavement is removed, a decrease in load carrying ability will result.

TABLE 14

SUMMARY OF PRELIMINARY RECYCLING ALTERNATIVES

	Recycling Process \ Road Condition	Surface Condition	Deflection	Roughness	Skid Resistance
Surface	Surface milling only				
Surface	Surface milling plus thin overlay				
Surface	Surface milling plus thick overlay				
Central Plant	Cold mix process without binder				
Central Plant	Cold mix process with binder				
Central Plant	Cold mix process - Econocrete				
Central Plant	Cold mix process - portland cement concrete				
Central Plant	Hot Mix process with binder				

TABLE 15

REPRESENTATIVE COSTS FOR PCC RECYCLING OPERATIONS

Category	Method	Description	Code	Representative Costs per Sq.Yd.$ Average	Range	Assumptions
Surface	Surface milling, grinding or planing	Surface milling only	A9	0.80	0.50-1.50	Milling, cleaning, hauling, traffic control (1-inch removal)
		Surface milling plus thin overlay	A10	2.80	2.50-3.50	Milling, cleaning, hauling, 200 lbs of asphalt concrete, traffic control (1-inch removal)
		Surface milling plus thick overlay	A11	4.80	4.50-5.50	Milling, cleaning, hauling, 400 lbs of asphalt concrete, traffic control (1-inch removal)
Central	Cold Mix Process	Without binder	C9	5.50	4.50-7.50	Remove and crush 9 inches of P.C.C., place 9 inches without binder, traffic control
		With binder	C10	6.50	5.50-8.50	Remove and crush 9 inches of P.C.C., place 9 inches with binder, traffic control
		Econocrete	C11	6.50	5.50-8.50	Remove and crush 9 inches of P.C.C., place 9 inches of econocrete, traffic control
		Portland cement concrete	C12	12.00	9.00-15.00	Remove and crush 9 inches of P.C.C., place 9 inches of P.C.C., traffic control
	Hot Mix Process	With binder	C13	8.00	6.25-10.50	Remove and crush 9 inches of P.C.C., place 9 inches of asphalt concrete, traffic control.

Application of Surface Recycling Techniques

Pavement milling operations are suitable for correction of portland cement concrete pavements with rutting (due to tire chains, studded tires, etc.); for removal of localized severe surface undulations caused by swelling clays, frost heave, etc.; for removal of pavement prior to overlay along gutters, at bridge approaches and other areas where a feathered edge of asphaltic concrete or portland cement concrete is likely to abrade; and for improved drainage, surface texture, and skid number.

An added advantage of surface recycling is the increase in bond strength between a milled portland cement concrete and an overlay as compared to a normal overlay operation. This anticipated increase in bond strength may allow the use of thin overlays on portland cement concrete pavements.

Milling of concrete often causes spalling of the joints and/or cracks. Care must be taken to minimize this problem.

Mixture Design

Materials and mixture design techniques used for overlays, either asphaltic concrete or portland cement concrete, should be based on procedures currently used by the agency involved in recycling. Particular attention should be given to providing a long lasting skid resistant surface. If the millings are to be used for unstabilized base, stabilized base and surface courses design procedures contained in Appendixes A, B, and C should be used.

Structural Design

Structural design considerations associated with surface recycling are limited to the thickness of overlay required to prevent failure due to traffic and reflection cracking. Appendix E contains a method to determine the thickness of asphaltic concrete overlay required to consider the effects of traffic. A satisfactory design method has not been developed to consider reflection cracking.

Economics and Energy

The costs associated with surface recycling operations on rigid pavements are given in Tables F-1 and F-2. Detailed cost information of materials used in various operations associated with surface recycling are also included in Appendix F.

The energy associated with surface recycling operations is included in Appendix G. Little data have been developed to define the energy required for the various recycling operations; however, sufficient data exist in Appendix G to calculate a representative energy for each of the surface recycling options given in Table 9.

Cost and energy consumption should be made on a life-cycle basis. A 20- to 30-year period is suggested for the analysis period. Details of the methodology involved in this analysis are given in Appendix J.

Construction Specifications

Specifications for surface milling are included in Appendix H. These are the same specifications that are suggested for use with aspshaltic concrete pavements. Specifications for asphaltic concretes used with these techniques should be those commonly used by the contracting agency.

Quality Control

Methods of testing for quality control purposes can be found in Appendix I, or methods commonly used by the contracting agency can be substituted.

Central Plant Recycling

As discussed earlier in Part A, central plant recycling techniques are different from the other methods of recycling in that the material is removed from the roadway and mixed either cold or hot at a central plant location. Additional portland cement or asphalt may be added at the plant to enhance the overall properties. These recycling operations, although maintaining good quality control, are often costly.

Equipment and methods, applications of central plant recycling techniques, mixture design, structural design, construction specifications, and quality control guidelines are discussed in the following.

Equipment and Methods

Recycling of portland cement concrete pavements using central plants is not a new concept. During World War II a crushed concrete pavement was used as unstabilized base in Illinois. Cement treated subbase made with crushed concrete was used at Love Field in Dallas, Tex., in 1964. The first econocrete or lean concrete section made with recycled portland cement was placed in California in 1975, and Iowa placed the first portland cement concrete pavement with crushed portland cement concrete in 1976. The first large scale job using recycled portland cement concrete as an aggregate for asphaltic concrete occurred in Texas in 1969. Techniques developed for central plant recycling of portland cement concrete pavements are shown in Figure 21.

The pavement removal and crushing operations are normally performed with conventional construction and demolition equipment. The old concrete pavement is normally broken with a headache ball or pneumatic ram. The size of the resulting slab is normally small enough to be received by the primary crusher. Additional reduction in slab size can be performed at the crushing location.

Central plant sizing can be performed with conventional, fixed and portable crushing equipment; however, reinforcing steel may be a problem and may have to be removed at one or more of six process locations: (1) on the grade during the loading operation, (2) during the loading operation for crushing if stockpiling occurs prior to crushing, (3) at the entry to the primary jaw crusher, (4) on the belt after primary crushing, (5) on the belt after final crushing, and (6) in the stockpile prior to remixing.

Blending and mixing operations in the central plant are standard operations as are the techniques used for placing and curing the recycled materials. Gradation adjustments are often made to improve workability.

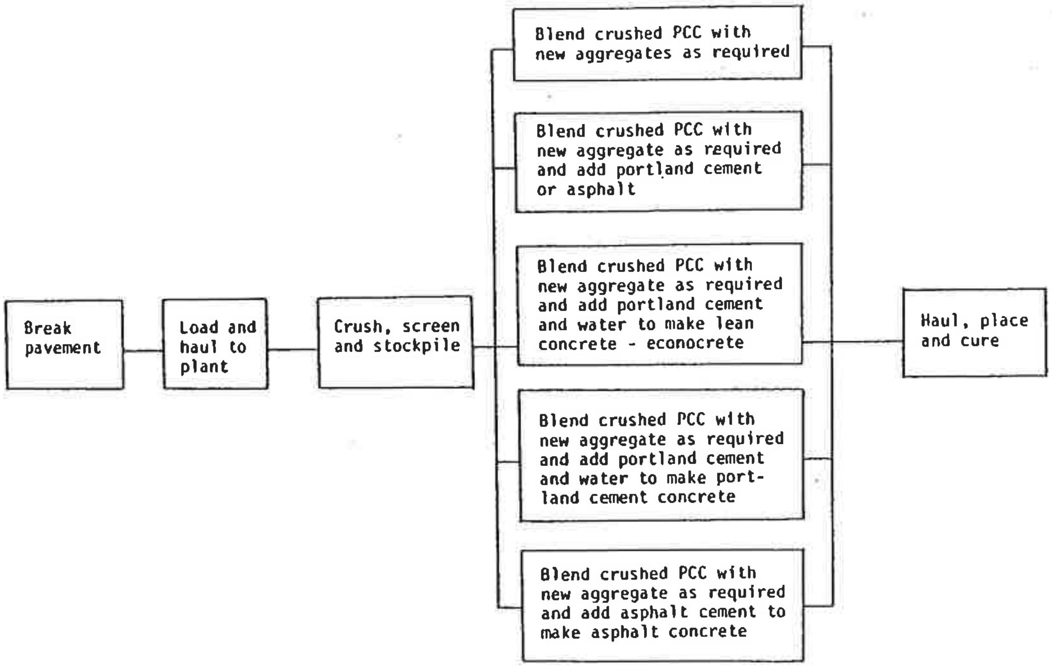


Figure 21. Central plant recycling operations.

The recycling techniques identified for the use of this equipment are items C9 to C13 as noted earlier in this chapter under Part A. Basic differences in these techniques are the types of materials that are produced. Techniques C9, C10, C11, and C12 are cold processes; technique C13 is a hot process. All of these techniques have the capability of providing major structural improvement.

Application of Central Plant Recycling Techniques

There are several advantages of central plant operations. Excellent quality control can be obtained in terms of particle sizing, binder content, blending percentages of new and recycled aggregate and mixture homogeneity. The process using heat to produce asphaltic concrete does not have to be cured before obtaining near maximum strength.

Other advantages of central plant operations include the ability of the process to repair nearly all types of pavement distress and to produce a significant structural improvement. Skid resistance problems can also be corrected by proper mixture design, including the addition of a non-polishing aggregate.

Central plant operations appear most promising where structural improvement is required, the haul distance to new aggregate sources is great, and the highway has fairly high traffic volumes. With proper scheduling, it is possible to remove a section of pavement and replace that section of pavement the same day. Recycled mixtures made with aggregate from the previous day's removal operation can be used.

The use of recycled portland cement concrete as econocrete appears to be an economical use of this recycled material, particularly if the crushed concrete has some contamination due to fines or asphalt stabilized materials. This lean concrete can be placed with standard construction equipment as the lower course in a composite pavement structure. The surface course can be constructed with portland cement concrete made from natural aggregate or good quality recycled aggregate with sand.

Construction Procedures

Detailed construction procedures for central plant recycling of portland cement concrete can be found in Appendix H (see also App. K).

Mixture Design

A number of different materials can be produced from central plant recycled materials. Mixture design methods for these mixtures can be found in an appropriate appendix as follows:

1. Unstabilized base and subbase (App. I).
2. Cement stabilized base (App. F in Vol. 3—see App. K for further details).
3. Emulsified asphalt stabilized base (App. A).
4. Econocrete (App. B).
5. Portland cement concrete (App. C).
6. Asphaltic concrete (App. A).

Structural Design

The AASHO Interim Guide, 1972, procedure for flexible pavement structure designs is suggested for use because layer coefficients, *a*, for upgraded materials either are published in the Guide or can be obtained from other agencies that have employed these guides for design (i.e., the U.S. Forest Service) (see App. D). Layer coefficients for recycled materials have been developed as a part of this NCHRP project and are also given in Appendix D.

Economics and Energy

The costs associated with central plant recycling are given in Tables F-1 and F-2. Energy data can be found in Appendix G.

Costs and energy comparisons should be made on a life-cycle basis. A 20- to 30-year period is suggested for the analysis period. Details of the methodology involved in this analysis are included in Appendix J.

Construction Specifications

Specifications for central plant recycling of portland cement concrete can be obtained in Appendix H.

Quality Control

Methods of testing for quality control purposes can be found in Appendix I, or methods commonly used by the contracting agencies can be substituted.

CHAPTER FIVE

FINDINGS—GUIDELINES FOR EVALUATION OF RESULTS

Data on performance of pavements and in-place material properties should be obtained in a uniform and continuous manner for a 20- to 30-year period. Project data collection should include preconstruction mixture design and structural design information, construction quality control records, properties of the materials after construction, and performance of the pavement after construction. A similar performance evaluation program should be used to study the behavior of selected conventional construction and rehabilitation projects for comparison purposes. These data should be used as feedback information to the design process described in Chapters Three and Four and, thereby, should form the basis for future selection of pavement rehabilitation alternatives.

A description of the types of information that should be considered for inclusion in this evaluation program is defined in the following and is shown in Figure 22. For convenience, data collection associated with preconstruction, construction, and postconstruction is discussed.

PRECONSTRUCTION INFORMATION

Preconstruction information that is of interest when studying the performance of pavements includes structural design information and mixture design information. Specific structural design information includes the amount and axle weight distribution of the present and projected traffic, the type materials and the thickness of materials used for the structural section, strength coefficients of materials, availability of materials, and other preconstruction information that may be useful for postconstruction evaluation.

Mixture design information should include data defining the properties at various binder contents and densities. This information will form the basis for comparing design and field mixture properties.

CONSTRUCTION INFORMATION

It is important to monitor the recycling operation from other than a construction quality control standpoint. For example, equipment capabilities in terms of production, operating costs, energy requirements, maintenance costs, and the like should be defined if equipment improvements are to be made. Modification of construction techniques or equipment should be encouraged because possible improvements could be used in future recycling operations. Traffic control, workmen safety, and air qualty problems should be identified and required solutions obtained.

Detailed records should be kept by the contractor or the agency to define cost and energy associated with component construction operations. For example, costs and energy associated with pavement removal, transportation, mixing, placing, and finishing would be useful if central plant operations are to be used.

Complete environmental records should be collected. These records should include daily temperatures and humidity records that define both maximum and minimum conditions. Moisture amounts (rainfall, snow, sleet) should be recorded. Environmental records should be kept for the life of the project. Environmental data from nearby permanent installations are usually satisfactory for this purpose.

Construction quality control records should be obtained. These daily records normally contain mixture design and property data as well as production quantities and location of placement of materials on the roadway. These types of data may be useful if localized failures occur.

Samples of the loose or fluid mixture should be obtained and samples fabricated. The testing plan shown in Figure 23 is suggested for recycling jobs where asphalt is used as a binder. This testing plan has been formulated for re-

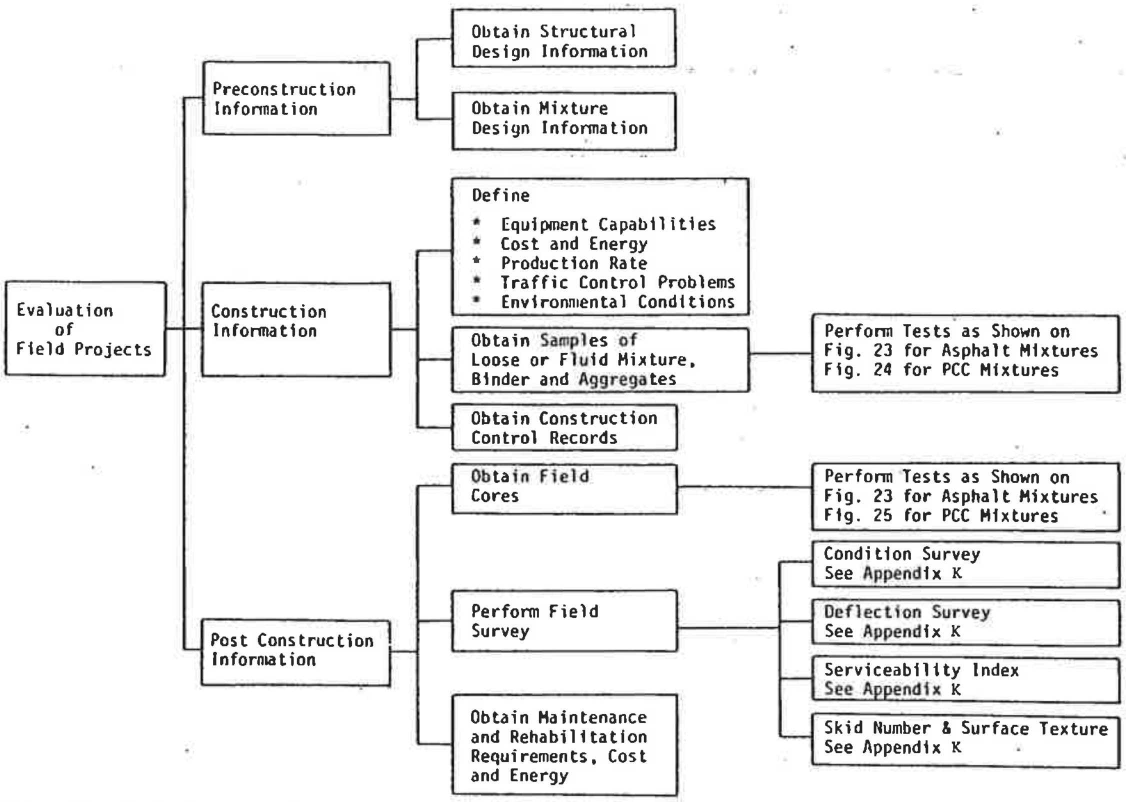


Figure 22. Evaluation of field projects.

search purposes and a particular agency may elect to perform a limited number of these tests.

Figure 24 can be used if portland cement is used as a binder in econocrete or portland cement concrete mixtures. This testing plan has been formulated for research purposes and a particular agency may elect to perform a limited number of these tests.

Recycling operations using lime, portland cement (other than econocrete or portland cement concrete), or other types of binder should be sampled after mixing and just prior to compaction. These materials should be used to fabricate samples suitable for strength and durability testing. The types of tests that should be used are those presently specified by the agency performing the recycling operation.

POSTCONSTRUCTION INFORMATION

The types of postconstruction information that should be obtained in a uniform and continuous manner are shown in Figure 23. It is suggested that field cores be obtained immediately after construction and at 0.5, 1.0, 1.5, 2.0, 3.0, 5.0, 7.0, and 12.0 years. Sufficient field cores or samples should be obtained to perform the test plans shown in Figure 23 if asphalt is used as a binder and in Figure 25 if portland cement is used as a binder in an econocrete or portland cement concrete mixture. The testing plans shown in Figures 23 and 25 have been formulated for research purposes and a particular agency may elect to perform a limited number of these tests.

Pavement condition surveys, deflection tests, and roughness measurements should be made on a yearly basis as a minimum. If rapid deterioration is likely, more frequent surveys should be scheduled. Skid measurements and surface texture measurements should be made on recycled mixtures used as surface courses.

ANALYSIS OF PERFORMANCE DATA

It should be pointed out that considerable detail is contained in Figures 22, 23, 24, and 25. The reader is encouraged to study these figures thoroughly, because a number of analyses are possible based on these data. As an example, proper selection of core locations will allow for an analysis of variance to be performed.

Cost and energy requirements for maintenance and rehabilitation operations performed subsequent to recycling should be recorded for the project. These costs and energy requirements are important in determining the pavement life and a realistic value for a pavement's time cost and energy demand over a 20- to 30-year period.

The laboratory and field data collected in a manner similar to that previously described will allow the engineer to compare the performance of recycled pavements with conventional pavements. Specific comparisons should be made on graphs describing the following relationships:

1. Surface condition versus time.
2. Deflection versus time.
3. Roughness versus time.

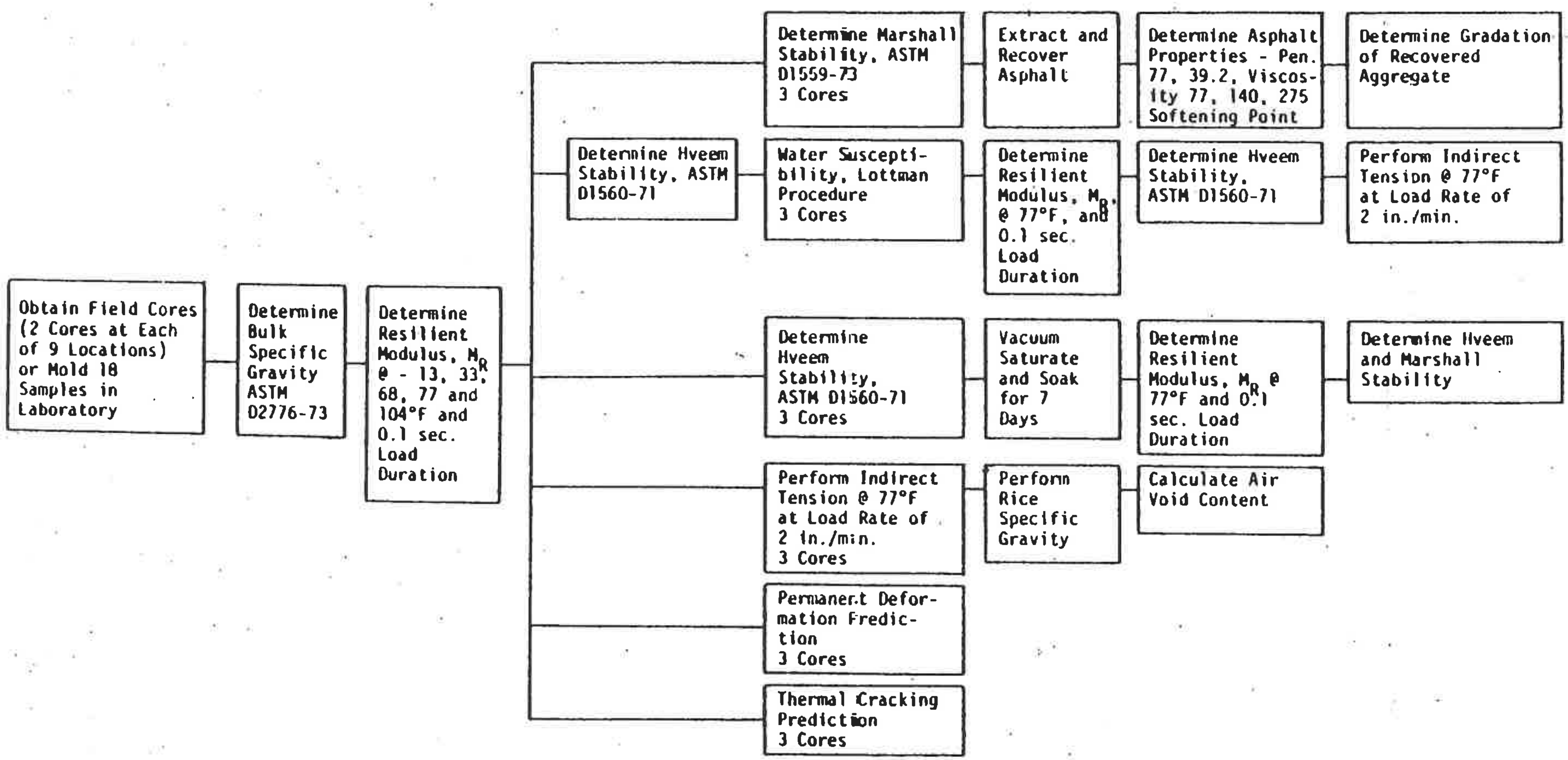


Figure 23. Suggested test sequence for field cores and laboratory-molded samples—asphalt recycling.

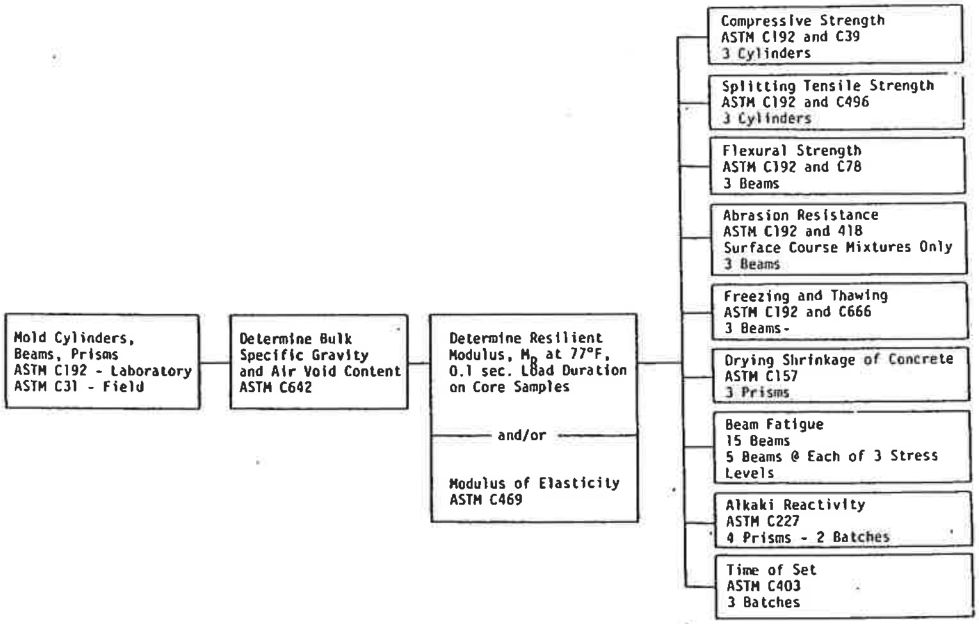


Figure 24. Suggested test sequence for samples molded in the field or laboratory (cured in laboratory) from fluid mixtures—PCC and econocrete recycling.

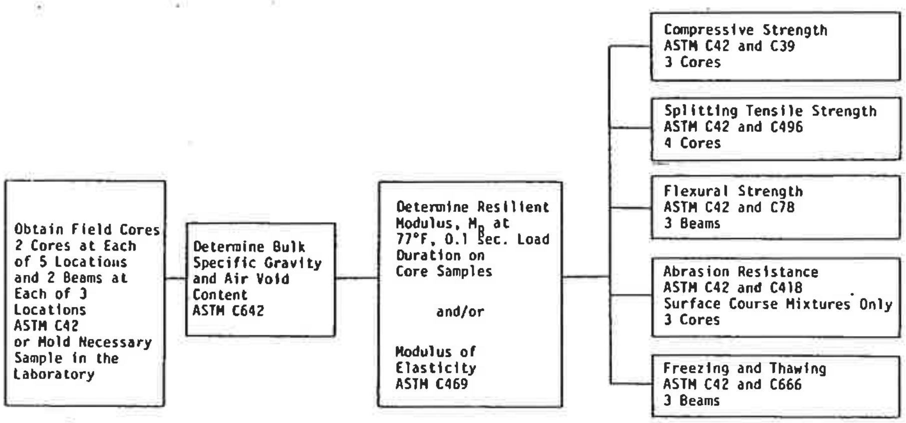


Figure 25. Suggested test sequence for field samples—PCC and econocrete recycling.

4. Skid number versus time.
5. Cost versus time.
6. Load carrying ability (stiffness, layer coefficient) versus time.
7. Stability versus time.
8. Tensile strength versus time.
9. Water susceptibility versus time.
10. Density and air void content versus time.
11. Temperature susceptibility versus time.
12. Binder hardening versus time.

The preparation of standard data input sheets and standard paper to display the foregoing relationships is encouraged, because it is extremely important that these data be collected over a period of years even though several individuals may be in charge of data collection and analysis.

Numerous structural analysis models can make use of the data described to predict pavement life. Selection of an appropriate model will depend on the preference of the agency.

SUMMARY

The evaluation of a recycling job is an extremely important part of a recycling project. If the engineering community is to define the proper place for recycling in pavement rehabilitation, these types of field performance data must be obtained.

In order to obtain the data outlined earlier, an agency or organization must be convinced of their usefulness and be willing to schedule these activities in order to make the necessary surveys, obtain the field samples, perform the laboratory tests, and make the appropriate analysis. Perhaps the most effective way to make sure the data are collected in a uniform and continuous manner is to assign responsibility to a specific individual or organizational unit for a 10- to 15-year period.

CHAPTER SIX

EXAMPLE PROBLEM

An example problem is included in this chapter to illustrate the approach that can be used (based on these guidelines) to define a recycling method suitable for a particular pavement. It should be realized that more than one recycling approach will likely be suitable for a given set of conditions. Details of some of the steps in the process have not been included, because the engineer no doubt will be familiar with the process described.

EXAMPLE

An Interstate highway in west Texas is in need of rehabilitation. The resident engineer would like to consider recycling as a rehabilitation alternative because aggregate supplies are not locally available (within 50 to 75 miles).

PRELIMINARY ANALYSIS

Information collected on this section of roadway is given in Table 16. An inspection of the roadway indicated a minor amount of alligator cracking and large amounts of longitudinal and transverse cracking (Table 17). On the basis of the results of Dynaflect tests, a 2-in. to 2½-in. overlay will be required (Table 18). The Serviceability Index as determined with the Mays Ride Meter is 2.3 (Table 19). Tables 16, 17, 18, and 19 were used to select preliminary recycling alternatives (Table 20). On the basis of this preliminary analysis, the following recycling options appear feasible:

A5—Heater-scarify plus thick overlay.
A8—Surface milling plus thick overlay.
B7—In-place recycling with major structural improvement and without new binder.
B8—In-place recycling with major structural improvement and with new binder.
C3—Central cold mix process with major structural improvements without new binder.
C4—Central cold mix process with major structural improvements with new binder.
C7—Central hot mix process with major structural improvement and without new binder.
C8—Central hot mix process with major structural improvement and with new binder.

Because local contractors were not familiar with in-place recycling alternatives, B7 and B8 were eliminated. Alternative C3 was eliminated because of the long haul distances required to obtain suitable material for the thicker sections. Alternative C4 was eliminated because the engineer preferred to use a bituminous binder rather than portland cement (lime is not a suitable stabilizer for the existing in-place material). Alternative C7 was not used because of the initial cost demonstrated in Table 8. Alternative A8 was not used because the millings, from an economic standpoint, would have to be recycled. Thus, recycling alternatives A5 and C8, together with conventional rehabilitation techniques, were considered in a detailed analysis.

DETAILED ANALYSIS

Equipment and Methods

Figure 4 was used as a basis to select the heater-scarification recycling technique. The surface is to be heated and scarified to a minimum depth of ¾ in.—the surface "screed" and a 2-in. asphaltic concrete overlay applied.

The central plant recycling technique will consist of ripping, loading, and hauling to a central crushing operation followed by a direct flame hot recycling operation (Fig. 10). Several contractors in the west Texas area have this type of recycling equipment, and it can be used with 30 percent new aggregate to produce an acceptable recycled asphaltic concrete while satisfying air quality regulations.

Mixture Design

Figure A-1 was used as a basis to determine the amount of recycling modifier to be used in the hot central plant recycling operation. (A similar procedure could be used for the heater-scarifications operation; however, sampling and testing should be confined to the top ¾ to 1 in. of the pavement.) The pavement was sampled at five locations and the asphalt extracted and recovered. Results of these tests indicated that the pavement could be considered homogeneous, because the penetration ranged from 15 to 22 and the gradation of the recovered aggregate varied

TABLE 16

SUMMARY OF EXISTING PAVEMENT CONDITIONS—EXAMPLE PROBLEM

Feature	Value	Comment
Location	15 miles west of Pecos	
Size of Project (Lane-Miles)	36	
Class of Roadway	Interstate	
Existing Pavement Cross Section (date, thickness and type of original pavement layers; date, thickness and type of subsequent rehabilitation and maintenance activities).	4" AC - 1965 2 course ST - 1963 12" Aggregate Base - 1963 CBR 8 Subgrade	
GEOMETRICS (number of lanes, width, vertical clearance, other constraints)	4-12' lanes Paved Shoulders - 8' No vertical constraints	
Traffic Characteristics ADT Average Daily E. 18 kip axle loads	100	
Subgrade Characteristics	CBR = 8	
Surface Condition (Pavement Rating Source, PRS)		Slight alligator cracking, >200 ft of moderate long cracks 100 severe transverse cracks
Structural Condition, (deflection, 0.001 inch) overlay required		
Roughness (Serviceability Index)	2.3	
Skid Resistance (SN 40)	41	
Other: Factors (distance to aggregate and binder source, available equipment and contractor experience)	60 mile haul to aggregate source Contractors not familiar with in-place recycling	

little. The average viscosity of the recovered asphalt was 50,000 poises at 140 F, while the average penetration was 19 as measured under standard conditions at 77 F.

The aggregate gradation was satisfactory as recovered from the pavement; however, 30 percent new aggregate was added to help control air quality. The total estimated asphalt demand for the recycled mixture containing 70 percent recycled material and 30 percent new aggregate was 6.5 percent by dry weight or aggregate. The amount of asphalt in the mixture to be recycled was 6.2 percent. The anticipated additional amount of bituminous modifiers is therefore 2.2 percent: $6.5 - [(0.70 \times 6.2) + (.30 \times 0.0)] = 2.2$.

Figure A-2, together with the following, can be used to determine the approximate desired viscosity of the recycling agent (step 8 of Fig. A-1):

1. The desired weight percent of recycling modifier is $(2.2/6.5) = 0.34$—or 34 percent of the total binder, assuming the specific gravity of the modifier is equal to that of the recovered asphalt.
2. The viscosity of the recovered asphalt from the old pavement is 50,000 poises.
3. The desired binder in the recycled mixture is an AC-10.
4. The approximate viscosity of the modifier is 650 to 700 centipoises.

Table A-1 indicates that an RA-5 recycling agent is suitable. Tests performed on blends of recovered asphalt and modifier confirm that approximately 35 percent of the total binder should be an RA-5 designated recycling agent. Tests on mixtures prepared with 70 percent recycled asphaltic concrete and 30 percent new aggregate indicate that adequate stability and air void contents can be obtained at 6.5 percent total binder. Water susceptibility of the mixture is also adequate. The 70-30 blend with 6.5 percent total binder is the mixture which should be tried first in the field.

Structural Design

The structural design was performed according to Appendix D and resulted in the thickness requirements associated with the various alternatives given in Table 21.

Economics and Energy

Table 21 contains rehabilitation alternatives based on detailed structural analyses as well as on pavement performance experience gained in the Southwest.

Anticipated life-cycle costs are given in Table 22 for a 20-year period. Costs were based on information obtained by the local resident engineer and are given in Table 23. Table 24 contains a summary of the cost and energy requirements for these 10 rehabilitation alternatives (App. F and App. G). Both initial and life-cycle costs and energies are shown. Life-cycle costs in terms of present worth for rates of return of 0 and 8 percent are given (App. J). Equal annual life-cycle costs (assuming an 8 percent rate of return) are of the order of \$0.50 to \$0.70 per square yard of pavement surface. Various hot recycling cost and

TABLE 17

SELECTION OF RECYCLING TECHNIQUES BASED ON SURFACE CONDITION OF ASPHALTIC CONCRETE—EXAMPLE PROBLEM

	RECYCLING METHODS / CONDITION OF EXISTING PAVEMENT →	
SURFACE	HEATER PLANER WITHOUT ADDITIONAL AGGREGATE	A1
	HEATER PLANER WITH ADDITIONAL AGGREGATE	A2
	HEATER SCARIFY	A3
	HEATER SCARIFY + THIN OVERLAY	A4
	HEATER SCARIFY + THICK OVERLAY	A5
	SURFACE MILLING	A6
	SURFACE MILLING + THIN OVERLAY	A7
	SURFACE MILLING + THICK OVERLAY	A8
IN PLACE	THIN ASPHALT CONCRETE-MINOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	B1
	THIN ASPHALT CONCRETE-MINOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	B2
	THIN ASPHALT CONCRETE-MAJOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	B3
	THIN ASPHALT CONCRETE-MAJOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	B4
	THICK ASPHALT CONCRETE-MINOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	B5
	THICK ASPHALT CONCRETE-MINOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	B6
	THICK ASPHALT CONCRETE-MAJOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	B7
	THICK ASPHALT CONCRETE-MAJOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	B8
CENTRAL PLANT	COLD PROCESS-MINOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	C1
	COLD PROCESS-MINOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	C2
	COLD PROCESS-MAJOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	C3
	COLD PROCESS-MAJOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	C4
	HOT PROCESS-MINOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	C5
	HOT PROCESS-MINOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	C6
	HOT PROCESS-MAJOR STRUCTURAL IMPROVEMENT WITHOUT NEW BINDER	C7
	HOT PROCESS-MAJOR STRUCTURAL IMPROVEMENT WITH NEW BINDER	C8

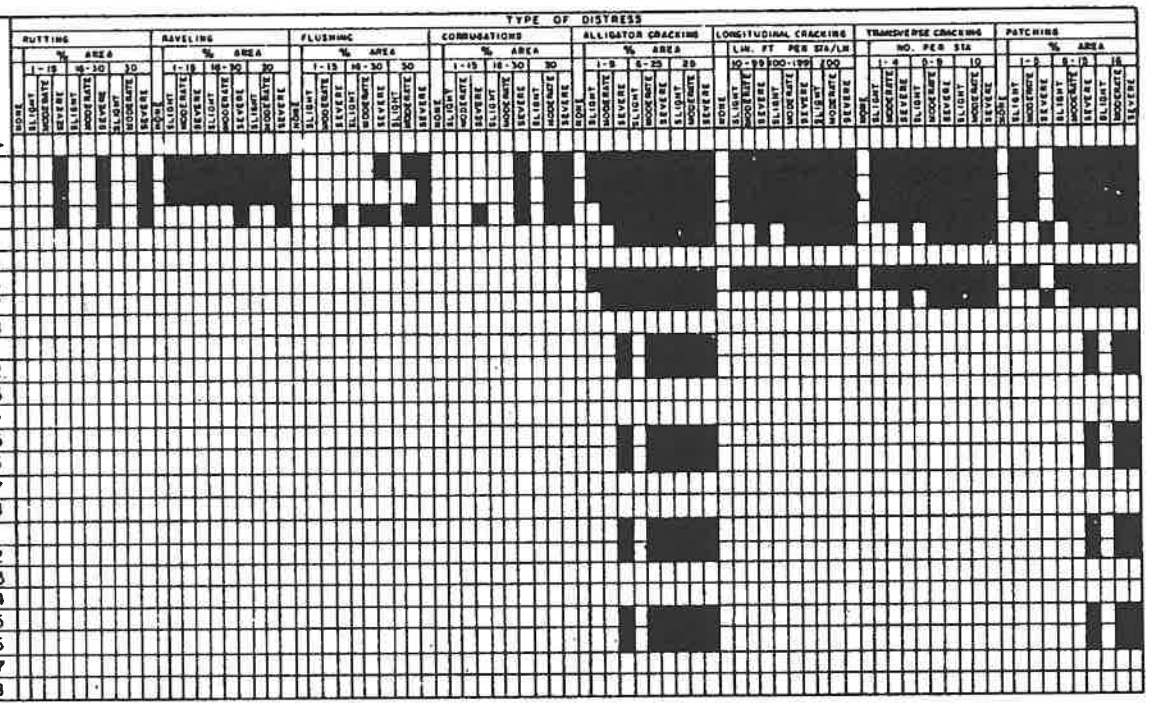


TABLE 18

SELECTION OF RECYCLING TECHNIQUES TO IMPROVE STRUCTURAL STRENGTH BASED ON PAVEMENT DEFLECTION—EXAMPLE PROBLEM

Recycling Methods			Thickness of Required Overlay		
			None	Less Than 2 inches	Greater Than 2 inches
Heater Planer	A1	Without additional aggregate			
	A2	With additional aggregate			
Heater scarify	A3	Heater scarify only			
	A4	Heater scarify plus thin overlay or aggregate			
	A5	Heater scarify plus thick overlay			
Surface milling or grinding	A6	Surface milling only			
	A7	Surface milling plus thin overlay			
	A8	Surface milling plus thick overlay			
Asphalt concrete surface less than 5 inches	B1	Minor structural improvement without new binder			
	B2	Minor structural improvement with new binder			
	B3	Major structural improvement without new binder			
	B4	Major structural improvement with new binder			
Asphalt concrete surface greater than 5 inches	B5	Minor structural improvement without new binder			
	B6	Minor structural improvement with new binder			
	B7	Major structural improvement without new binder			
	B8	Major structural improvement with new binder			
Cold mix process	C1	Minor structural improvement without new binder			
	C2	Minor structural improvement with new binder			
	C3	Major structural improvement without new binder			
	C4	Major structural improvement with new binder			
Hot mix process	C5	Minor structural improvement without new binder			
	C6	Minor structural improvement with new binder			
	C7	Major structural improvement without new binder			
	C8	Major structural improvement with new binder			

TABLE 19

SELECTION OF SURFACE RECYCLING TECHNIQUES BASED ON ROAD ROUGHNESS—EXAMPLE PROBLEM

Type of Facility / Serviceability Index / Recycling Methods		Interstate Urban Freeway				Primary				Secondary				Urban Streets			
		+3.0	2.5-2.9	2.0-2.4	-2.0	+3.0	2.5-2.9	2.0-2.4	-2.0	+3.0	2.5-2.9	2.0-2.4	-2.0	+3.0	2.5-2.9	2.0-2.4	-2.0
Heater Planer Without Additional Aggregate	A1																
Heater Planer With Additional Aggregate	A2																
Heater Scarify	A3																
Heater Scarify and Thin Overlay	A4																
Heater Scarify and Thick Overlay	A5																
Surface Milling	A6																
Surface Milling and Thin Overlay	A7																
Surface Milling and Thick Overlay	A8																

TABLE 20

SUMMARY OF PRELIMINARY RECYCLING ALTERNATIVES—
EXAMPLE PROBLEM

Recycling Methods				Surface Condition	Deflection	Roughness	Skid Resistance
Surface	Heater Planer	Without additional aggregate	A1	X	X	X	
		With additional aggregate	A2	X	X	X	
	Heater scarify	Heater scarify only	A3	X	X	X	
		Heater scarify plus thin overlay or aggregate	A4	X	X	X	
		Heater scarify plus thick overlay	A5				
	Surface milling or grinding	Surface milling only	A6	X	X	X	
		Surface milling plus thin overlay	A7	X	X		
		Surface milling plus thick overlay	A8				
In Place	Asphalt concrete surface less than 5 inches	Minor structural improvement without new binder	B1		X		
		Minor structural improvement with new binder	B2		X		
		Major structural improvement without new binder	B3				
		Major structural improvement with new binder	B4				
	Asphalt concrete surface greater than 5 inches	Minor structural improvement without new binder	B5		X		
		Minor structural improvement with new binder	B6		X		
		Major structural improvement without new binder	B7				
		Major structural improvement with new binder	B8				
Central Plant	Cold mix process	Minor structural improvement without new binder	C1		X		
		Minor structural improvement with new binder	C2		X		
		Major structural improvement without new binder	C3				
		Major structural improvement with new binder	C4				
	Hot mix process	Minor structural improvement without new binder	C5		X		
		Minor structural improvement with new binder	C6		X		
		Major structural improvement without new binder	C7				
		Major structural improvement with new binder	C8				

TABLE 21

REHABILITATION ALTERNATIVES DEFINED—
EXAMPLE PROBLEM

Plan 1: Two-inch asphalt concrete overlay with maintenance on a 7-year cycle (asphalt concrete $25.00 per ton).

Plan 2: Chip seal plus 2-inch asphalt concrete overlay with maintenance (chip seal $0.55 per square yard, asphalt concrete $25.00 per ton).

Plan 3: Fabric reinforcement plus 2-inch asphalt concrete overlay with maintenance (fabric reinforcement $1.25 per square yard, asphalt concrete $25.00 per ton).

Plan 4: Recycle existing 4 inches of material and blend a selected aggregate into recycle mixture. A 2-inch overlay is scheduled after 5 years (recycling at $20.00 per ton and overlay at $25.00 per ton).

Plan 5: Recycling existing 4 inches of asphalt materials and 2 inches of asphalt concrete overlay with maintenance (recycling $16.00 per ton, asphalt concrete $25.00 per ton).

Plan 6: Recycling existing 4 inches of asphalt materials and 2 inches of asphalt concrete overlay with maintenance which includes a 2-inch overlay (recycling $16.00 per ton, asphalt concrete $25.00 per ton).

Plan 7: Recycling existing 4 inches of asphalt materials and 2 inches of asphalt concrete overlay with maintenance (recycling $20.00 per ton, asphalt concrete $25.00 per ton).

Plan 8: Delay recycling 4 years and then recycle and add 2 inches of asphalt concrete overlay with maintenance (recycling $16.00 per ton, asphalt concrete $25.00 per ton).

Plan 9: Heater-scarify to a depth of 1 to 1.5 inch and 2 inches of asphalt concrete overlay with maintenance (heater-scarification $0.90 per square yard, asphalt concrete $25.00 per ton).

Plan 10: Asphalt-rubber interlayer and 2 inches of asphalt concrete overlay with maintenance (asphalt-rubber interlayer $1.25 per square yard, asphalt concrete $25.00 per ton).

TABLE 22

REHABILITATION ALTERNATIVES COST SCHEDULES*—EXAMPLE PROBLEM

Year	Plan 1 2" A.C. Overlay	Plan 2 Seal Coat +2" A.C. Overlay	Plan 3 Fabric Rein-force-ment +2" A.C. Overlay	Plan 4 Recycle	Plan 5 Recycle +2" A.C. Overlay	Plan 6 Recycle +2" A.C. Overlay	Plan 7 Recycle +2" A.C. Overlay	Plan 8 Recycle +2" A.C. Overlay	Plan 9 Heater-Scarify + 2" A.C. Overlay	Plan 10 Asphalt-Rubber Interlayer + 2" A.C. Overlay
1980	2.50	3.05	3.75	4.00	5.70	5.70	6.50	.15	3.40	3.75
1981								.15		
1982								.15		
1983	.08							.15		
1984	.13	.08	.08					6.50	.08	.08
1985	.15	.13		2.50						
1986	.15	.15	.13						.13	.13
1987	2.50	.15								
1988		.15	.15		.08	.08	.08		.15	.15
1989		2.50								
1990	.08		2.50		.13	.13	.13		2.50	2.50
1991	.13			.08				.08		
1992	.15	.08			.15	.15	.15			
1993	.15	.13	.08	.13				.13	.08	.08
1994	2.50	.15	.13		.15	2.50	.15		.13	.13
1995		.15	.15	.15				.15	.15	.15
1996		3.05	.15		.15		.15		.15	.15
1997	.08		.15	.15				.15	.15	.15
1998	.13		.15		.15	.08	.15		.15	.15
1999	.15		.15	.15				.15	.15	.15
2000	.15	.08	.15		.15	.13	.15		.15	.15

*Numbers represent costs per square yard.

TABLE 23

COST DATA USED TO ANALYZE REHABILITATION STRATEGIES—EXAMPLE PROBLEM

Material or Operation	Cost	
	$ Per Ton	$ Per Sq. Yd.
Asphalt Concrete	25.00	1.25*
Recycle Asphalt Concrete	20.00	1.00*
Recycle Asphalt Concrete	16.00	0.80*
Chip Seal Coat		0.55
Fabric		1.25
Heater-Scarification		0.90
Crack Sealing		0.15
Asphalt Rubber Interlayer		1.25

*Cost per square yard for one-inch thickness.

TABLE 24

COST AND ENERGY SUMMARY—EXAMPLE PROBLEM

Plan No.	Method	Energy, BTU/Sq.Yd.		Cost, Dollars/Sq.Yd.		
					20-Year Life*	
		Initial	20-Year Life	Initial	0 Percent	8 Percent
1	2" AC Overlay	57,800	200,000	2.50	9.03	5.50
2	Seal Coat + 2" AC Overlay	61,700	203,000	3.05	9.85	5.80
3	Fabric + 2" AC Overlay	60,000	145,000	3.75	7.72	5.44
4	Recycle	119,600	190,000	4.00	7.16	5.91
5	Recycle + 2" AC Overlay	177,400	195,000	5.70	6.66	6.03
6	Recycle + 2" AC Overlay	177,400	244,000	5.70	8.77	6.76
7	Recycle + 2" AC Overlay	177,400	195,000	6.50	7.46	6.83
8	Recycle + 2" AC Overlay	2,200	201,000	0.15	7.76	5.52
9	Heater-Scarify + 2" AC Overlay	74,800	160,000	3.40	7.37	5.09
10	Asphalt Rubber Interlayer + 2" AC Overlay	64,000	149,000	3.75	7.72	5.44

*Equal annual costs assuming 0 and 8 percent rate of return.

timing options (plans 4, 5, 6, 7, and 8) were investigated to demonstrate the sensitivity of the assumptions made in the analysis. Salvage values were not included in the analysis.

The selection of the appropriate rehabilitation alternative is based on the amount of money initially available for the project, and, if life cycle costs are considered, the rate of return expected is on the monies available. The lowest first cost alternative is a 2-in. asphaltic concrete overlay (plan 1). (The "do nothing" alternative, plan 8, has not been considered in making this statement.) Alternative plan 5 has the lowest 20-year life-cycle cost if 0 percent rate of return can be expected. For an expected 8 percent rate of return, plan 9 is desirable. From a life-cycle energy standpoint, plans 3 and 10 are desirable. Table 24, therefore, forms a basis from which the decision can be made by the engineer. Local conditions and expected life cycles of the various alternatives must be considered in considerable detail before making the final decision.

Guide Specifications and Quality Control

Specifications used for hot central plant recycling in other Texas highway districts were reviewed together with information from other states (App. H). Quality control procedures followed those typically used for asphaltic concrete surface courses (App. I).

CHAPTER SEVEN

INTERPRETATION, APPRAISAL, AND APPLICATION

GUIDELINES FOR RECYCLING MATERIALS

The recycling guidelines provide the practicing engineer with a complete document for selecting the recycling method that is best suited for a particular distressed pavement. Laboratory and field testing programs have been established to aid the engineer in the selection of the most appropriate alternative. The authors believe that the guidelines are suitable for federal, state, and local government engineers as well as consulting engineers. Engineering judgment in some cases may be substituted for the detailed laboratory and field testing recommended.

A review of existing literature, personal conversations, and correspondance with knowledgeable individuals and opinions of the research team provided the background for this study. The criteria used for selection of preliminary recycling alternatives are based on the authors' opinions and have not been subjected to extensive implementation. The criteria given in Tables 4, 5, 6, 11, 12, and 13 can be improved and may have to be revised based on local conditions.

Typical cost data given in Tables 8 and 15 should be considered as representative only. If costs for these operations are available from the agency's historical records, they should be substituted appropriately. Costs of construction materials are expected to escalate on the average of 15 percent for the next several years.

Typical energy data reported are intended to be representative only. If energy requirements for recycling operations are available from the agency's historical records, they should be substituted appropriately.

Implementation of the guidelines is necessary if revision of the guidelines is to be meaningful. This implementation effort should be closely monitored by the research study team.

MODIFIER SPECIFICATION

Specifications for modifiers have been suggested by Chevron (*32*), Pacific Coast User-Producer Group (*17*), and Witco Chemical (*35*) (Tables 25, 26, and 27). The specifications developed by the Pacific Coast User-Producer Group is suggested for use in this report because it represents a consensus by groups. The specification does not contain specification limits for Rostler parameters (ASTM D 2006), but rather determines chemical composition based on ASTM D 2007. In addition, a weight loss is specified by the rolling thin-film oven test, RTF-C (ASTM D 2872), rather than by the thin-film oven test (ASTM D-1754). It should be noted that the proposed Pacific Coast User-Producer Group specifications do not allow the use of two commonly used, commercially available recycling modifiers. The proposed specifications contained in Table 26 consider the compatibility requirements of the old asphalt

TABLE 25

PROPOSED SPECIFICATIONS FOR HIGH FLASH RECYCLING AGENTS

TEST	AASHTO TEST METHOD	GRADE H-1	H-2.5	H-5
TEST ON ORIGINAL MATERIAL				
Viscosity, 60°C(140°F), poise	T-202	50-200	200-300	400-600
Viscosity, 135°C(275°F), cs, min.	T-201	50	80	110
Flash Point, COC, °F, min.	T-48	450	450	450
TESTS ON RESIDUE FROM RTFC PROCEDURE AASHTO T-240*				
Weight Loss, % max.	T-240	1.0	1.0	1.0
Aging Index, ** max.	--	3.0	3.0	3.0

* TFO may be used but RTFC shall be the referee method

**Aging Index = $\frac{\text{RTFC viscosity at } 60°C\ (140°F)}{\text{Original viscosity @ } 60°C\ (140°F)}$

°C = 5/9 (°F -32)
CS = 0.001 Pa.s

and the modifier by specifying a maximum allowable saturates concentration. Rostler N/P ratio needs to be recommended for inclusion as well as the concept of "effectiveness ratio" as developed by Dunning (*33*).

The proposed specification uses the weight loss after the RTF-C test and the viscosity ratio to control asphalt durability. Rostler's work, advanced by Witco (*30, 34, 35*), should be reconsidered for use in future specifications as additional field performance information is developed. This will define more accurately the relationship between asphalt durability and pavement performance.

MIXTURE DESIGN

Mixture design methods have been proposed by Chevron (*32*), Pacific Coast User-Producer Group (*17*), and Witco (*34*). The method used in these guidelines is based on these approaches and appears to work satisfactorily. The use of Marshall stability for establishing the binder demand of the recycled mixture must be approached with the knowledge that specified flow values may be exceeded. Insufficient field performance is available to indicate whether these high flow values should be of concern to the engineer. High flow values can be tolerated more readily in base course mixtures than in surface course mixtures.

The resilient modulus appears to be an excellent test to determine the relative effects of modifiers on the properties of recycled mixtures. The value of the resilient modulus appears to be greatly dependent on binder properties and hence is a good measure of the effectiveness of the modi-

TABLE 26

PROPOSED SPECIFICATIONS FOR HOT MIX RECYCLING AGENTS[1]

TEST	ASTM TEST METHOD	RA 5 min.	RA 5 max.	RA 25 min.	RA 25 max.	RA 75 min.	RA 75 max.	RA 250 min.	RA 250 max.	RA 500 min.	RA 500 max.
Viscosity @140°F, cSt	D2170 or 2171	200	800	1000	4000	5000	10000	15000	35000	40000	60000
Flash Point COC, °F	D92	400	-	425	-	450	-	450	-	450	-
Saturates, wt. %	D2007	-	30	-	30	-	30	-	30	-	30
Residue from RTF-C Oven Test @325°F	D2872[2]										
Viscosity Ratio[3]	-	-	3	-	3	-	3	-	3	-	3
RTF-C Oven Weight Change, ±, %	D2872[2]	-	4	-	4	-	2	-	2	-	2
Specific Gravity	D 70 or D1298	Report		Report		Report		Report		Report	

1. The final acceptance of recycling agents meeting this specification is subject to the compliance of the reconstituted asphalt blends with current asphalt specifications.

2. The use of ASTM D1754 has not been studied in the context of this specification, however, it may be applicable. In cases of dispute the reference method shall be ASTM D2872.

3. $\text{Viscosity Ratio} = \frac{\text{RTF-C Viscosity at 140°F, cSt}}{\text{Original Viscosity at 140°F, cSt}}$

°C = 5/9 (°F -32)
1 cST = 0.001 Pa.s

TABLE 27

SPECIFICATIONS FOR RECLAIMING AGENTS

Property	Function & Purpose	Test Method	Cyclogen L*	Cyclogen M*	Cyclogen H*
Viscosity @ 140°F, cSt	Asphalt viscosity adjustment in recycled mix	ASTM D 2170-74	80-500	1000-4000	5000-10000
Flash Point, COC, F	Handling precaution	ASTM D 92-72	350 min.	350 min.	350 min.
Volatility, 1 BP, F 2%, F 5%, F	Avoidance of air pollution and hardening by evaporation	ASTM D 1160-61, 10 mm	300 min. 375 min. 410 min.	300 min. 375 min. 410 min.	300 min. 375 min. 410 min.
Compatibility, N/P	Avoidance of syneresis	ASTM D 2006-70	0.5 min.	0.5 min.	0.5 min.
Chemical Composition, $(N + A_1)/(P+A_2)$	Durability of asphalt in recycled mix	ASTM D 2006-70	0.2-1.2	0.2-1.2	0.2-1.2
Specific Gravity	Calculations	ASTM D 70-72	Report	Report	Report

*Suitable pumping temperatures are the following: L=115 F, M = 190 F, and H = 200 F.

°C = 5/9 (°F -32)
1 cST = 0.001 Pa.s

fier to alter the binder. Correlations between binder viscosity and resilient modulus for a wide range of mixtures should be established.

Water susceptibility tests should be performed on recycled mixtures. The Lottman procedure (*40*) is suggested for immediate use; however, improved acceptance criteria need to be developed. Test methods such as the vacuum saturation and soaking procedure used in this study should be considered for inclusion in future specifications because of their relative simplicity.

Low temperature properties of recycled mixtures should be considered prior to final selection of the binder. Data have been presented to illustrate that the blends (old asphalt and modifier) temperature susceptibility is a function of the modifier used.

A review of data presented indicates that acceptable mixtures have been produced with four widely different modifiers. Three of the four modifiers used do not meet current proposed specifications. A continual updating of modifier specifications is needed as more experience is gained.

STRUCTURAL STUDY

In this study recycled pavement materials were evaluated in-situ and in the laboratory in order to predict their capabilities as part of a structural pavement system. Structural capability was defined in this study in terms of the AASHTO structural coefficient, dynamic or resilient modulus, pavement deflection, and thickness equivalencies. Unfortunately, only limited conclusions can be drawn on the basis of these criteria. Although these conclusions are quite valid, they do not tell the "whole story" for every type of pavement.

On the basis of the analyses discussed in this study, it would appear that the stiffer a pavement layer is, the better is its structural response. This, of course, may not be the case for the pavements subject to extreme thermal effects which cause the stiffer pavement layer to crack earlier than a softer pavement layer.

The conclusion is that the analyses herein are primarily focused toward the ability of a recycled pavement layer to protect the system's structural integrity by favorable distribution of stresses and strains within the pavement system. This technique is generally valid in thicker pavements where stiffer layers generally are more effective in stress distribution. However, a stiff layer used as a relatively thin surface may crack earlier than a softer layer because of either load or temperature.

The associated recommendation is that a characterization of the recycled materials in terms of load associated (fatigue) and thermal cracking is necessary to understand the recycled layers used as relatively thin surfaces. Of paramount importance here is the effect of the amount and type of modifier used in the recycling process.

On the basis of the structural evaluation, recycled asphaltic concrete bases stabilized either with emulsion, cutback, cement, lime, or with the addition of a modifier are greatly superior to aggregate bases in terms of load distribution. Recycled bases used as part of a pavement of significant depth appear to be an excellent way to bolster the structural capability of the pavement. The recycled bases in this study are structurally equivalent to, or superior to, conventional stabilized bases. This statement, to have merit, of course, must be backed by laboratory tests that evaluate the water susceptibility of the recycled bases. As part of a more thorough laboratory characterization study, the water susceptibility of the recycled bases should be tested more thoroughly.

The dual parameteric analysis similar to that first defined by Vaswani (*56*) is the preferred method for Dynaflect deflection basin analysis in that it can be used to differentiate the structural contribution of the subgrade from that of the overlying pavement. This permits a seasonal evaluation of the recycled pavement's structural response to load. Also correlations between the Dynaflect deflection basin and the Benkelman Beam basin may be used to estimate the structural response of the recycled pavement under the design wheel load, (i.e., a dual 4,500-lb (20-kN) wheel load).

Because the analysis curves for the dual parametric analysis may be developed easily from layered elastic computer programs for various loading conditions and wheel configurations, this analysis is readily adaptable to nondestructive devices such as the Cox Van and the Benkelman Beam. It is recommended that the deflection basin be measured under a dual wheel load with the Benkelman Beam, and the basin analyzed on the basis of the dual parametric analysis developed for that particular loading situation. This will allow analysis of the structural contributions of the pavement and subgrade under actual design loads.

The deflection basin for the recycled pavements should be measured and analyzed on a seasonal basis and at the same time during the season each year in order to evaluate comparatively the performance of the recycled material with time and change in environmental conditions.

Although recycled materials of all types have yet to be sufficiently characterized in terms of fatigue, thermal cracking potential, water susceptibility, and modifier effects, this study is in itself significant. The recycled materials studied have favorable structural responses to in-situ dynamic load testing and laboratory diametral resilient modulus testing.

The structural characterization of recycled bases and surfaces developed in this study provides an initial approximation of the load carrying capability of these recycled pavement materials. The structural layer coefficients may be used as a guide to determining layer thickness in the AASHTO flexible pavement design method.

FIELD CORE STUDY

In this study, laboratory investigations were conducted to determine the mechanical properties of field-recycled mixtures on core samples taken from the following locations: Washington (Rye Grass, Blewitt Pass); Texas (Abilene; Lyons, US 36; Dalhart, US 54; Snyder, US 84; Abilene, US 277; Mission, Loop 374); Oregon (Woodburn); Arizona (Gila Bend, US 666); Minnesota (Trunk Highway 94); Iowa (Kossuth County); Kansas (US 56); Nevada (Henderson); and Utah (Holden, US 50). These cores were obtained from 1,000 ft (305 m) of pavement section; and resilient modulus, Hveem stability, Marshall stability, and indirect tension tests were performed. A vacuum saturation and 7-day soaking test was performed to evaluate the water susceptibility of the mixtures.

As a result of this program, it is evident that the material properties of recycled mixtures are dependent on the properties of the old asphalt and aggregate; however, these properties can be adjusted by the addition of modifiers and/or aggregates. Laboratory test results indicate that recycled mixtures can be water susceptible. Laboratory compaction of field-mixed recycled materials produces samples with properties different from field-compacted and cored samples. Material property variations along a project can be significant and should be considered in both mixture and pavement design. The resilient modulus appears to be an excellent test to evaluate the properties of recycled asphaltic concrete mixtures. The test appears to be sensitive to binder properties.

CHAPTER EIGHT

CONCLUSIONS AND SUGGESTED RESEARCH

CONCLUSIONS

On the basis of the information presented in this report the following conclusions appear warranted:

1. Realistic guidelines for the recycling of pavement materials have been developed. The guidelines can be used by the practicing engineer and will provide the following information:

   a. Point out the potential advantages of recycling.
   b. Assist both in making a preliminary analysis of recycling as a pavement rehabilitation alternative and in identifying a suitable methodology.
   c. Provide guidance and criteria for making a detailed analysis of cost, energy, materials design, structural design, construction specifications, and quality control.
   d. Recommend a methodology for evaluating project results so that recycling alternatives can be compared with conventional methods of rehabilitation.

2. Laboratory testing associated with recycling projects is necessarily more extensive than that required for typical rehabilitation alternatives.

3. Mechanical properties of recycled asphalt mixtures as measured both in the laboratory and in the field are typical of those obtained from normal asphaltic concrete mixtures.

4. The material properties of recycled mixtures are dependent on the properties of the old asphalt and aggregate; however, these properties can be adjusted by the addition of modifiers and/or aggregate.

5. Laboratory test results indicate that recycled mixtures can be water susceptible.

6. Material property variations along a project can be significant and should be considered in both mixture and pavement design.

7. The resilient modulus appears to be an excellent test to determine the properties of recycled asphaltic concrete mixtures. Its sensitivity to binder properties allows modifier types and contents to be adjusted for design purposes.

8. Portland cement concrete made with recycled portland cement concrete or combinations of recycled portland cement concrete and asphaltic concrete can be designed such that acceptable strength characteristics can be obtained in both compression and tension. Increased water contents will normally be required when crushed recycled aggregates are used to produce the desired workability. Higher shrinkage and poorer durability can be expected for recycled aggregate portland cement concrete.

9. Structural coefficients of recycled materials are typical of those obtained for conventional materials of a similar nature.

10. Recycled asphaltic concrete used as a base course is generally compared to conventionally stabilized (chemical or asphalt) bases as demonstrated by the stiffness responses of the layer to in-situ testing and computed structural layer coefficients.

11. On the basis of in-situ stiffness responses and laboratory resilient modulus versus temperature analysis, as well as computations of structural coefficients, recycled asphaltic concrete surfaces are generally slightly stiffer than conventional asphaltic concrete.

SUGGESTED RESEARCH

1. Improved criteria need to be developed for preliminary selection of recycling alternatives.

2. Performance of recycling projects needs to be defined and related to the type of distress corrected.

3. Specifications and quality control for pavement recycling operations need to be improved.

4. Improved specifications for pavement modifiers need to be established.

5. Compatibility of modifiers and old recycled asphalts needs to be defined better.

6. Additional laboratory and field testing of recycled portland cement concrete is necessary to better define durability, shrinkage, and other properties.

7. A more thorough laboratory evaluation of recycled asphaltic concrete is required to establish fatigue characteristics, permanent deformation, and creep characteristics. The performance of recycled materials may then be predicted based on mechanistic systems such as PDMAP, VESYS II, and FPS-BISTRO.

8. In-place material properties need to be defined for both conventional and recycled materials.

9. Water susceptibility of recycled materials needs to be defined more accurately.

10. Cost, energy, and environmental requirements associated with recycling operations need to be defined better. Costs should be identified in terms of manpower, material, and equipment costs for each unit operation.

REFERENCES AND BIBLIOGRAPHY

1. WITCZAK, M. W., "A Generalized Investigation of Selected Highway Design and Construction Factors by Regional Geomorphic Units Within the Continental United States." Res. Rep., NCHRP Project 1-3(1), Purdue U. (1970).
2. MAREK, C. E., ET AL., "Promising Replacements for Conventional Aggregates for Highway Use." *NCHRP Report 135* (1971) 53 pp.
3. "Recycling Materials for Highways." *NCHRP Synthesis of Highway Practice 54* (1978) 53 pp.
4. BECKETT, S., "Recycling Asphalt Pavements." Demonstration Project No. 39, Interim Report No. 1, FHWA, Region 15 (Jan. 1, 1977).
5. BROWN, D. J., "Interim Report on Hot Recycling." Demonstration Projects Division, FHWA, Region 15 (Apr. 1977).
6. "Concrete Recycling Project Ready." Issue No. 8, *FHWA Newsletter* (Oct. 1978).
7. "Initiation of National Experimental and Evaluation Program (NEEP) Project No. 22—Pavement Recycling." NOTICE N 5080.64, FHWA (June 3, 1977).
8. "Recycled Asphalt Concrete." Implementation Package 75-5, FHWA (Sept. 1975).
9. ANDERSON, D. I., PETERSON, D. E., WILEY, M. L., and BETENSON, W. B., "Evaluation of Selected Softening Agents Used in Flexible Pavement Recycling." *Report No. FHWA-TS-79-204,* FHWA (Apr. 1978).
10. *Highway Focus.* Federal Highway Administration, Vol. 10, No. 1 (Feb. 1978).
11. LAWING, R. J., "Use of Recycling Materials in Airfield Pavements—Feasibility Study." *Report AFCEC-TR-76-7,* Air Force Civil Eng. Center, Tyndall Air Force Base, Fla. (Feb. 1976).
12. BROWNIE, R. B., and HIRONAKA, M. C., "Recycling of Asphalt Concrete Airfield Pavements." Naval Civil Eng. Lab., Port Hueneme, Calif. (Apr. 1978).
13. "Asphalt Pavement Recycling Using Salvaged Materials." The Asphalt Inst., West Coast Division.
14. "State of the Art: Hot Recycling." Recycling Report, Vol. 1, No. 1, Natl. Asphalt Pavement Assn. (May 27, 1977).
15. "State of the Art: Hot Recycling 1978 Update." Recycling Report, Vol. 2, No. 3, Natl. Asphalt Pavement Assn. (Oct. 1978).
16. "Recycling Failed Flexible Pavements with Cement." Portland Cement Assn. (1976).
17. Pacific Coast User-Producer Specification Committee, miscellaneous internal reports (1978, 1979).
18. *Recycling of Bituminous Pavements.* STP 662, ASTM (1978).
19. "Hot Recycling of Yesterday." Recycling Rep., Vol. 1, No. 2, Natl. Asphalt Pavement Assn. (Sept. 1977).
20. SMITH, R. W., "NAPA-Asphalt Institute Committee Agree on Recycling Definitions." NAPA Spec. Rep. (May 1977).
21. "Model Specifications." Asphalt Recycling and Reclaiming Assn. (May 1977).
22. Sales information. Jim Jackson Contractor, Little Rock, Ark.
23. "Kansas Salvages Old Road Base." *Soil Cement News,* Portland Cement Assn. (1942).
24. NOVAK, E. C. JR., and MAINFORT, R. C., "Base Course Stabilization with Asphalt Emulsion—U.S. 131 South of Cadillac." *Research Rep. No. R-598,* Research Lab. Div., Michigan Dept. of State Hwys. (Sept. 1966).
25. EPPS, J. A., "Pavement Recycling in Texas." Presented at Natl. Asphalt Pavement Assn. meeting (Jan. 1976).
26. FOSTER, C. R., Oral presentation, Natl. Asphalt Pavement Assn. meeting (Jan. 1976).
27. DUNLAP, W. A., EPPS, J. A., BIESWAS, B. R., and GALLAWAY, B. M., "United States Air Force Soil Stabilization Index System—A Validation." *AFWL-TR-73-150,* Air Force Weapons Lab. Kirtland AFB, N.M. (Jan. 1975).
28. *AASHO Interim Guide for Design of Pavement Structures.* AASHO, Washington, D.C. (1972).
29. Personal correspondence, ASTM Subcommittee D04.37 (Modifier Agents for Bitumen in Pavements) (1977 to date).
30. DAVIDSON, D. D., CANESSA, W., ESCOBAR, S. J., "Practical Aspects of Reconstituting Deteriorated Bituminous Pavements." STP 662, ASTM (Nov. 1978).
31. FAULKNER, J. A., Office Memo to W. J. Tolonen, Arizona DOT (May 3, 1977).
32. KARI, W. J., SANTUCCI, L. E., and COYNE, L. D., "Hot Mix Recycling of Asphalt Pavements." Paper presented at Assn. of Asphalt Paving Technologists (1979).
33. DUNNING, R. L., and MENDENHALL, R. L., "Design of Recycling Asphalt Pavements and Selection of Modifiers." STP 662, ASTM (Nov. 1978).
34. DAVIDSON, D. D., CANESSA, W., and ESCOBAR, S. J., "Recycling of Substandard or Deteriorated Asphalt Pavements—A Guideline for Design Procedures." Assn. of Asphalt Paving Technologists, *Proc.,* Vol. 46 (1977).
35. ESCOBAR, S. J., and DAVIDSON, D. D., "Role of Recycling Agents in the Restoration of Aged Asphalt Cements." Paper presented at Assn. of Asphalt Paving Technologists (1979).
36. BETENSON, W. B., "Recycling Asphaltic Concrete Pavement." Paper presented at Assn. of Asphalt Paving Technologists (1979).
37. HEUKELOM, W., "An Improved Method of Characterizing Asphaltic Bitumens with the Aid of Their Mechanical Properties." Assn. of Asphalt Paving Technologists, *Proc.,* Vol. 42 (1973).
38. HALSTEAD, W. J., "The Relation of Asphalt Ductility to Pavement Performance." Assn. of Asphalt Paving Technologists, *Proc.,* Vol. 32 (1963).

SECTION III - USE REGULATIONS

In any district, no building or structure shall be erected or used for any purpose other than those set forth in the Schedule of Use Regulations and in accordance with the following notations:

P - **Permitted Use**

A - **Use allowed under Special Permit by the Special Permit Granting Authority as provided in Section VI-E hereinafter.**

O - **Prohibited Use**

Permitted Uses and uses allowed by the Special Permit Granting Authority shall be in conformity with the provisions of Section IV and V of this Zoning By-Law

(This Section was amended March 1978 – STM, Art. 1. The Apartment District was amended March 1974 – ATM, Art. 10. A single-family dwelling in an Apartment District shall be governed by the requirements for the Residential or Agricultural-Residential District on which the Apartment District is superimposed. The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.)

III-A SCHEDULE OF USE REGULATIONS

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
1. Church or other place of worship, parish house, parsonage, rectory, convent and hereafter required by the other religious institutions to the extent only as no or hereafter required by the General Laws, Chapter 40A.	P	P	P	P	P	P	P
2. Educational uses or structures which are public, religious, or run by a non-profit educational corporation duly licensed in Massachusetts to the extent only as now or hereafter required by the General Laws, Chapter 40A.	P	P	P	P	P	P	P
3. Educational uses or structures which are not public, religious, or run by a non-profit educational corporation duly licensed in Massachusetts.	A	A	A	A	P	P	P

* *The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
4. Public buildings, structures and premises owned or leased by, or from the municipality for their use or other uses expressly allowed elsewhere within this By-Law, or M.G.L. Chapter 40A, and which may also include uses such as passive and active recreational areas, and be inclusive of structures which may exceed the height limitations to which they would otherwise be subject under Section IV-B of the Town of Holliston Zoning By-Law. *(Amended May 1996 - ATM, Article 40)*	P	P	P	P	P	P	P
5. Public Utilities.	P	P	P	P	P	P	P
6a. Public Service Corp.	A	A	A	A	A	A	A
6b. Use of Municipal property by a Public Service Corp. or a provider of telecommunication services under lease by the Board of Selectmen after first holding a public hearing including giving notice to all abutters within 300 feet or as further governed by M.G. L. Chapter 40.	P	P	P	P	P	P	P

** The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
7. Library, Museum or Civic Center	A	A	A	A	A	A	A
8. Civic, fraternal, historical, religious, social, educational, or other non-profit organizations whose primary function is non-commercial, with ancillary uses permitted to the extent appropriate for their support; also country, tennis or similar clubs whether or not for profit or not, subject to such screening, buffer areas or other applicable conditions as the Board of Appeals may require. *(Amended October 1987 – STM, Art. 15)*	A	A	A	A	A	A	A
9. Horticulture, floriculture or agriculture except the raising of livestock for commercial use on parcels of less than five acres.	P	P	P	A	A	A	A
10. Raising of poultry or livestock for commercial use on parcels of less than five acres.	P	P	A	A	A	A	A
11. Agriculture, horticulture, floriculture on parcels of five acres or more.	P	P	P	P	P	P	P

* *The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag – Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
12. Salesroom or stand for the display of agricultural or horticultural products, the major portion of which is grown or produced on the premises by a resident proprietor.	P	P	P	P	P	P	O
13. Single-family detached dwelling.	P	P	P	O	O	O	P#
14. Two-family or semi-detached house.	O	O	A	O	O	O	O
15. Alteration & conversion of single-family dwelling existing prior to the effective date of this by-law, to accommodate two or more families, provided that all intensity, off-street parking & additional residential floor area requirements are met, and exterior design of this structure is not changed from the character of a single-family dwelling excepting that the exterior of the building may be reconstructed to accommodate an exit from the second floor.	P	P	P	A	P	O	O

** The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*
 # The Apartment District was amended March 1974 – ATM, Art. 10. A single-family dwelling in an Apartment District shall be governed by the requirements for the Residential or Agricultural-Residential District on which the Apartment District is superimposed.

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
16. Multi-family dwellings.	O	O	O	O	O***	O	O
17. Apartments.	O	O	O	O	O***	O	A
17a. Accessory Family Dwelling Unit. *(Amended May 1995 – ATM, Art. 44)*	P	P	P	A	P	O	O
18. Federal or State subsidized Housing for the Elderly or Low Income under the supervision of the Holliston Housing Authority.	P	P	P	A	A	A	P
19. Renting of 1 or 2 rooms and the furnishing of board by a resident family to no more than 3 non-transient persons.	P	P	P	O	A	O	O
20. Professional office or studio of a resident physician, dentist, attorney, architect, artist, musician, engineer or other member of a recognized profession provided that not more than 2 other persons are regularly employed therein in connection with such use, and provided that not more than 25% of the total floor area not to exceed 400 square feet, is regularly devoted to such use.	P	P	P	P	P	O	A

**The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*

****Except 'A' in limited cases. See Section V-K4.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
21. Customary home occupation conducted by a Resident of the premises provided that not more Than one other person is regularly employed Therein in connection with such use, and that not More than 25% of the total floor area, not to exceed 400 square feet, is regularly devoted to such use, And that there is no exterior storage of material or Equipment, and that no exterior display of products is visible from the street.	P	P	P	P	P	O	A
22. Nursery School or other use for the day care of children. *(Amended May 1991 - ATM, Art. 26)*	P	P	P	P	P	P	P
22a. Privately organized camp.	A	A	A	A	A	A	A
23. Hospital, sanitarium, nursing, rest or convalescent home, charitable institution or other non-correctional institutional use.	A	A	A	O	O	O	O
24. Tourist home, but not including an overnight cabin, motel or hotel.	O	O	P	A	A	O	O

**The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
25. Hotel, motel or overnight cabin.	O	O	O	A	A	A	O
26. Commercial greenhouse.	A	O	O	P	P	P	O
27. Retail stores, not including drive-in or open air business.	O	O	O	P	P**	A***	O
28. Business or professional offices shall include but not be limited to other uses such as a bank or financial institution, real estate office, barber shop, office of a contractor, dressmaker, tailor, optician, and photographer. *(Amended 5/95 – ATM, Art. 44.)*	O	O	O	P	P**	P	O

* *All uses within the Village Center Commercial District are also subject to Section V-K.*

** *Except 'A' for a new building over 5,000 s.f. gross floor area or an addition resulting in a building over 5,000 s.f. gross floor area.*

*** *Retail stores ancillary to an existing industrial use.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
28a. Uses as allowed within use group #28 and where not more than 20% of the gross floor area not to exceed 15,000 square feet is devoted to warehouse facilities, packaging, or fabrication and is otherwise in compliance with local, state and federal laws, rules and regulations, but not including any use which involves the manufacture, storage, transportation, discharge or disposal of hazardous, toxic or radioactive materials or which generates perceptible vibration or noise levels greater than 65 db at the property line. *(Amended May 1995 - ATM, Art. 44)*	O	O	O	A	A	P	O
29. Undertaking establishment or funeral home.	O	O	A	A	A	O	O
30. Craft, consumer, professional or commercial Service establishments dealing directly with the General public.	O	O	O	P	P**	O	O
31. Commercial parking lot and/or parking charging fees.	O	O	O	A	A	A	O

* *The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*
** *Except 'A' for a building over 5,000 s.f. gross floor area or an addition resulting in a building over 5,000 s.f. gross floor area.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
32. Salesroom for motor vehicle, trailers, boats, farm implements or machinery with repair services and storage permitted. *(Amended September 1970 – STM, Art.25)*	O	O	O	A	A	P	O
33. Repair garage and/or gasoline station with Service by attendant only. *(Amended February 1977 – STM, Art. 8)*	O	O	O	A	A	A	O
33a. Repair garage and/or self-service gasoline station. *(Amended March 1982 – ATM, Art. 27)*	O	O	O	A	A	A	O
34. Auto body, soldering or welding shop. *(Amended September 1970 – STM, Art. 25)*	O	O	O	A	A	A	O
35. Restaurant or other place serving food or beverages only to persons inside a building.	O	O	O	P	P**	A	O
36. Restaurant or other place serving food or beverages with live or mechanical entertainment.	O	O	O	A	A	A	O

** The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*

*** Except 'A' for a building over 5,000 s.f. gross floor area or an addition resulting in a building over 5,000 s.f. gross floor area.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	**Ag - Res. Dist. A**	**Ag-Res. Dist. B**	**Res. Dist.**	**Comm. Dist.**	**Vill Ctr Comm***	**Ind. Dist.**	**Apt. Dist.**
37. Wholesale office or showroom, including warehouse facilities.	O	O	O	A	A	P	O
38. Commercial indoor or outdoor amusement or recreation place or place of assembly, not including outdoor movie theater, provided that the building is so insulated and maintained as to confine the noise to the premises and is located not less than one hundred feet from a residential district.	O	O	O	A	A	A	O
39. Outdoor movie theater.	O	O	O	O	O	A	O
40. Drive-in or open-air business and appurtenant buildings or structures.	O	O	O	A	A	O	O
41. Animal or veterinary hospital or kennel. *(Amended May 1996 - ATM, Art. 39)*	A	A	A	A	A	A	O

**The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
42. General industrial uses including manufacturing, storage, processing, fabrication, packaging and assembly comprised of not more than 15,000 square feet of floor area devoted to such use and otherwise in compliance with local, state and federal laws, rules and regulations, but not including any use which involves the manufacture, storage, transportation, discharge or disposal of hazardous, toxic or radioactive materials or which generates perceptible vibration or noise levels greater than 65 db at the property line. *(Added May 1995 – ATM, Art. 44)*	O	O	O	O	O	P	A
42a. General Industrial uses including manufacturing, storage, processing, fabrication, packaging, and assembly that occupy more than 15,000 square feet of floor area, or those that have no more than 15,000 square feet of floor area and which involve the manufacture, storage, transportation, discharge or disposal of hazardous, toxic, or radioactive materials. *(Added May 1995 - ATM, Art. 44)*	O	O	O	O	O	A	O

* *The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
43. Spur tracks, team tracks, railroad sidings and other appropriate railroad facilities. *(Amended June 1969 – STM, Art. 10)*	O	O	O	P	P	P	O
44. Helioports, landing areas or platforms for helicopters or other hovering-type aircraft subject To an evaluation of noise and nuisance effects on business or residential occupants of the area and subject also to all national, state laws, regulations and codes pertaining hereto. *(Amended June 1969 – STM, Art. 10)*	O	O	O	O	O	A	O
45. Accessory uses to activities permitted as a matter of right, whether or not on the same parcel as activities permitted as a matter of right, which activities are necessary in connection with scientific development, scientific research or related production, provided that the Special Permit Granting Authority finds that the proposed accessory uses do not substantially derogate from the public good.	O	O	O	A	A	A	O

** The Village Center Commercial District was added June 1982 – STM, Art. 12. All uses within that district are also subject to Section V-K.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

Use	Ag - Res. Dist. A	Ag-Res. Dist. B	Res. Dist.	Comm. Dist.	Vill Ctr Comm*	Ind. Dist.	Apt. Dist.
46. Building materials and equipment exposed to view the extent actually necessary during active continuous construction work on the same lot. *(Amended April 1981 – STM, Art. 5)*	P	P	P	P	P	P	O
47. Customary use and keeping of outdoor furniture, structures, firewood logs, recreational and other equipment appropriate to the normal occupancy of a dwelling on the lot provided that the same complies with other provisions of this by-law. *(Amended April 1981 – STM, Art. 5)*	P	P	P	P	P	P	A
48. Outdoor storage of building materials and equipment, excluding scrap and junk, which is not provided for elsewhere in this by-law, if the same is subjected to screening and does not occupy an area exceeding 25% of the ground floor area of the main building on the lot. *(Amended April 1981 – STM, Art. 5)*	P	P	P	P	P	P	A
49. Outdoor storage of building or other materials or equipment not covered elsewhere in this by-law. *(Amended April 1981 – STM, Art. 5)*	A	A	A	A	A	A	A

* *All uses within the Village Center Commercial District are also subject to Section V-K.*

P – Permitted Use; A – Use allowed under Special Permit; O – Prohibited Use

TOWN OF HOLLISTON
ZONING BOARD OF APPEALS
TOWN HALL
HOLLISTON, MASSACHUSETTS 01746

Middlesex, ss.

April 10, 1978

Re: Independent Bituminous Co. Inc.
105 Lowland Street

LEGAL NOTICE
TOWN OF HOLLISTON

The Holliston Zoning Board of Appeals will hold a public hearing on WEDNESDAY, MARCH 15, 1978, at 8:15 P.M. at the Town Hall, Holliston, Ma., to hear the Petition of INDEPENDENT BITUMINOUS CO., INC., by Atty. John J. Hughes, 21 Charles Street, Holliston, Ma. The Petitioner seeks a Special Permit under the provisions of Section VI-D (2), to vary the terms of Section I-B and Sections V-I to allow the filling of land at the locus for the parking of trucks. The site is located within the confines of the Wetlands and Flood Plain Protection Zone. The premises is located at 105 LOWLAND STREET, HOLLISTON, MA., as shown on the Assessor's Atlas Map as Sheet 9, Block 3 and Lot 5 in the Industrial Zoning District.

Holliston Zoning
Board of Appeals
Jean R. Heavner
Clerk

3/1, 3/8

A public hearing on the Petition was held on Wednesday, March 15, 1978 at 8:15 P.M. at the Town Hall. Notice of the hearing was sent to all persons required by Law and deemed by the Board to be affected by the subject matter of the Petition. Notice of the hearing was also published in the South Middlesex Daiáy News on March 1, and March 8, 1978 as required by Law.

Attorney John J. Hughes appeared before the Board and set forth the details of the Petition.

ATTACHMENTS:

Petition — Filed with the original Decision in the Office of the Town Clerk.

Proposed Plan — Filed with the original Decision in the office of the Town Clerk.

PRESENTATION:

Attorney John J. Hughes presented a petition to the Board for Independent Bituminous Co.,Inc. requesting a Special Permit to fill in wetlands located on their property at 105 Lowland Street.

Attorney Hughes refreshed the memory of the Board by detailing the situation when this same petition was denied by the Board without prejudice in 1977. Specifically, the subject area is a sometimes muddy area which, in past times, has been used as a dump. Atty. Hughes gave the Board copies of correspondence between Independent Bituminous and the Holliston Conservation Commission establishing that they have been working jointly toward a satisfactory solution to the problem.

TOWN OF HOLLISTON

ZONING BOARD OF APPEALS

TOWN HALL

HOLLISTON, MASSACHUSETTS 01746

Independent Bituminous Co.
April 10, 1978
Page -2-

The plan presented to the Board involved a ditch that would act as a siltation basin and a run-off capacity storage area for Bogastowe Brook, with a lock located where the ditch and brook meet. This was designed and engineered by Schofield Brothers.

Mr. Curtis N. Potter of the local Conservation Commission was present and stated that the Conservation Commission has no objection and is willing to accept the judgement of the engineer (Schofield).

DECISION:

The Board voted to grant Independent Bituminous Co.,Inc a Special Permit to fill in the wetlands area, as approved by the Conservation Commission, located at 105 Lowland Street, Holliston, as shown on the attached drawing.

The Board does not feel it necessary to impose any conditions on this Special Permit as the Conservation Commission will impose and enforce conditions which they deem necessary and appropriate.

The Board finds that granting this Special Permit will not be detrimental to the established or future character of the neighborhood or the Town, but on the contrary, will improve the unsightly appearance of this area.

Upon a motion duly made and seconded by those members sitting, namely, John C. Losch, Jean R. Heavner and Peter T. Mitchell, it was unanimously Voted to grant the requested Special Permit.

John C. Losch

John C. Losch, Chairman

RECEIVED
APR 1 0 1978
TOWN OF HOLLISTON
BY

TOWN OF HOLLISTON
CONSERVATION COMMISSION

NOTICE OF PUBLIC HEARING

Notice is hereby given of a Public Hearing in accordance with the General Laws of Massachusetts, Chapter 131, Section 40, titled Wetlands Protection Act, as amended, and the Town of Holliston Wetlands Protection By-Law, on the petition of H.E.B. Land Development Corp.

for the purpose of extension of Order of Conditions, File 185-50 issued to Independent Bituminous Co.

Such proposed action will take place on property located at Lowland Street.

This hearing will be held in the Lower Town Hall, Holliston, at 9:30 p.m. on April 6, 1987.

Ed Mullaney, Clerk

Please send tear sheets to the Holliston Conservation Commission, P.O. Box 520, Holliston, MA 01746

Please send bill to: same

Brockett

Form 7

Commonwealth of Massachusetts

DEQE File No. 185/50
(To be provided by DEQE)

City/Town Holliston

Applicant H.E.B.

Extension Permit
Massachusetts Wetlands Protection Act
G.L. c. 131, §40

From: Holliston Conservation Commission Issuing Authority

To: H.E.B. Land Development Corp. 760 Central Street
(Name) (Address)

The Order of Conditions (or Extension Permit) issued on 3/23/87 (date) to H.E.B. Corp. (name) for work at 205 Lowland St. Holliston (address) is hereby extended for a period of one year(s) from the date it expires.

This Extension Permit will expire on April 1, 1988 (date)

This document shall be recorded in accordance with General Condition 8 of the Order of Conditions.

....

(Leave Space Blank)

BK 16566 PG 542

MASSACHUSETTS QUITCLAIM DEED BY CORPORATION (LONG FORM) 798

1125

INDEPENDENT BITUMINOUS CO., INC.

a corporation duly established under the laws of the Commonwealth of Massachusetts

and having its usual place of business at Holliston

Middlesex County, Massachusetts

for consideration paid, and in full consideration of $15,000.00

grants to HEB Land Development Corporation, a Corporation duly organised under the laws of the Commonwealth of Massachusetts,

of 360 Central Street, Holliston, Massachusetts with quitclaim covenants

the land in said Holliston on the northwesterly side of Lowland Street shown as Lot 1 on a plan entitled "Plan of Land in Holliston,

Scale 1" 40', March 2, 1982, Schofield Brothers Inc., Registered Land Surveyors, 1071 Worcester Road, Framingham, Mass." with additions made March 5, 1982, which plan is recorded as Plan No. 438 of 1982 in the Middlesex South District Registry of Deeds in Book 14605 Page 520.

Containing 2 acres + 30,080 sq. feet, more or less, according to said plan.

For title reference see deeds of Eric J. Stenholm recorded with said District Deeds in Book 11347, Page 34 and Benjamin P. Montenegro in Book 11347, Page 36, both deeds executed on June 27, 1967.

This conveyance does not represent all or substantially all of the assets of Independent Bituminous Co., Inc. in the Commonwealth of Massachusetts.

ADDRESS OF THE GRANTED PREMISES: Lot 1, Lowland St., Holliston, Mass. 01746 11/12/85 02:51 1R 585 RE 75.00

In witness whereof, the said INDEPENDENT BITUMINOUS CO., INC.

has caused its corporate seal to be hereto affixed and these presents to be signed, acknowledged and delivered in its name and behalf by Robert Gabriel,

its President/ Treasurer hereto duly authorized, this 29th

day of October in the year one thousand nine hundred and eighty-five

Signed and sealed in presence of

William J. [illegible]

Independent Bituminous Co. Inc.

by Robert Gabriel Pres. & Treas.

The Commonwealth of Massachusetts

Middlesex ss. October 29 1985

Then personally appeared the above named Robert Gabriel, Pres + Treas

and acknowledged the foregoing instrument to be the free act and ~~deed of the~~ Independent Bituminous Co. Inc.

before me,

[illegible signature]

Notary Public — Justice of the Peace

My commission expires 19

My Commission Expires Sept. 4, 1987

CHAPTER 183 SEC. 6 AS AMENDED BY CHAPTER 497 OF 1969

Every deed presented for record shall contain or have endorsed upon it the full name, residence and post office address of the grantee and a recital of the amount of the full consideration thereof in dollars or the nature of the other consideration therefor, if not delivered for a specific monetary sum. The full consideration shall mean the total price for the conveyance without deduction for any liens or encumbrances assumed by the grantee or remaining thereon. All such endorsements and recitals shall be recorded as part of the deed. Failure to comply with this section shall not affect the validity of any deed. No register of deeds shall accept a deed for recording unless it is in compliance with the requirements of this section.

Building Inspector

ORDER

WETLAND PROTECTION ACT

G.L. C. 131 s. 40

FILE NUMBER: 185-50

PROJECT LOCATION: 205 Lowland St.

TO: Independent Bituminous Co., Inc.

CERT. MAIL NO:

RE: NOTICE OF INTENT AND PLANS DATED: 4/6/78
DATE OF PUBLIC HEARING: 5/15/78

DATE OF RECEIPT BY CONSERVATION COMMISSION: 5/1/78

205 Lowland St

Pursuant to the authority of G.L. C. 131 s. 40, the Holliston Conservation Commission has considered your notice of intent and plans submitted therewith, and has determined that the area on which the proposed work is to be done is significant to one or more of the interests described in the said act. The Holliston Conservation Commission hereby orders that the following conditions are necessary and all work must be performed in strict accordance with said conditions and with the Notice of Intent and Plans, unless modified by said conditions:

CONDITIONS

1. Failure to comply with all conditions stated herein, and with all related statutes and other regulatory measures, shall be deemed cause to revoke or modify this order.
2. This order does not grant any property rights or any exclusive privileges; it does not authorize any injury to private property or invasion of private rights.
3. This order does not relieve the permittee or any other person of the necessity of complying with all other applicable federal, state or local statutes, ordinances, by-laws and/or regulations.
4. The work authorized hereunder shall be completed within one (1) year from the date of this order unless otherwise stated below pursuant to Regulation 6.7. The order may be extended by the issuing authority for one or more additional one-year periods upon application to the said issuing authority at least thirty days prior to the expiration date of the order or its extension.
5. Any fill used in connection with this project shall be clean fill, containing no trash, refuse, rubbish or debris, including, without limiting the generality of the foregoing, lumber, bricks, plaster, wire, lath, paper, cardboard, pipe, tires, ashes, refrigerators, motor vehicles or parts of any of the foregoing.

"D"

CONDITIONS CONTINUED

FILE NO. 185-50

6. No work may be commenced until all appeal periods have elapsed from the order of the Conservation Commission or from a final order by the Department of Environmental Quality Engineering.

7. No work shall be undertaken until the final Order, with respect to the proposed project, has been recorded in the Registry of Deeds for the district in which the land is located within the chain of title of the affected property. Copy to be furnished to issuer of this Order showing book and page prior to commencement of work.

8. Upon completion of the work described herein, the applicant shall forthwith request, in writing, that a Certificate of Compliance be issued stating that the work has been satisfactorily completed. Written request for Certificate of Compliance shall be accompanied by "as built" plans.

9. A sign shall be displayed at the site not less than two square feet or more than three square feet bearing the words, "Massachusetts Department of Environmental Quality Engineering. Number____________".

10. Where the Department of Environmental Quality Engineering is requested to make a determination and to issue a superseding order, the Conservation Commission shall be a party to all agency proceedings and hearings before the Department.

11. The work shall conform to the following described plans and additional conditions. All construction shall conform in each and every respect to the plan entitled "Plan Showing Drainage Improvements on land in Holliston, Massachusetts" prepared by Schofield Brothers, Inc., dated December 30, 1977.

12. Prior to commencement of filling of wetlands area, all trash, debris, refuse and rubbish (excepting bituminous materials shall be removed to the satisfaction of the Conservation Commission.

13. The applicant shall prepare a duly executed and notarized Conservation Restriction, in recordable form, encompassing at a minimum the drainage ditch, a four-foot wide set-back area on each side of the drainage ditch, and the outlet structure leading into Bogastow Brook, which restruction shall run to the Holliston Conservation Commission, and which instrument shall be delivered to the Holliston Conservation Commission upon completion of the work shown on the plan.

14. Any change made or intended to be made in the plans shall require the applicant to file a new Notice of Intent or to inquire of the Commission in writing whether the change is substantial enough to require a new filing.

15. Members and agents of the Holliston Conservation Commission shall have the right to enter upon and inspect the premises to evaluate compliance with these conditions and to require the submittal of any data reasonably

(over)

deemed necessary by the Commission for such evaluation.

636
3039

16. Accepted engineering and construction standards and procedures shall be followed in the completion of this project. Particular care shall be taken during all phases of construction to eliminate or minimize siltation or sedimentation impacts on Bogastow Brook, in accordance with the "Guidelines for Soil and Water Conservation," published by USDA Soil Conservation Service in April 1975.

17. The drainage ditch structure shall be lined with stone on bottom and sides throughout its length.

18. Certain conditions listed below are on-going and do not expire at the end of one year, or with the issuance of the Certificate of Compliance:

    (a) the entire drainage system shall be maintained free from debris so as to allow free flow and storage of water.

    (b) the outlet structure shall be regularly inspected and maintained free of sediment and debris so as to insure an acceptable quality of outflow into Bogastow Brook.

    (c) the four-foot set-back strips on each side of the drainage ditch shall be maintained free and clear of trash, refuse, rubbish and debris.

19. This Order of Conditions shall apply to any successor in interest or successor in control.

TOWN OF HOLLISTON
PLANNING BOARD
703 Washington Street
Holliston, MA 01746
(508)429-0635

MEMORANDUM

TO: Zoning Board Members
FROM: Karen Sherman, Town Planner
DATE: June 19, 2020
RE: 157 Lowland Street

Attached pleased find the Planning Board's 2011 Special Permit for use of 157 Lowland Street as a materials recycling facility (asphalt, brick and concrete). The site is also permitted by the MA DEP as BWP SW 47 – Recycling, Composting or Conversion (RCC) Operation for American Recycled Materials, Inc. (X267053) issued June 2018 (replaced a March 2012 Determination of Need Permit because of regulatory changes).

Enforcement of Condition #14 as well as several other conditions of the approval have been ongoing issues with abutters and the owner for many years. During the 2017/18 DEP permit review permit, numerous issues were raised with regard to compliance with local zoning and permitting (see Planning Board memorandum dated April 6, 2018 with exhibits and Board of Selectmen memorandum dated April 9, 2018). As noted in the Selectmen's memo, a stack of complaints about operations at #157 was entered into the record of a public hearing for 194 Lowland Street. The Planning Board denied the request at 194, citing principally adverse traffic and noise impacts of the proposal. Their denial was upheld by the Land Court.

Recently in May 2020, the Board of Selectmen sought the Planning Board's support of a heavy vehicle exclusion through DOT for Woodland Street and the portion of Lowland Street from Jeffrey Avenue to Woodland. The Police Chief has also issued a traffic advisory to local businesses about ceasing use of that portion of Lowland Street and instead, entering and existing the industrial park via Jeffrey Avenue an Whitney Street or Fiske Street.

At its meeting of June 11th, the Planning Board voted unanimous to express their support for Mr. Canney's enforcement action regarding this site.

TOWN OF HOLLISTON
PLANNING BOARD
TOWN HALL

HOLLISTON, MASSACHUSETTS 01746

CERTIFICATE OF ACTION

SPECIAL PERMIT AND SITE PLAN REVIEW – MICHAEL BRUMBER

Decision Date:	**August 11, 2011**
Applicant:	**Michael Brumber**
Address:	**157 Lowland Street, Holliston, MA**
Owner:	**BA Simeone c/o Aggregate Industries, 400 Green Street, Wrentham, MA 02093**
Site Location:	**157 Lowland Street**
Assessors' Reference:	**Map 12, Block 4, Lot 34**
Zoning District:	**Industrial (I)**

It is hereby certified by the Planning Board of the Town of Holliston, Massachusetts, in accordance with the Rules and Regulations of the Holliston Planning Board, Article VII, Site Plan Review, a duly called and properly posted public hearing of said Planning Board was held on July 28, 2011 and continued to August 11, 2011. At a duly posted meeting on August 11, 2011, it was voted to **approve** a Special Permit and site plan application based on a plan entitled "Site Plan of Land in Holliston, MA" prepared for Michael Brumber of 815 Highland Street, Holliston on a motion made and duly seconded. The plan set was prepared and stamped by Bruce E. Wilson, Jr., PLS of GW Site Solutions Inc. of Franklin, MA. The application was filed with the Planning Board Office on July 7, 2011 and concerns a 7.07-acre property on Lowland Street in the Lowland Industrial Park identified as Map 12, Block 4, Lot 34.

Hearing notice under the requirements of the By-Law and MGL, c. 40A included the following:
1. Publication of a hearing notice in the Metrowest Daily News on July 13 and 20th,
2. Posting of the public hearing notice with the Town Clerk on July 7th, and
3. Abutter notification (including surrounding towns) by mail on July 12th.

The Applicant filed with the Planning Board the following, which are contained in the records at the Planning Board office and are incorporated into this Decision by reference:
1. Application and narrative for Site Plan Review filed with the Planning Board and Town Clerk on July 7, 2011 signed by the Applicant and Owner's Representative.
2. Plans entitled "Site Plan of Land in Holliston, MA", consisting of two sheets, dated July 7, 2011 (revised through August 11, 2011) prepared and stamped by Bruce Wilson, Jr. PLS.

The Planning Board also received correspondence from the Town of Holliston Fire Chief (dated July 27) and Police Chief (dated August 2) as well as Richard T. Westcott, PE of Westcott Site Services, civil engineering consultant for the Planning Board (dated July 18, 2011). The aforementioned are contained in the Planning Board files and are incorporated into this Decision by reference.

PUBLIC HEARING AND FINDINGS

During the course of the public hearing, the following individuals made appearances on behalf of the Applicant and Owner: Michael Brumber (applicant), Attorney Mark Helwig, Dennis Lydon of Aggregate Industries (owner), Bruce Wilson, PLS of GW Site Solutions, Inc.(surveyor), Russell Waldron of AES Applied Ecological Sciences (wetland ecologist) and J. David Simmons, Esq. of Angle Tree Consulting. No abutter or other party of interest was in attendance.

The Applicant explained that the property, which is the subject matter of several historical Zoning Board of Appeals Special Permits and Variances and this application, is located on Lowland Street within the Lowland Industrial Park. The existing buildings, parking, and outdoor storage areas are all located within the Industrial zoning district. The Applicant will occupy one of the buildings as an office and will store excavating equipment, construction materials and the company's fleet on site.

The Applicant requested a Special Permit under the Holliston Zoning By-Laws, Section III-A Schedule of Use Regulations (#42a "General industrial uses…" and #49 "Outside storage of building or other materials not covered elsewhere in this by-law") for processing and outside storage of building materials and equipment year-round. The exterior material storage areas are not proposed to be individually enclosed but are identified on the site plan with piles labeled as raw and processed materials, and the site perimeter is primarily comprised of concrete barriers and earthen berm. The Applicant is primarily engaged in processing and recycling of asphalt and concrete rubble material to produce "recycled aggregate" materials suitable for construction projects. Such processing requires a Determination of Need (Large Operation) from the Massachusetts Department of Environmental Protection (BWP SW 02). The quantity identified in that permit application totals 125,000 tons per year with a maximum of 1,000 tons received per day (300 tons on average). This aspect of the operation – receiving unprocessed materials -- is limited to approximately 6 months per year (April – October). Materials will be acquired from rehabilitation and construction of roadways, parking areas, storage area restoration and construction sites as well as demolition of bridges, buildings and other structures. The Applicant has indicated that a maximum amount of 10,000 tons of materials will be stored while "in process" and 10,000 tons of processed materials will be stored prior to shipment. Approximately 20 tons of non-recyclable residue (primarily rebar and wire mesh) have been identified and will be stored until shipped to another recycler.

Proposed site improvements were described, including truck circulation, screening, parking and security. Manufacturer specifications for a portable track-mounted crusher which will feed a portable screener that will sort and disperse recycled asphalt material into assorted sizes from ¾" to 3" have been provided.

At the public hearing sessions, no abutters offered testimony for or against the proposal. Upon motion made and duly seconded, the public hearing was closed on August 11, 2011.

Special Permit and Site Plan Certificate of Action
Michael Brumber, 157 Lowland Street

Having reviewed all the plans and reports filed by the Applicant and his representatives and the representatives of the Town, considered the testimony at the Public Hearing and having viewed the site, the Planning Board has determined that the Application for Special Permit and Site Plan Review is consistent with the requirements of Sections III-A and VII of the Zoning By-Law.In connection with the application for Special Permit for Use pursuant to Section III-A, the Board makes the finding that the use is in harmony with the general purpose and intent of the By-Law.

The Site, as noted, is presently vacant within a planned industrial park. The proposed use of the site for outside storage of materials (sand & gravel, recycled asphalt and concrete products, and equipment) is consistent with the uses allowed under the zoning by-law within the Industrial district. The Board finds that the aforesaid uses can be made at the Site in a manner that is not detrimental to the surrounding areas provided that the conditions of this decision and that of the Commonwealth are complied with.

The Board finds that the intended use and associated traffic will not have a negative impact upon safety, as Lowland Street is a planned industrial roadway and that the entry provides for appropriate sight distance for vehicles exiting the site. Finally, the Board finds that the completion of the facility will result in improvement of the Site and will promote business development in the community. The Board also finds that the proposal meets the General Conditions for approval specified in Section VII (2)(a-g) of the Holliston Zoning Bylaw.

<u>CONDITIONS OF APPROVAL</u>

The Board's decision to grant the Application for Site Plan Review is subject to the following conditions:

1. This Special Permit is issued solely to the applicant and is not transferable or assignable. The Special Permit is not valid until recorded and indexed at the Registry of Deeds in accordance with the provisions of MGL, c. 40A, s. 11. The copy of the decision to be filed must contain a certification by the Town Clerk that 20 days have elapsed since after the decision was filed and that no appeal has been filed or if such appeal has been filed, that it has been dismissed or denied.
2. **A copy of the recorded decision and revised plan set shall be presented to the Inspector of Buildings.** Unless amended with the approval of the Planning Board, the endorsed plan set shall be the plan of record and operations shall proceed in accordance with the improvements shown on said plan and this Certificate of Action.
3. The Applicant shall not receive or process asphalt and concrete rubble material requiring a Determination of Need (Large Operation) from the Massachusetts Department of Environmental Protection (BWP SW 02) until said "permit" is presented to the Inspector of Buildings.
4. No corrections, additions, substitutions, alterations or any changes shall be made in any plans, proposals, and supporting documents approved and endorsed by the Planning Board without the written approval of the Planning Board. Any requests for modifications shall be made in writing to the Planning Board for review and approval and shall include a description of the proposed modification, reasons the modification is necessary, and any supporting documentation.

5. A copy of this decision shall be kept on site and shall be made available to all site contractors.
6. Non-security lighting shall be extinguished overnight within 30 minutes after close of operations.
7. Prior to commencement of authorized site activity, the Applicant shall provide to the Planning Board Office the name, address and business phone number of the individual(s) who shall be responsible for all activities on the site. Additionally, the Police and Fire Departments should be provided with an emergency notification sheet.
8. Street numbers (5-6" in height) are to be added to any freestanding sign installed along Lowland Street.
9. Outside storage of materials and equipment not associated with site environmental cleanup is limited to areas designated on the site plan. Pile heights are limited to 25' and safe site circulation must be maintained at all times..
10. The applicant shall install/repair the dust suppression system prior to commencement of processing operations and shall operate that system at all times when the crusher and screener are operating.
11. The applicant shall not cause a nuisance to residents due to dust and/or odors. If, in the opinion of this Board, the above measures do not sufficiently mitigate noise and dust migrating off the property, the Board will notify the Applicant in writing and the Applicant shall supply a corrective action plan within thirty (30) days for the Board's review and approval. The Inspector of Buildings may take additional measures as the Town's Zoning Enforcement Officer.
12. No outside activity, including loading of materials is allowed on-site prior to 7:00 a.m. or after 7:00 p.m. Monday through Saturday with the exception of seasonal snow plowing activity and properly-noticed overnight activity to receive millings. Notification must be given to the Building Department and Police Department a minimum of 24-hours in advance of overnight activities. A maximum of 20 nights for such activities are allowed per calendar year. No processing shall occur after 6 p.m.
13. The Applicant shall take measures to prevent vehicle queuing at the site entrance and along Lowland Street, especially before 7 a.m.
14. The applicant shall also direct his vehicles as well as deliveries to utilize the industrial roads in the area in order to minimize impacts to residential areas. This includes utilization of Jeffrey Avenue and Whitney Street to access Washington Street.
15. The responsibility for the maintenance and operation of the drainage system will be the responsibility of the applicant. The applicant shall maintain the drainage system and shall provide semi-annual inspection of the sedimentation basin to the Planning Board. If necessary, the Applicant shall clean the basin so as to maintain the system in proper working order.
16. The Board reserves the right to impose additional requirements in the event that the drainage system fails and water overflows, creating a safety issue.
17. Prior to the issuance of a Certificate of Occupancy, the Applicant shall submit an as-built plan stamped by a professional engineer certifying that all site improvements are completed in accordance with the approved plan. The Applicant shall submit a statement certifying that all conditions of approval of this decision have been met.
18. Prior to the issuance of a Certificate of Occupancy, the Police and Fire Department shall be provided with keys to any proposed gates and buildings (e.g. Knox box) and an accurate materials list depicting the contents of the storage areas (including MSDS).

Special Permit and Site Plan Certificate of Action
Michael Brumber, 157 Lowland Street

19. The double-walled aboveground fuel storage tank shown on the site plan shall be inspected and approved by the Holliston Fire Chief.

Planning Board Vote

The Board's vote in favor of granting Special Permit and Site Plan approval for Michael Brumber is as follows on a motion made and duly seconded:

John J. Donovan	Yes
Parashar Patel	Yes
Jonathan Loya	Yes
Geoffrey Zeamer	Yes
Warren Chamberlain	Yes

HOLLISTON PLANNING BOARD
BY:

John J. Donovan
Chairman

I hereby certify 20 days have elapsed since after the decision has been filed in my office and that no appeal has been filed or if such appeal has been filed, that it has been dismissed or denied.

__________________ Date:

Elizabeth Greendale

Town Clerk

MEMORANDUM

TO:	James McQuade, DEP Solid Waste Section Chief
CC:	Board of Selectmen
FROM:	Holliston Planning Board Karen Sherman, Town Planner/Economic Development Director
DATE:	April 6, 2018
RE:	DEP Recycling, Composting or Conversion Operation (RCC) Draft Permit – BWP SW47 ABC Rubble Recycling Operation American Recycled Materials, Inc. – 157 Lowland Street

Based on review of the draft RCC permit (dated February 9, 2018), the permit application and enforcement materials provided to the Board of Health, the prior RCC permit and the approved Special Permit and Site Plan Review Certificate of Action issued by the Planning Board in 2011, we offer the following questions and comments for consideration:

<u>Site Plan Issues: Request for additional information and/or clarification</u>

- The June 21, 2017 DEP Administrative Deficiency Notice in point 5 on page 2 calls for "...a list of equipment (loaders, excavators, crushers, etc) related to facility operations." No such list appears in Atty. Connors' response letter of August 7, 2016.
- Labels on the application's "Plan of Land of 157-165 Lowland Street in Holliston, MA" dated January 15, 2018 prepared by Connorstone Engineering, Inc. are not consistent with either the 2011 plan or the January 2017 "revised schematic". How are the specific areas that fall under the draft RCC permit determined as there are clearly other materials and processes occurring on the site? Basics questions seem unanswered such as: Where is equipment stored, processing equipment positioned, and area(s) designated for waste material and/or dumpster location(s)?
- What is the large rear pile labeled "berm" comprised of and what part of that pile(s) is dynamic? The "revised schematic" by Connorstone submitted to DEP in January 2017 place the berm up against "processed materials".
- There are no elevation labels on the material piles and berm depicted. We are assuming they are 2' contours. Are pile heights determined by use of Network RTK as indicated in the May 2, 2016 correspondence between Connorstone Engineering and Atty. Connors that was submitted to DEP staff?
- There appears to be a growing encroachment onto adjacent property (N/F Ty-Wood Corporation, Century-TyWood Corporation) at 79 Lowland Street that includes a portion of the loaded truck route, retaining wall and portion of rear pile/berm. The Quitclaim Deed of 2/27/15 for the locus does not indicate any easements (Middlesex South Registry Book 64979, Page 86). Is there a written agreement with this property owner? This encroachment seems inconsistent with Draft RCC Permit Section V(H) Operations as "proximate surrounding areas" likely do not include unauthorized sprawl onto an

adjacent property and if the encroachment is occurring with owner's knowledge, shouldn't they formally be part of the application?

Special Permit Consistency

Since issuance of the Special Permit in 2011 and the site's operation under the prior RCC permit in 2012, the Town of Holliston Building, Board of Health and Planning Departments have received multiple complaints from residents and business owners about various operational aspects at the locus including: excessive noise, hours of operation, vehicle queuing on Lowland Street, clientele usage of Woodland and Fiske Streets, excessive pile heights and management, lack of dust suppression, and lack of stormwater system inspection. These complaints go to both specific operational conditions spelled out in the Special Permit as well as more subjective nuisance issues. The following is a comparison of local Special Permit requirements under local zoning and the draft RCC as well as suggestions for additional RCC permit requirements:

Holliston PB Special Permit	**Draft DEP RCC Permit**
Hours of operation: 7-7, 6 days/week with no processing after 6 p.m., no "outside activity" prior to 7 a.m.; 20 nights with notice to receive millings; measures to prevent queuing, especially before 7 a.m. (Special Permit Conditions 12 and 13)	Hours of operation: 7 – 7, 6 days/week with trained attendant on duty and visual inspection of loads (Draft RCC Permit Section VI(C) and (D)).
Plan and operational changes: Written Planning Board approval required (Special Permit Conditions 2 and 4).	Plan and operational changes: Notice to DEP and Holliston Board of Health (Draft RCC Permit Section VI(G)).
Nuisance mitigation: Board notice to applicant with corrective action plan in 30 days and Building Inspector enforcement action per Section VI-G penalty of the Zoning By-Law and MGL c. 40, s. 21D (Special Permit Condition 11).	Nuisance mitigation: Section V(B) Compliance provides for overall operational conduct. DEP may modify the permit per Section VI(H). Section VI(K) specifically addresses Air Quality/Noise Control.
Site access and management: Employment of operational measures to prevent vehicle queuing on Lowland Street and utilizing and directing use of industrial roads to access Washington Street (Conditions 13 and 14).	Site access and management: All vehicles entering, waiting and leaving the site shall comply with the requirements of 310 CMR 7.11 for exhaust and sound emissions, including unnecessary idling.

- Hours of operation.
    - The draft RCC permit at Section VI Specific Conditions(C) Hours of Operations (page 9) indicates hours of operations for receipt and handling of ABC rubble material. We would like to suggest the following more restrictive additions to the Draft RCC: Special Permit condition #12 states "No outside activity….is allowed on-site prior to 7:00 a.m." We have received numerous complaints of systematic violation of the hours of operations (especially in the mornings) and suggest that the RCC include language that includes and defines "start-up" in addition to

receiving and processing materials. The Special Permit also restricts "processing" after 6:00 p.m. in condition #12. Limiting twilight hours is especially important after the end of daylight savings time when any aspect of operation with lights and headlights is particularly impactful on residents.

- The draft RCC permit does not make allowance for "other" hours for asphalt millings. The overnight operations allowed in the Special Permit, however limited, have been very disruptive to residents and businesses as have unauthorized snow storage operations (see Exhibit A - Inspector of Buildings February 12, 2018 Cease and Desist Order). Condition #12 of the Special Permit allows for a maximum of 20 nights per calendar year to accept millings. We strongly support this limitation/exclusion in the draft RCC permit and suggest the following language change to RCC Draft permit at Section V(C) Compliance with Other Regulations: In the event that a conflict exists between the state and local permits governing the operation, the more restrictive requirements shall prevail.
- Is there a stated definition/qualification for "trained attendant" as identified in Section VI(D) and (E)?

- Plan and operational changes.
  - Atty. Connors states in his May 4, 2016 correspondence to DEP staff that "Brumber is in the process of preparing a filing for an amendment to his town and state permits." To date, no amendment has been filed with the Planning Board and there is as-built plan on file per Condition #17 of the Special Permit. Special Permit condition #4 states the "No corrections, additions, substitutions, alterations or any changes shall be made in any plans, proposals, and supporting documents approved and endorsed by the Planning Board without the written approval of the Planning Board." As noted in the June 21st Administrative Deficiency Notice on page 1, #1 "Application form page 1 of 5, section III.A.1, requires the Applicant to identify all other applicable local, state, federal permits required." Atty. Connors' response letter of August 7, 2016 makes no mention of any local permits or permit revisions.
  - Special Permit Condition #9 that states "Outside storage of materials and equipment…is limited to areas designated on the site plan…" On the approved site plan, there are no piles shown in the location of the current "Wood Chips" pile or "Processed Materials Temporary Storage". The internal bituminous access roadway has been modified to gravel and a retaining wall has been added to accommodate the wood chip pile access. A retaining wall of unknown construction and height has been constructed to accommodate the processed material storage.
- Nuisance mitigation.
  - The draft RCC permit at Section VI(K) on page 11 addresses Air quality /Noise control and the Special Permit addresses the issues in condition #11 which states that "The applicant shall not cause a nuisance to residents due to dust or odors." The draft RCC Permit states on Page 3 that "The Applicant has implemented several measures to prevent potential noise nuisances associated within the

processing and recycling operation, including: the installation of a twenty-seven (27) foot earthen berm at the rear of the property; re-routing the customer trucking driveway to avoid trucks from ascending a hill near the rear of the Site; ....and keeping the processing and screening equipment surrounded by the unprocessed and processed ABC material, which are approximately twenty-five feet high, for the attenuation of noise." As noted by the Conservation Commission in their comments to the Board of Selectmen dated March 7, 2018 (Exhibit B), the earthen berm at the rear of the property was installed without their approval, nor was it reviewed and approved by the Planning Board.

- The draft RCC permit Section V(C) Compliance with Other Regulations states "This permit does not relieve the Owner and/or Operator from the obligation or requirement to comply with all applicable laws and regulations (whether local, state or federal). This permit shall not supersede, nor otherwise diminish, the Owner and/or Operator's requirement to comply with other permit(s) issued by the Town of Holliston." Additionally, Special Permit Condition #9 states "Pile heights are limited to 25'..." The "berm" depicted on the January 2018 Connorstone plan appears to have merged with one or more working piles, the height of which appears to be 32'. This alteration may well have occurred after Cavanaugh Tocci's May 2017 measurements and issuance of their June 5th supplemental report as the Connorstone Plan is dated January 15, 2018.
- It would appear that whatever noise mitigation has been put in place could use monitoring and/or revisiting. As noted by Michael and Audrea Szabatura of 31 Noel Drive in their March 19, 2018 correspondence to the Board of Selectmen (Exhibit C) "...the berm in place does not cover the entire rear of the property. The back-left corner of the property has no coverage and most of the noise funnels out of that area directly to the back of our yard. We are consistently woken by diesel engines idling in the mornings and even during the evenings...." and by Patrick and Cherie Hafford of 242 Lowland Street in their correspondence to the Board of Selectmen of March 17, 2018 (Exhibit D) "The truth is the noise nuisance has not been abated or mitigated. The crusher and the screener are visible from the road, which means the sound is not being blocked by any berms...A rock crusher operating anytime on the weekend and holidays...is a nuisance. At 7:00 AM on Saturdays, the sound is oppressive for neighbors in the surrounding areas."
- Attached please find the Disclosure of Christopher Menge, Senior Vice President with Harris Miller Miller & Hanson, Inc. in Burlington, MA (Exhibit E) who was retained to assess potential impacts from Mr. Brumber's proposed operation at 194 Lowland Street, across the street from the locus under consideration in the draft RCC. His findings seem to be consistent with complaints that have received.

- Site Access and Management.
  - Special Permit conditions #13 and #14 are meant control site management and traffic impacts on abutters and surrounding neighbors. Use of Lowland Street to Woodland Street by the Applicant and his clients has consistently been a source

of complaints for the Town. Residents of Lowland, Regal and Norland Streets continue to express frustration about systematic miss-use of this route, use of air brakes, noise, and dust as well as fear for safety of Upper Charles Trail users and children walking to and from nearby schools on Woodland Street.

- Attached please find the Disclosure of Robert Michaud, Managing Principal and President of MDM Transportation Consultants, Inc. of Marlborough, MA (Exhibit F) who was retained to assess potential traffic impacts from Mr. Brumber's proposed operation at 194 Lowland Street. Mr. Michaud's findings seem to be consistent with complaints we have received.

Record Keeping and Reporting

What action, if any has been taken by DEP on the Notice of Enforcement issued to the Applicant dated January 2018 regarding overages in the 500-ton per day limit?

Why is there no requirement for an operational scale and realistically, what is the accuracy of estimation of materials by volume per draft RCC permit Section VI(A) given that the materials themselves are not uniform? It would appear that estimation of quantities stored on the site as both "in process" and "processed" is quite an involved task as shown in the May 2, 2016 exercise completed by Connorstone Engineering using digital models of various piles. A scale location has been documented on all vintage of plans.

Also, the Draft RCC permit Section IV(G) Record Keeping and Reporting states that "The Operator shall, upon request, make all such records and information available to authorized representatives of MassDEP and all appropriate municipal authorities" On several occasions since 2012, the Building Inspector has requested records and has been either directed to DEP or has received no response.

In that same section of the draft RCC under 2(e) Operational Records & Daily Log "A log of any complaints received regarding the Operation, including but not limited to a description of the complaint, a description(s) of the findings of the complaint investigation, and a description of the actions taken and/or intended to be taken to address the complaint" is required. Our experience with the Applicant is that any complainant would be reluctant to call the facility directly, let alone discuss any complaint rationally. Is there an official clearinghouse or single point of contact for complaints?

Third Party Inspections

The draft RCC permit at Section VI(J) states that "DEP is not requiring third party inspections of the operations at this time." We believe strongly that such a requirement is warranted because of the litany of complaints received by the Town of Holliston as well as yourselves and the caustic relationship between the Applicant and town officials. This approach has proven to be highly effective at the nearby Covanta transfer station (BWP SW 07 Large Handling Facility) located at 115 Washington Street. In that case, the third-party contractor is managed by the Board of Health and the review/inspection scope is agreed upon and funded by the Applicant.

In conclusion, it would appear that there is a direct relationship between some of the operational aspects of the permitted site and its documented nuisance impacts. We would appreciate clarification of the identified site plan deficiencies. We would also respectfully request that you consider some of the outstanding local issues as being impediments to permitting the operation without additional controls and honor any additional or amended decisions issued by Town regulatory boards as a result of this review.

EXHIBIT A

February 12, 2018

Michael Brumber
157 / 165 Lowland Street
c/o 34 Prospect Street
Holliston, MA 01746

CEASE AND DESIST ORDER

Dear Mr. Brumber:

As the Towns' Zoning Enforcement Officer and on behalf of the Planning, please be advised that this letter constitutes a formal order under the Massachusetts Zoning Act (G.L. c. 40A) and the Holliston Zoning Bylaws. Specifically, you are hereby directed to cease and desist from any storage of snow on the property located at 157 / 165 Lowland Street (the "Property").

As you are aware, the allowed business on the Property are described in Special Permit issued to you on August 11, 2011. Snow storage is not described in such Permit. Similarly, such permit: (1) states that all changes to the allowed activities requires the approval of the Planning Board (condition 4); (2) prohibits excessive noise (condition 11); (3) limits the hours of activity on the Property (condition 12). Your snow storage activities are in violation of all of these requirements. Furthermore, the Zoning Bylaws prohibit snow storage in the Ground Water Protection District in which your Property lies.

Based upon the foregoing, you are hereby ordered to immediately cease and desist all snow storage activities on the Property. Should you fail to do so, the Town will be compelled to take any and all available remedial remedies, including, but not limited to, fines, injunctive relief and the institution of criminal proceedings.

You may appeal this Order to the Holliston Zoning Board of Appeals in accordance with G.L. c. 40A.

Sincerely,

Peter N. Tartakoff
Inspector of Buildings / Zoning Enforcement Officer

EXHIBIT B

TOWN OF HOLLISTON

Commonwealth of Massachusetts

Conservation Commission

MEMORANDUM

Date: March 7, 2018

To: Town of Holliston Board of Selectmen

From: Ryan Clapp, Conservation Agent

Re: **Request for a public hearing - Draft Permit Approval RCC Operation - 157-165 Lowland Street**

A draft of an approved permit for a Recycling, Composting or Conversion Operation at 157-165 Lowland Street has been submitted to the Conservation Commission for review. The Massachusetts Department of Environmental Protection has reviewed and determined that the information supplied the Application is in compliance with their requirements, and has issued a draft permit approval for the Operation. However, the Commission has taken issue with several points within the Application.

The Order of Conditions issues by the Conservation Commission under DEP #185-720 has expired without a Certification of Compliance issued. As part of the Order, a critical stormwater management structure was required to be reconstructed (originally constructed under DEP #185-50). The Applicant agreed to reconstruct said structure, but there is a lack of evidence that he has done so. Additionally, as per the Order of Conditions, an As-Built Plan was required to be submitted to the Conservation Commission for review and approval. No such plan has been submitted.

To prevent potential noise nuisances, a "Noise Mitigation Berm" has been constructed on the site. Said berm has, according to the Application, a height of 27 feet and was installed with the oversight of the DEP. There was no notification to the Conservation Commission, and therefore no review or permitting despite being located in areas subject to the Massachusetts Wetland Protection Act and the Town of Holliston Wetland Protection Bylaw.

The original application submitted to the DEP for the site's BWP SW 47 contained a report from GW Site Solutions that significantly misrepresented the onsite soil conditions. While the report

EXHIBIT B
page 2

accurately notes USDA-SCS soil mapping as "Udorthents," in actuality, the site soils are not the as-described "deep, excessively drained soils on an outwash plain." Rather, portions of the site are formed wetlands (permitted to be filed under DEP #185-50) and the existing "sedimentation pond" on the site is a shallow excavation site which intercepts the groundwater surface.

The draft RCC permit may be subject to a public hearing if one or more criteria of 310 CMR 16.05(5)(d) is met. One such criterion is a request from the Town. With these concerns in mind, the Conservation Commission requests that the Board of Selectmen request the DEP to hold a local public hearing on the license application for 157-165 Lowland Street.

EXHIBIT C

March 19, 2018

Board of Selectmen:
Kevin Conley
Jay Marsden
Mark Ahronian
703 Washington Street
Holliston MA 01746

Dear Selectman,

We are writing to ask that the Town of Holliston request an open hearing regarding the permit for Recycling, Composting, or Conversion (RCC) Operations by American Recycled Materials, Inc. at 157-165 Lowland Street.

We continue to have concerns about following: inadequate noise abatement, the storm water management system and lack of a storm water drainage permit, composting, vehicle storage and cleansing at the edge of the property, odors and discharges to the air and ground.

Although, changes to the site plan have made slight changes to the noise patterns, there is still a significant amount that impacts our neighborhood, as the berm in place does not cover the entire rear of the property. The back-left corner of the property has no coverage and most of the noise funnels out of that area directly to the back of our yard. We are consistently woken by diesel engines idling in the mornings and even during the evenings for the "snow activities". This is in addition to the overall noise that is generated from this site all day.

As residents of this town and neighbors to this company, we would like to raise our questions and concerns and to have these addressed. Almost 7 years ago the town did not fulfill its legal obligation to inform the neighbors of this company's proposed operations and we've suffered from these actions ever since. We ask that you request an open hearing to give neighbors an opportunity to provide insights into what is working and not working with the site as it currently stands. Please request that the DEP holds a public hearing on this permit.

Sincerely,

Michael & Audrea Szabatura

EXHIBIT D

DEP Public Hearing Request re:
RCC Permit application FMF #526217; Transmittal #X267053

Cherie and Patrick Hafford
242 Lowland Street
Holliston MA 01746

March 17.2018

Board of Selectmen
Kevin Conley
Jay Marsden
Mark Ahronian
703 Washington Street
Holliston MA 01746

Dear Selectmen:

We are writing to ask that the Town of Holliston request the DEP hold an open hearing regarding the permit for Recycling, Composting or Conversion (RCC) Operation by American Recycled Materials, Inc. (ARM) at 157-165 Lowland Street, Holliston. We understand that the DEP is not involved in special permits, but issues permits to as part of their responsibility to proactively protect "clean air and water, safe management and recycling of solid and solid and hazardous waste, and [for the] protection and preservation of wetlands and coastal resources."

In conversations and meetings with representatives from the DEP, we have been told that these permits are based only on the information supplied to them by the person/organization applying for the permit, and that the DEP does no investigation or verification. We believe some of the information provided for this permit may be missing or misleading regarding the site and its operation, because:

- There is no adequate noise abatement in place.
- There is no evidence of a reliable stormwater management system.
- Materials are stored at the very edge of the brook and within the wetlands zone.
- The operation is not limited to ABC recycling but includes composting.

In the permit application, under Section II DESCRIPTION OF PERMIT APPLICATION AND OPERATION, it states:

Facility Operation

> The Applicant has implemented several measures to prevent potential noise nuisances associated with the processing and recycling operation, including: the installation of a twenty-seven (27) foot earthen berm at the rear of the property; re-routing the customer trucking driveway to avoid trucks from ascending a hill near the rear of the Site; installation of new mufflers on heavy equipment; installation of new self-adjusting back-up alarms on all American Recycled Materials, Inc. mobile equipment; and keeping the processing and screening equipment surrounded by the unprocessed and processed ABC material. which are approximately twenty-five feet high, for the attenuation of noise.

EXHIBIT D
p. 2

> The DON permit restricts the amount of material accepted at the Site and the amount of material allowed to be stored on Site and limits the operating hours to Monday through Saturday 7:00 AM to 7:00 PM. This draft RCC Permit contains the same restrictions.

The truth is that the noise nuisance has not been abated or mitigated. The crusher and screener are visible from the road, which means the sound is not being blocked by any berms. Front loaders regularly ascend all of the mounds of material.

A rock crusher operating anytime on the weekend and holidays (and they do operate on most holidays) is a nuisance. At 7:00AM on Saturdays, the sound is oppressive for neighbors in the surrounding areas.

The berm at the back of the operation is against the brook and in well within wetlands.

The operation opens most often before 7:00AM.

According to the Wetlands Manual provided on the DEP website, there must be a stormwater management system in place. How can the stormwater runoff be managed if there is a 27 foot berm positioned directly at the edge of the brook? When the operation accepts truckloads of snow (all night long) during a storm, how is the stormwater being managed? The facility hasn't even obtained any permitting for snow disposal.

http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/wetfinan.pdf

The application claims to be exempt from solid waste requirements, but according to Energy and Environmental Affairs there are regulations about Using or Processing Asphalt Pavements, Brick & Concrete Rubble (ABC Rubble), detailed in Section B:

> **BWP SW 46: Permit for Recycling, Composting or Conversion (RCC) Operations**
> **BWP SW 47: Modification or Renewal**
>
> **B. Design and Operation is Feasible (16.05(3)(b))**
> **1. Materials can and will be recycled, composted or converted**
> **2. Incoming material and product specifications will be met**
> **3. Product markets are viable**
> **4. Storage of materials and their products will not exceed one year.**
> **5. Residuals generated by the RCC operation will not average more than:**
> **a. 5% for organic materials;**
> **b. 5% for recycling of construction and demolition waste;**
> **c. 10% for recycling of recyclable material except at a single-stream operation;**
> **d. 15% for recycling of recyclable material at a single-stream operation; or**
> **e. Other percentage to be established by the Department**
>
> **C The Operation will not create a significant threat to public health, safety or environment or create a public nuisance.**

EXHIBIT D
p. 3

D. The operation will not result in unpermitted discharges to the air, water, or natural resources of the Commonwealth.

E The operation is appropriately sized.

We have several issues with this operation. First is the nuisance issue. The operation is incredibly noisy and the noise nuisance is exacerbated by early morning starts (prior to 7:00AM) and work on weekends and holidays. The ABC permit does not permit organics and yet trucks have been seen entering 157 Lowland with brush and other organic material, and there has been a mountain of composting material (at times up to approximately 30 feet high) immediately adjacent to the road. This has created an odor nuisance, especially in the warmer months.

Second is the harm to Holliston wetlands, something that according to the DEP, the Conservation Commission has the right to regulate and even set—and enforce—more stringent regulations and policies than the DEP. Asphalt and other materials are encroaching on the wetlands area shown on map of Zone II and III Delineation, Holliston MA, Figure 6.2. In addition, there has been snow collection and melting on the premises.

Third is the traffic safety hazard as trucks queue up before dawn during certain times of the year. We have safety hazards, environmental issues and a public nuisance.

We also have other questions:

We realize that the local Board of Health has a copy of the application to the DEP. Does the Board of Health have all the various plans that are required for the Board of Health to review and approve, particularly the compliance inspection plan? Has anyone from the Holliston Board of Health investigated the claims made in the permit application?

The Holliston Highway Department was told ARM was going to create a new driveway directly across the street from the 157 Lowland Street operation, but it is not now and never was a driveway: it is a parking lot for this growing problem. There was quite a bit of trees, brush, and other organic material removed and a paved apron added. As all this activity falls within the areas supposedly to remain undisturbed (wetlands, riparian zone, flood zone, etc.) why did this not require a permit?

The town did noise testing. How can we find out about the results of that test? We wish someone had been testing Saturday, March 17 when at 7am we were awakened by the sound of heavy equipment pounding on rock.

We have lived in our home for 30 years. We have never before found it necessary to file a complaint. We recognize that we share our area of Holliston with businesses such as an auto body and repair shop, landscaping companies, an asphalt plant, contractors and tradespeople, and a variety of manufacturing and service businesses. In those 30 years, *none* created the trouble or negative impact that this business has in the short time it's been in operation here. We had taken some solace in the special permit's specific restriction of activity (nothing in the winter months).

EXHIBIT D
P.4

However, the permit does not appear to be enforceable and the company seems to be above the rules, able to operate when and as they wish.

After years of an ongoing struggle that has taken up time and money—the town's and the residents' on several surrounding streets, it's beginning to look as if this is the wrong type of business for a mixed residential/industrial location. When you add to this that many of these residents are threatened when they speak up and others are being harassed. we are depending heavily on our town representatives to do everything they can to restore this area to a law-abiding place to live, if not a harmonious one.

Please request the DEP hold a public hearing on this permit.

Sincerely,

Patrick F. and Cherie M. Hafford
508.429.8194
cherie@silverleafdesign.com