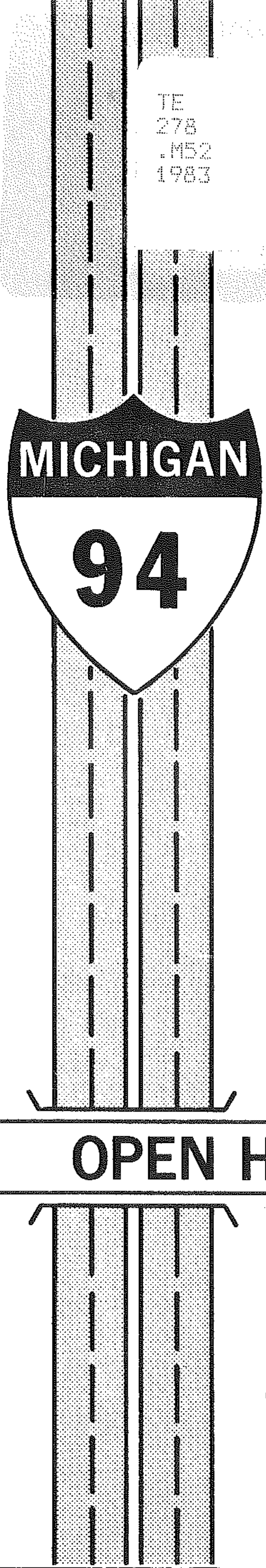

MICHIGAN CONCRETE PAVEMENT RECYCLING

OPEN HOUSE AUGUST 16, 1983

MICHIGAN DEPARTMENT OF TRANSPORTATION

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

american concrete pavement association

MICHIGAN CONCRETE PAVING ASSOCIATION

STATE OF MICHIGAN

TRANSPORTATION COMMISSION
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CARL V. PELLONPAA
WESTON E. VIVIAN
RODGER D. YOUNG

JAMES J. BLANCHARD, GOVERNOR

DEPARTMENT OF TRANSPORTATION

TRANSPORTATION BUILDING, 425 WEST OTTAWA PHONE 517-373-2090
POST OFFICE BOX 30050, LANSING, MICHIGAN 48909

JAMES P. PITZ, DIRECTOR

August 16, 1983

We welcome you to this tour of the first major recycling project in Michigan. In this age of conservation, emphasis has been shifted from building new highways to maintaining and improving our present system. In meeting these challenges there is no better way than utilizing the existing available materials in the concrete pavement and recycling them into a new modern highway.

The methods being employed here have been developed and proven around the nation as exemplified by the Edens Expressway project in Illinois. New techniques are constantly being developed by innovative contractors and, therefore, costs of concrete recycling are bucking the trend of inflation. The time has now arrived when a new, upgraded highway can be built which will last at least another 20 years. From a pavement which has at least served it's original design life the salvage value of the old concrete will result in a cost effective solution which will out last other relatively short term alternatives.

In cooperation with the Federal Highway Administration, research has been incorporated to test some of these new ideas and evaluate the performance of recycled Portland Cement Concrete Pavement. We are proud to be a part of a cooperative effort between the Federal Highway Administration and our cosponsoring Concrete Paving Associations in presenting this demonstration project.

On behalf of the Michigan Department of Transportation I welcome you to view this project during the construction stage and to follow its future progress. If you should desire additional information now or in the future you may contact me or any Michigan Department of Transportation personnel involved with this project.

Sincerely,

James P. Pitz
Director

PCC Recycling
Open House
August 16, 1983

Stouffer's Battle Creek Hotel **Battle Creek, Michigan**

8:00 - 9:00 a.m. REGISTRATION

9:00 a.m. MORNING SESSION Presiding: Gerald E. Wixson
Engineer-Manager
Michigan Concrete Paving Assn.

Welcome

G. J. McCarthy, Deputy Director
Michigan Department of Transportation

Introduction to Recycling

Douglas Bernard, Chief, Demonstration Projects Div.
Federal Highway Administration

National Overview

Harold J. Halm, Executive Director
American Concrete Pavement Association

10:00 a.m. COFFEE BREAK

10:30 a.m. MICHIGAN INTERSTATE 94 RECYCLING

Project Overview

Fred Copple, Research Engineer
Michigan Department of Transportation

Traffic Control

Robert Briere, Asst. District Traffic Engineer
Michigan Department of Transportation

What You Will See

Robert Welke, Senior District Engineer
Michigan Department of Transportation
and

John E. Eisenhour, Jr., Chairman
Eisenhour Construction Company

Tour Instructions

Gerald E. Wixson

12:00 noon LUNCH

1:00 p.m. BUS DEPARTURE FOR I-94 RECYCLING INSPECTION

3:30 p.m. BUSSES RETURN TO HOTEL

DEMONSTRATION PROJECT NO. 47

RECYCLING PORTLAND CEMENT CONCRETE PAVEMENTS

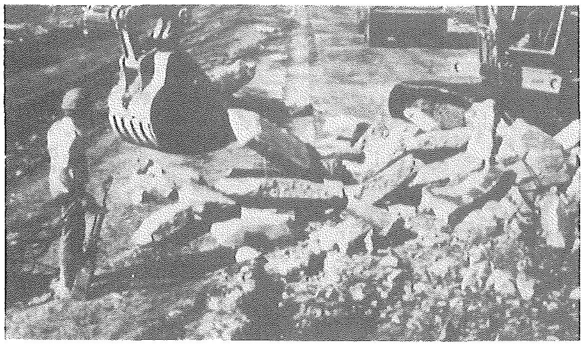
Many regions in this country lack readily available supplies of high quality aggregates for use in portland cement concrete (PCC) pavements. In these regions, it is often necessary to remove large amounts of overburden to expose acceptable aggregate sources or to transport aggregates from distant locations. Both methods of obtaining durable aggregates encourage higher prices and greater energy consumption.

A convenient source of durable aggregates that is often overlooked is the existing concrete in pavements that must be reconstructed. Crushing this concrete and reusing it as aggregates in new PCC pavements would not only conserve raw materials but would reduce construction costs and conserve energy for projects in aggregate-short regions. Whenever a PCC pavement must be reconstructed in an area where the price of durable aggregates is high, one of the alternatives that should be considered is recycling.

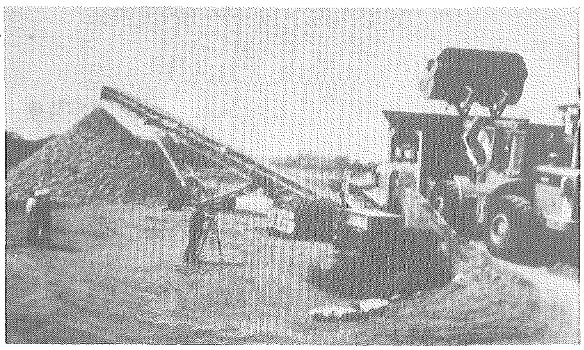
The objective of this demonstration project is to encourage interested highway agencies to construct and evaluate PCC recycling projects. Demonstration Project No. 47 provides the following:

- A visit by a project manager to discuss the current status of recycled PCC pavements.
- Technical and financial assistance for the construction and/or evaluation of experimental PCC recycling projects.

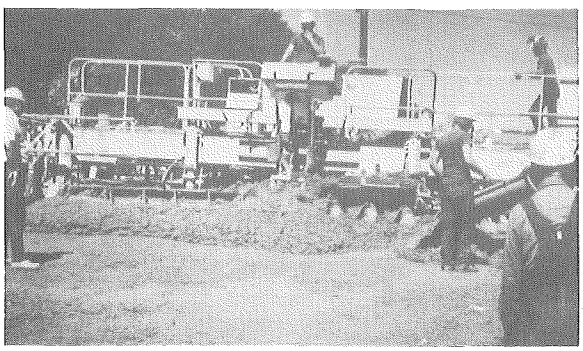
U.S. DEPARTMENT OF TRANSPORTATION/Federal Highway Administration, Region 15
Demonstration Projects Division, 1000 North Glebe Road, Arlington, Virginia 22201



Removal
After the pavement breaking operation (see front photograph) has been completed the PCC is removed and transported to the crushing site.

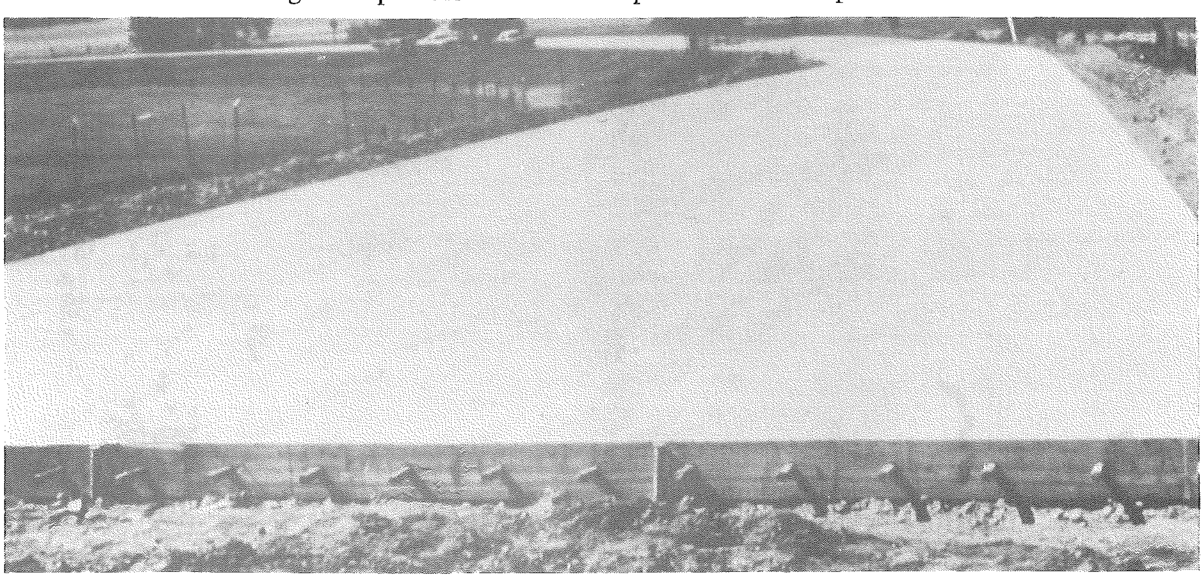


Crushing
The PCC is crushed to a specified size and stockpiled.



Paving
The crushed PCC aggregates are incorporated in a paving mixture which is placed with conventional equipment.

Finished Product The recycled pavement appears similar to pavements using conventional aggregates and the long-term performance should prove to be comparable.



Any agency desiring additional information or presentation of this demonstration should contact the FHWA Division Office in that state.

MICHIGAN OPEN HOUSE

AUGUST 16, 1983

PORTLAND CEMENT CONCRETE RECYCLING

NATIONAL OVERVIEW

Harold J. Halm, Executive Director
American Concrete Pavement Association
2625 Clearbrook Drive
Arlington Heights, IL 60005
(312) 640-1020

MICHIGAN OPEN HOUSE

AUGUST 16, 1983

PORTLAND CEMENT CONCRETE RECYCLING

NATIONAL OVERVIEW

By:

Harold J. Halm, Executive Director
American Concrete Pavement Association

The purpose of this presentation is to provide a national overview of concrete recycling.

Concrete recycling is a technology that is getting increased attention in many areas of the country and can result in significant benefits to specifying agencies.

Recycling has gained its momentum primarily in areas where there is a shortage of, or a complete lack of, aggregates meeting present day quality standards. Another equally important factor is the problem of solid waste disposal, particularly in urban areas. A reduction in construction costs and conservation of energy have also sparked interest in recycling. Under the recycling concept, existing roadways, airport pavements, or any suitable waste concrete becomes a readily available source for producing aggregates.

Laboratory research and field experience at several recent projects have shown that recycling concrete to produce aggregate for concrete, base courses - both stabilized and unstabilized, econocrete (lean mix) subbases, shoulders, and drainage materials is feasible and should be considered whenever reconstruction of a highway or airport facility is undertaken. Giving the contractors the option to recycle the existing pavement will determine the economic feasibility of this operation.

Why Recycle

There is an increasing demand for quality construction materials to meet the needs of our growing society in providing the necessary structures and transportation facilities.

The reserves of commercially usable aggregate are vast, however, in some areas the remaining aggregate sources are becoming less and less accessible for convenient and economical use. Often it is buried deep in the earth or it is too distant from markets to offer a desirable return on investment. Hauling costs from these sources are becoming more and more expensive as the cost of energy escalates. In many areas there is a complete void of aggregates meeting present day specifications.

There is a need to develop replacements for conventional aggregates in these aggregate short areas. In the past, concrete pavements have been built in many of the aggregate short areas because they required less granular materials than a flexible pavement. These pavements are good candidates for recycling when they have served their useful life.

Other prime candidates for recycling are the pavements constructed with "D" cracking aggregates located primarily in the central United States.

With growing environmental awareness, the disposal of rubble and other waste materials by dumping or burial is becoming increasingly more costly and difficult. As a consequence, recycling of rubble and other wastes into usable construction aggregate is receiving increased attention. This is particularly true in urban areas. The disposal of the massive quantities of concrete waste generated in these areas poses a difficult problem.

These wastes have for years been used in landfill. The demand for fill today, especially in the highly developed metropolitan centers, is insufficient to accommodate the amount of waste generated to make way for new construction. It has also become increasingly difficult and expensive to dispose of construction debris in these areas due to stricter environment requirements. Reconstruction of urban streets and expressways presents massive disposal problems. Here recycling can be of tremendous benefit producing savings in material and disposal costs.

There is also the potential for a savings in the cost of aggregates in many areas where aggregate sources are far from the jobsite. With the continues increase in haul costs for construction materials, recycling will become attractive in more areas. Conservation of fuel through a reduction in haul distance may also be realized in many regions of the country.

State and Federal Agencies and others are actively encouraging recycling of portland cement concrete where it is economically feasible. The Federal Highway Administration is actively promoting demonstration projects on recycling of portland cement concrete pavements. These projects are intended to assist in developing the technology and to determine the feasibility of recycling old pcc pavements.

History of Recycling of Portland Cement Concrete

Whenever a new technology is introduced, it is invariably faced with some doubts and skepticism. Concrete recycling technology had to overcome some of these same barriers.

Among the unanswered questions were: Will the recycled material make good aggregate, will it be economically feasible, how do you remove steel from the pavement in a cost-effective manner, how do you proportion concrete mixtures using recycled coarse and fine aggregates, what strengths can be obtained, etc. All these questions have been answered through the innovation of contractors and studies by various agencies.

The practice of using roadbed materials for landfill and rip rap has changed substantially in the past few years with the increased emphasis on the conservation of materials, energy, environmental consideration and cost savings. In addition to recycling of streets and highway pavements, the number of commercial recycling operations in urban areas has increased considerably.

When an urgent rebuilding need was found in Europe after World War II, there was a massive job of recycling waste material, especially building rubble, into new concrete construction with generally good success. As soon as the need for this action was satisfied, such recycling was generally abandoned. More recently an urban expressway, north of Paris, France, was recycled and the aggregates used in a lean concrete base and porous concrete shoulders.

Laboratory Studies

In the materials research area, a number of studies have been conducted by such agencies as the Army Corps of Engineers, Waterways Experiment Station, the Iowa Department of Transportation, Massachusetts Institute of Technology, the Minnesota Department of Transportation, and Federal Highway Administration. These studies were conducted to determine the suitability of recycled aggregates and the economic feasibility of recycling.

Following are some of the findings of these studies:

A. The aggregate particles produced by crushing concrete have good particle shape, high absorptions, and low specific gravity by comparison with conventional mineral aggregates.

B. The use of crushed concrete as a coarse aggregate had no significant effect on mixture proportions or workability of the mixtures by comparison with the control mixtures.

C. When crushed concrete was also used as fine aggregate, the mixture was less workable and required more cement because of water demand. It was found that substitution of a natural sand for a portion of the fine aggregate was required to produce a workable concrete. Iowa uses about 30% natural sand to obtain the workability of their standard pavement mixture which contains a 50-50 mixture of coarse and fine aggregates.

D. Research has shown a substantial increase in frost resistance of concrete made from recycled aggregates when compared to concrete made from normal conventional aggregates.

E. The durability of concrete made with aggregate subject to "D" cracking can be substantially improved by recycling.

F. The use of recycled aggregate did not have any significant effect of the volume change of specimens to temperature and moisture effects.

G. The use of low strength recycled concrete as aggregate is not detrimental to the compressive strength of concrete mixtures that contain this aggregate.

H. The use of concrete aggregate of building rubble that contains excessive amounts of contaminating sulfate resulted in deleterious sulfate reactions. Therefore, the amount of sulfate should be restricted to 1 percent or less of the total aggregate by weight to be safe.

I. The use of water reducing admixtures to lower the water content is effective in increasing strengths of concrete mixtures that contain recycled concrete as aggregate.

Field Studies

Iowa has been a leader in the development of concrete recycling technology. They conducted their initial recycling project in 1976 on U.S. 75 in Lyon County, Iowa. The existing roadway was a portland cement concrete pavement 7 inches thick and thickened to 10 inches at the edges. The pavement was 18 feet and 20 feet wide, paved in 1934 and 1936, using gravel as a coarse aggregate. It had been widened with 10 inches of portland cement concrete in 1958 and resurfaced with 3 inches of asphalt concrete in 1963.

Two objectives were involved in this recycling project:

1. To determine if the asphalt concrete surfacing could be removed, the existing portland cement concrete pavement broken, removed, crushed to 1 1/2 inch minus, proportioned through a conventional central mix proportioning plant with the addition of concrete sand, and placed with a conventional slipform paver.
2. To determine if a two course, composite pavement, each course of different mix proportions, could be placed monolithically with conventional slipform equipment after being proportioned and mixed in a conventional central mix plant.

The pavement was broken with a pneumatic hammer mounted on a backhoe/loader which punched holes in the concrete slab following the lines of reinforcing steel.

The broken pavement was removed by a backhoe and trucked to a stockpile at the crushing site.

To free the slabs where steel connected large pieces, a hydraulically operated shear was used to cut the rebars.

The broken slab, consisting of approximately 2 to 3 foot pieces, was charged into a primary jaw crusher directly from the stockpile.

Virtually all of the remaining steel separated from the concrete during the crushing operation. It was removed manually from a 36-inch wide belt below the crusher.

Crushing this gravel aggregate concrete to 1 1/2 inch size resulted in about 24% and 22% respectively passing the No. 4 screen for the recycled pcc pavement and the pcc pavement-asphalt combination.

The crushed material was not separated on this initial project and contained particles from 1 1/2 inch top size to the -200 sieve material. Some segregation did occur in the stockpile The feed through the bin gates was inconsistent, causing abnormal difficulties in setting the automatic gate closure operation. This caused mix problems making the concrete difficult to batch.

The crushed material was used as aggregate in a concrete mix with 564 pounds of cement and a natural sand for approximately one mile of the project. This concrete was placed 9 inches thick.

The last half mile of the project was an econocrete composite section. A 7 inch lower course consisting of a mixture of recycled concrete and asphalt was placed 23 feet wide with a slipform paver. The mix also contained a natural sand, but only 470 pounds of cement. It was necessary to add natural sand to obtain a workable mix. The addition of natural sand of 20 to 25 percent seems to provide an easy to finish mix proportion.

Immediately after placing the lower course, the slipform paver placed a 4 inch top course that used only recycled concrete as coarse aggregate and 564 pounds of cement.

This top layer wrapped around the base to form a final slab 24 feet wide and 11 inches thick. The project was completed with no major problem. The objectives were satisfactorily met. The project was such a success that the Iowa Department of Transportation proceeded with two more recycling projects for the 1977 construction season.

To help solve the segregation problem, future recycling projects should require splitting the crushed product at about the 3/8 inch screen size. By providing the crushed aggregate in both coarse and fine fractions, the mix proportions should be easier to control. Separating the crushed product would also facilitate mix design. An economical and workable mix design should result when using a three-aggregate mix of uniform coarse and fine crushed product plus concrete sand.

It has been found that washing of recycled aggregates is not necessary if proper removal and processing practices are followed. Specifications require that the portland cement concrete pavement be removed in a manner that does not produce a large amount of fines in the salvaged concrete. This requires that subgrade and subbase material be excluded to the maximum extent practicable. It is intended that this operation be conducted in such a manner as to salvage, in the stockpile, at least 80% of the portland cement concrete to be removed.

In order to control fines, processing equipment can include a screen by which excessive fines in the minus 3/8 inch product can be controlled by removal of fines passing a No. 8 screen. Some specifications provide that the maximum passing the No. 200 sieve in the minus 3/8 inch material is 5%.

There was some concern expressed initially about the removal of steel from a reinforced concrete pavement, particularly pavements with heavy mesh. Through the innovation of contractors in developing breaking, removal and crushing equipment and procedures, this problem has been largely overcome.

A 17-mile recycling project on Iowa Route 2 allowed the contractor more options and the consideration of more specialized equipment. The old slab of this project contained more steel than the first two Iowa projects.

With this in mind, the contractor intended to extensively shatter the concrete, but because the concrete rubble was to be picked up, care was required not to punch the concrete into the grade. The special diesel pile driver breaker was designed to accomplish these tasks.

A rubber tire hydraulic excavator equipped with a ripper tooth which was referred to as a "Rhino horn" was used to dislodge and remove part of the reinforcing steel. The steel was hooked and elevated to expose it for removal.

This operation was conducted from each shoulder so the rubble was moved toward the center of the old slab. A percentage of the steel was pulled free of the concrete in this operation. The few remaining chunks of concrete that were attached to the steel were sheared free by a man with a pair of hydraulic shears.

The steel remaining in the detached concrete chunks were to be removed later at the crushing plant.

The steel from mesh reinforced pavement has been removed by use of a diesel hammer type of breaker combined with the use of a dozer to push the broken concrete on top of broken slabs. The combination broke most of the mesh; however, it did not eliminate altogether the longer wires which were either field cut or removed after primary crushing.

Mixture Designs Using Recycled Aggregates

Recycling projects have demonstrated that some natural sand is necessary to provide a workable mixture.

Iowa has utilized both the coarse (+3/8 in.) and fine aggregates produced by recycling in their mixtures and as shown earlier.

They also use about 30% of a natural sand to obtain the workability of the standard pavement mixture. Iowa does use a 50-50 mixture of coarse and fine aggregate in their standard mixture. This is somewhat higher on the sand percentage than many state agencies specify.

The mixture used on the Minnesota U.S. 59 project utilized about 40% natural sand and the crushed coarse aggregate with a 3/4 inch top size. The crushed fines (1/4 inch minus) was used as a base under the pavement and as a shoulder base material. The increased water demand with the crushed fines and the resultant increase in cement needed favored its use for base material. The mixture used on this project was workable and no problems were encountered in finishing the pavement.

Concrete made from recycled aggregates in general has a higher flexural strength to compressive strength ratio than is normally found with many conventional aggregates. Since pavement thickness design is based on the flexural strength of concrete, the flexural properties of recycled concrete should be determined.

If the compressive strength of cylinders is used for control purposes, a relationship should be established between the flexural strength of beams and the compressive strength of cylinders using the recycled materials. Concrete abrasion tests conducted on both recycled aggregate concrete and concrete made with virgin aggregate showed very similar wear characteristics.

Recycling "D" Cracked Pavement

Construction of the first major concrete recycling project in the United States to utilize a "D" cracked concrete pavement as a source of aggregate for a new portland cement concrete was accomplished in 1980.

The project was developed through extensive laboratory research studies and field testing by the Minnesota Department of Transportation.

The project involves recycling of 16 miles of U.S. 59, from Worthington to Fulda in sourthern Minnesota.

The pavement was constructed in 1955 utilizing a gravel coarse aggregate with approximately 60% soft limestone particles susceptible to "D" cracking.

The rehabilitation of this section of highway involved the recycling of the pavement into coarse aggregate for a new portland cement concrete pavement and No. 4 screen materials for a granular base under the pavement and shoulders.

Laboratory research and field performance have shown that crushing a potential "D" cracking aggregate to a smaller size substantially reduces the "D" cracking potential of concrete made with the aggregates. With this in mind, Minnesota DOT specified crushing the concrete to 3/4 inch top size with 95 to 100% passing the 3/4 inch screen and 0 to 5% passing the No. 4 screen.

The pavement was broken with shop fabricated breaker using a Link Belt 440 pile hammer equipped with a 14 x 18 inch metal shoe plate.

Four passes were made for each 12 foot lane breaking the slab into 2 foot pieces.

The broken concrete was picked up with a power shovel with an extra wide bucket or a dozer with special teeth welded to the bucket to screen out the gravel subbase material.

The contractor added a one inch screen at the primary crusher to remove any gravel subbase that was picked up. The primary crusher reduced the material to less than 6 inches.

Although no intermediate gradation requirements were specified, gradation tests run during the aggregate processing operation indicated a very uniform and clean material was being produced. During the initial testing of the recycled aggregate it was found that the -200 sieve materials were not deleterious so washing was not required.

During the trial mixture investigation, mix designs were developed using fly ash as a replacement for cement. Three mixtures were investigated with one containing no fly ash, a 10% fly ash replacement for cement and a 20% fly ash replacement for a 15% reduction in cement content. It was the intent to use the fly ash as a plasticizer, thereby reducing the water demand.

Freeze-thaw durability testing was performed on these concretes to detect "D" crack activity. The fly ash concretes showed a reduced "D" crack potential with the concrete having the 20% fly ash replacement showing a greatly reduced potential for "D" cracking.

This project is a milestone in salvaging an old "D" cracked pavement by recycling.

Cost Comparison

The economic feasibility of concrete recycling will depend on There are many miles of pavement showing distress from "D" cracking in aggregate short areas or where good quality aggregates are not readily available. These pavements would be prime targets for recycling when rehabilitation is needed. Proper sizing of aggregates made from these pavements along with the increased resistance to freezing and thawing as shown by tests will produce aggregates with greatly reduced potential to "D" cracking distress. It is estimated that the cost savings on the recycling project on U.S. 59 in Minnesota amounted to about $725,000.

The economic feasibility of concrete recycling will depend on many factors. In papers exploring the subject in 1977 and 1978, two researchers from MIT concluded that recycled aggregates held the advantage in many metropolitan areas where natural aggregates are locally unavailable and a 15-mile haul is a relatively short distance. They estimated a plant price for recycled concrete aggregates, even under conservative assumptions, at $2 per ton compared to $3.03 per ton for natural aggregates. Based on the research at the Waterways Experiment Station, they assumed slightly lower strengths for somewhat larger volumes of concrete (thicker paements) when recycled concrete aggregates are used.

In a paper presented during a session on concrete recycling at the 1978 Transportation Research Board meeting, Professor Frondistou-Yannas of MIT presented additional information on the economics of recycling. She concluded that a commercial plant producing 225,000 tons of recycled aggregate a year should be able to make a profit selling aggregate at $1.67 per ton compared to $3.30 per ton for natural aggregate. This would establish an economic savings from the use of recycled concrete aggregate even if 10% more cement is required to obtain the same strength that could be obtained from natural aggregate.

Energy Comparison

Recycling provides a direct benefit in conservation of raw material and energy. On one project in southeastern Iowa, (Route 20) 28,124 tons of coarse and 12,661 tons of fine crushed concrete aggregate were used. This eliminated the need of disposing of 40,785 tons or 20,602 cubic yards (Sp.Gr. = 2.35) of concrete rubble. It also saved 45,991 tons of virgin aggregate (Sp. Gr. = 2.65). Approximately 200 tons of steel were salvaged from recycling. It is estimated that over 40,000 gallons of fuel was saved by recycling on this project.

If the gasoline and diesel fuel used in reclaiming the old slab are considered similar to that used for removing the overburden and obtaining virgin aggregate, there is a substantial fuel savings in eliminating the aggregate transportation from the quarry to the project (estimated 75 miles). The savings in haul and fuel cost on this project were estimated at approximately $115,000 which included $27,000 for haul road repair.

The possible savings in energy through the use of recycled concrete aggregate was explored in a paper presented by Ray and Halm at the TRB meeting in January, 1978. Table 1 is a summary of the information. Calculations were made of the energy required to produce the materials (aggregates and cement), haul them, mix them, and place a mile of 24-ft. wide, 10-inch concrete pavement.

The table shows a comparison of total BTU's per mile between pavement using natural coarse aggregate (gravel or crushed stone) for various haul distances and pavement using recycled pavement at the same location or aggregate from a commercial recycling plant in a metropolitan area with a 10-mile haul to the job. Using aggregate from a commercial plant where the concrete rubble can be obtained as waste would make recycled concrete energy efficient regardless of haul distance since the energy to crush old concrete appears to be less than that to produce new natural aggregate.

TABLE 1
ENERGY REQUIREMENTS

Millions of BTU's Per Mile of Pavement

Natural Aggregates	
10 Mile Haul	7931
20 Mile Haul	7977
50 Mile Haul	8115
100 Mile Haul	8346
Recycled Pavement (on the job plant)	8148
Recycled Concrete (10 mile haul)	7829

Uses for Recycled Aggregates:

California has been recycling portland cement concrete pavements for a number of years. They were the first to use recycled concrete aggregates in the econocrete (lean concrete) base for new concrete pavement.

The contractor used a mixture of recycled concrete and asphalt obtained from reconstruction of streets, highways, and building rubble.

The subbase was placed .4 feet thick and 50 feet wide in one pass with a slipform paver. The same paver was later used to slipform the 48 foot wide concrete pavement on the subbase. The subbase using the recycled concrete and asphalt looked like a concrete slab.

The average 28-day compression strength on cores from the lean concrete base was 734 psi.

The contractor used the econocrete subbase as a haul road for hauling double 8 yard batches in bottom dumps for the pavement construction.

Iowa has also used recycled concrete aggregate for econocrete on subbases and shoulders on Interstate I-680 near Council

Bluffs.

Econocrete (Lean Base) Airports

Early in 1977, concrete recycling was used in construction of new keel strip in a runway at the Jacksonville, Florida, International Airport.

Rather than overlay the entire runway, it was decided to recycle the existing concrete in the two center 25 foot wide lanes.

The 11 inch concrete was broken up by a drop hammer, removed and hauled to a crushing plant on the airport site.

The crushed product was crushed to 2 inches top size and separated on the 3/8 inch screen and stockpiled for use in the filter course and econocrete base.

A 6 inch filter course (3/8 inch plus material) of the recycled coarse aggregate was placed and compacted.

On the filter course, a 6 inch layer of econocrete base was placed by a slipform paver. The lean concrete used the two sizes of recycled concrete as aggregate with 250 pounds of cement per cubic yard, water, and an admixture for greater workability.

Cement-Treated Base - Airports

In 1964, at Love Field, Dallas, Texas, an 8800 foot runway, parallel taxiway, high-speed turnoffs, holding apron, and an extension of an existing 4500 runway were built of 13 inch concrete.

A project at the Will Rogers World Airport in Oklahoma City, Oklahoma, involved the use of recycled concrete aggregate in a cement-treated base. The project involved complete reconstruction of this terminal apron. The pavement is a mesh-dowel design 12 inches thick on a lime-treated subbase.

To remove the mesh from the broken concrete, an electromagnet with a rubber belt was suspended over the conveyor belt between the primary and secondary crusher. The magnet removed the mesh, dowels and tiebars.

The recycled concrete minus 1 inch size was used as aggregate in the cement-treated subbase.

The work is phased in order to schedule pavement removal and reconstruction so that it would result in a minimum amount of interference in normal airline operations. The specifications gave the contractor the option of recycling or wasting the existing pavement.

Aggregate for Concrete Pavements

In addition to the projects in Iowa and Minnesota (discussed earlier, on the use of recycled concrete as aggregate for pcc pavements), a recycling project at the site of the Greater Southwest Airport located between Dallas and Fort Worth was completed in 1981.

With the opening of the new Dallas/Ft. Worth Airport in 1974, this airport is being transformed into a modern industrial development called Centre Port. They were faced with removal of 320,000 tons of concrete from the old 10 inch reinforced concrete runways built in 1953. Sixty thousand tons of this material will be crushed and used as aggregate in the new concrete pavement to serve the park. The balance will be sold by the crushing contractor for use on other projects.

Two pile driving hammers did the primary breaking.

Four passes were made in each 12 1/2 foot lane at approximately 3 foot centers.

A backhoe equipped with a ripper tooth (rhino horn) broke the mesh and separated the broken slabs.

The primary crusher with an 18 foot vibratory feeder and scalper was followed by a 42 inch jaw crusher.

Immediately following the jaw crusher, the 3 1/2 inch material feeds onto a 36 inch wide belt which flows under a magnet removes approximately 95% of the mesh, dowels and tiebars. The steel drops into a truck below the conveyor and is sold for scrap.

Three sizes of aggregate are made; minus 3/8 inch, 3/8 inch to 1 1/2 inch and base material.

Recycling Streets

In Wyoming, Michigan, a suburb of Grand Rapids, a busy farmland arterial commercial street was rebuilt in 1981 for one mile. Here the contractor had to remove and reconstruct the old street pavement, curb and gutter, sidewalks, and driveways from property line to property line.

The old pavement consisted of a 50-year-old PCC slab with asphalt overlay. The new pavement was to be asphalt with new PCC curb and gutter, sidewalks, and driveways. The contractor requested and received permission to recycle the old concrete and use it as the new aggregate in the new concrete.

A portable crushing plant was set up near the center of the project on the two lanes that were being rebuilt while traffic was carried on the other two lanes.

The existing asphalt was milled off and the PCC base broken with a standard pavement breaker for removal. The crushed concrete was delivered to a nearby ready mix plant that made the new concrete of the recycled material and delivered it back to the site. The concrete made with this recycled aggregate developed 28-day strengths higher than could be attained with available new aggregates.

Another of the FHWA demonstration projects was built in 1982 in Macomb County, Michigan. Here on Garfield Road in an urban area the existing 20-foot-wide pavement was broken up, removed, crushed and used as coarse aggregate in a portion of the new 55-foot-wide street.

The one-mile project included an engineering evaluation by the county to qualify for the FHWA demonstration money.

Recycling Urban Freeways

In the north suburbs of Chicago, the Illinois Department of Transportation reconstructed the first major urban freeway in the United States.

The Edens Expressway was designed in the 1940's for an estimated 80,000 vehicles per day. It was opened to traffic in 1951. In 1966, the 10 inch reinforced concrete was resurfaced with 3 inches of asphalt. Today the Edens Expressway, which is a 6-lane divided expressway, is carrying 130,000 vehicles per day, of which 10% are trucks.

A decision was made that the contract for this work would involve removal and replacement of all existing pavement, removal and replacement of the existing crushed stone subbase, and removal and replacement of the subgrade in many locations. The contract called for widening and redecking six mainline bridges, lowering the grades under underpasses for a minimum of 14 feet 6 inches clearance, full width energency shoulders, improving and modifying the drainage, correction of super elevations, new and improved lighting systems, full width shoulders on both bridges and pavement, and a permanent concrete safety shaped barrier in the median.

In 1979, the contract called for the installment of a temporary concrete safety shape barrier in the middle of the southbound lanes so that two lanes could proceed in each direction, removal and replacement of the pavement on the northbound lanes, and repaving of the northbound lanes with 10 inches of continuously reinforced concrete pavement.

In 1978, an earlier contract was awarded to add a temporary asphalt lane on the west side of the southbound lanes to provide for four lanes on the west side of the southbound lanes to provide for four lanes of traffic separated by a precast median barrier. The precasst barrier was placed in the center of the southbound roadway using the 3 lanes of the original pavement plus the temporary asphalt lane to handle both northbound and southbound traffic.

This is also the first major recycling project where a dowel-mesh pavement has been recycled.

Three hundred fifty thousand tons of the original pavement were crushed and recycled on site, producing two useful products. Approximately 85% was graded for use as porous granular embankment, specified for backfilling undercuts and the remainder was classified into Illinois CA-6 which was used as a 3 inch lift under the new stabilized subbase.

The 10 inch mesh reinforced pavement was pulverized by two large mobile diesel hammers which were fabricated by the contractor for this project. This equipment fractures the old slab into pieces about 24 inches maximum size at a rate of between 1,500 and 2,000 lineal feet of 36 foot wide pavement during a twelve-hour work shift.

All crushing was accomplished in the cloverleaf area of a major intersection. Because of the limited space, a careful balance between the incoming and outgoing material was required.

The shattered concrete was then dozed into piles before loading into semi-trailer trucks and transportiing to the crushing site established at mid-project. A portion of the steel mesh was broken by the diesel hammers but the major portion of the mesh was broken by the dozers pushing the broken concrete into piles on the existing broken pavement.

The steel mesh was removed manually and with electromagnets operating above the conveyor belts along with hand picking of the mesh and other steel items.

This project is an excellent example of reuse of pavement materials into a new pavement structure. A considerable savings in energy and costs resulted from the recycling of the old pcc pavement on this project.

Recycling eliminated the cost of disposal of 350,000 tons of pavement rubble and provided material for the porous granular backfill and a granular base material. This project also illustrates the feasibility of complete reconstruction of a heavily traveled urban expressway.

Ii is estimated that 200,000 gallons of diesel fuel was saved by recycling this pavement.

Commercial Recycling

The recycling of concrete rubble in metropolitan areas contributes to the solution of two problems of increasing magnitude in these areas. The first is the availability problem of obtaining aggregates in many of these areas because urban expansion has led to closing aggregate sources and the enforcement of environmental regulations has led to the closing of still others. The second problem solved is that of waste disposal. Concrete amounts to 75%, by mass, (6) of all construction materials used and therefore, will account for three-quarters, by mass, of all demolition wastes. The disposal of such massive quantities of concrete waste in a metropolitan area poses a difficult problem. The selection of recycling plant sites poses a problem in these areas due to environmental regulations.

Commercial concrete recycling operations are successful in many areas of the country. There are commercial recycling operations in and around most major cities throughout the country.

In Chicago, one material company runs a regular concrete recycling operation. At two sites, wrecking contractors dump old concrete at a fee of $16 for a large trailer load.

A portable crusher is then moved from site to site when a large enough stockpile is accumulated.

The crushed material meeting state specifications is sold for base course aggregate and railroad ballast.

The contractor sets up a portable office and scales at the site to sell the crushed concrete aggregate.

At La Guardia Airport in New York, a contractor tore up and recycled a concrete landing strip that he originally paved 42 years ago. The recycled pavement was crushed at the contractor's recycling plant in Carona, New York, and hauled back to La Guardia to be used as base and pavement aggregate around the Delta Airlines terminal.

The contractor stated that recycling saves hauling and dumping cost of $4 to $6.50 per cubic yard around New York City and it provides specification material at less cost than virgin aggregate. This contractor became interested in recycling 10 years ago as landfill space became more critical and hauling costs soared. There Barber-Greene-Telsmith recycling plant is enclosed as a building 160 feet long with a 21 foot ceiling to satisfy local air pollution standards.

Future Potential for Recycling PCC Pavements

The potential market for recycling pcc pavements should increase substantially due to shortage of materials in certain areas, the problem of solid waste disposal, particularly in urban areas, the increased cost of materials, and hauling these materials to the job sites and savings in cost and energy.

Many segments of the interstate highway system will require reconstruction after they have served their useful life and would be suitable for recycling projects. The "D" cracked pavements would provide a huge market for recycling.

Airport pavements have been grossly overloaded in many instances and will require reconstruction. These pavements will provide recycled aggregates suitable for base course, subbase and new pavement construction.

The U.S. Navy Air Station at Crow's Landing in North Central California utilized this new Resonant Technology Pavement Breaker to shatter this 10 inch pavement at rates up to 12,000 square feet per hour.

This machine employs a high frequency beam which vibrates much like a tuning fork at 44 strokes per second. It is mounted on a 50,000 pound wheel mounted rig. It was used on Iowa Route 330 near Des Moines on a pavement breaking and as part of the cable car rehabilitation project in San Francisco, California.

A Concrete Solution

In a growing number of areas in the United States, it is becoming increasingly advantageous to recycle old concrete. The conservation of materials, the problem of solid waste disposal, the reduction in construction costs and conservation of energy all contribute to an increased interest in recycling of old pcc pavement and concrete rubble.

The projects constructed to date have included the use of recycled concrete aggregates for an econocrete (lean concrete) base (highways and airports), shoulder concrete, mainline pavement concrete, porous granular fill, granular base course and porous concrete shoulders, cement-treated base courses, asphalt stabilized base courses, and asphaltic concrete.

Contractors, equipment manufacturers and commercial aggregate producers will continue to develop and improve the techniques for breaking, crushing, removal of embedded items and handling of recycled concrete aggregates. These improvements will make recycling more and more attractive as a construction option.

PROPOSAL FOR A RESEARCH STUDY

RECYCLING CONCRETE PAVEMENT
I 94, CALHOUN AND KALAMAZOO COUNTIES

Research Laboratory Section
Testing and Research Division
Research Project 78 B-99

Lansing, May 1983

The Problem

Rehabilitating concrete pavements, especially in urban areas, presents a problem that has defied satisfactory solution. Thin asphalt overlays suffer reflection cracks after very short service lives and offer little, other than low initial cost. Long-term remedies have usually involved either removing the old pavement and constructing a new one or covering the existing pavement with thick layers of materials. Both treatments are very expensive and the latter one reduces bridge clearances to what are often intolerable dimensions.

If an old pavement is removed, there is often a problem of disposal. Also, in some areas, aggregates must be hauled long distances and are expensive. These reasons, together with the possibility of saving energy, are incentives for recycling.

Scope

This project has been planned to investigate rehabilitation of rigid pavements by recycling the existing surface into aggregate for use in a new concrete pavement. A 6.5-mile length of I 94 in Calhoun and Kalamazoo Counties will be recycled. These dual roadways, each 24 ft wide, are mesh-reinforced concrete pavement constructed in 1958 and 1960.

The average daily traffic in the area is about 31,000 vehicles per day with about 5,500 of them being commercial. Measurements with the Department's Rapid Travel Profilometer show the pavement to be one of the rougher riding lengths of Michigan's Interstate system.

The existing concrete pavement will be taken to a central plant, probably moved onto the job site, where it will be crushed and screened to a maximum size of 95 to 100 percent passing the 3/4-in. sieve, and not more than 10 percent passing the No. 4 sieve. The relatively small maximum size is to deter D-cracking, now obvious in the pavement. It is planned that the coarse aggregate in the new concrete surface will consist entirely of crushed material from the existing road. Both pavement and shoulders will be concrete.

Objectives

Although recycling of concrete is not entirely new in Michigan, there are a number of reasons why the project now proposed should be worthy of being designated a demonstration project. This project is much larger than any other done in the State. Reinforcement in the I 94 pavement on this project is typical of that in other State highways and is greater than that encountered in the recent Garfield Rd recycling job.

Removal of the existing pavement adds about 5 to 7 dollars to the cost of each ton of recycled aggregate produced; crushing costs about 3-1/2 to 4 dollars per ton. Therefore, the greatest potential for cost savings lies in the removal operation. By letting a job of the size of the I 94 project and by closing the entire eastbound or westbound pavement during reconstruction, a contractor will be encouraged to use larger equipment and reduce pavement removal costs. Also, a job of this size will show contractors that we are serious about a concrete recycling program and encourage them to invest in developing more efficient equipment.

This project is planned to evaluate construction problems encountered in recycling a concrete pavement. Cost data and experience gained should provide a great deal of technical information. Also, the size of the project should encourage contractors to develop more efficient methods for removing the old slabs.

Status of Known Research

The first known instances of successfully using crushed rubble as concrete aggregate was in Europe at the end of World War II (1). At that time, there were massive quantities of building rubble, especially brick, to be disposed of and a great demand for new concrete. In 1964, crushed runway pavement concrete was used in a cement-treated subbase mix at Love Field, Dallas, Texas (2). The mix consisted of 72 percent crushed concrete and was processed through a continuous-flow pugmill mixer.

The first use of crushed concrete and asphalt in econocrete (lean concrete) base was in California (3). After processing through a central mixing plant, the material was placed 0.4 ft thick and 50 ft wide by a slipform paver.

In 1976, the Iowa Department of Transportation recycled a 41 year old length of US 75 (4). After breaking the pavement into pieces about 2 ft square, the asphalt overlay was removed. The concrete was crushed to a maximum size of 1-1/2 in. and the entire gradation used with natural sand to produce sufficient concrete for a one mile length of roadway. For another one-half mile length, both recycled concrete and asphalt materials were used in an econocrete base.

The Iowa DOT concluded that concrete recycling is a feasible alternative and will be considered on future projects. They also made certain technical recommendations such as stockpiling crushed material in two piles, and using natural sand to improve workability. Results of the 1976 Iowa recycling project impressed the DOT enough so that additional projects were let in 1977 and 1978.

Crushing of concrete for reuse as base material is quite common in several areas of the United States. Washington, D.C., Minnesota, California, Illinois, and Michigan all have sites with continuous concrete crushing operations (2). However, no evidence could be found that new concrete had been made from aggregate produced at any of those sources. There does seem to be a demand for the crushed material for use as a base aggregate.

Laboratory tests in Russia by Gluzhge and in the United States by Buck indicate that, at equal water-cement ratios, recycled concrete will have lower compressive strengths than virgin mix (5). Buck, however, showed that higher strengths could be achieved, with recycled concrete, by reducing the water-cement ratio.

Buck also showed that frost resistance was at least as good and sometimes better for recycled mixes than for conventional. Improved frost resistance for recycled concrete was also found in selected laboratory tests made in Michigan.

Demonstration Procedure

Plans are to advertise in spring 1983, for bids to recycle the pavement in the summer of 1983. The concrete pavement over a 6.5-mile length of dual roadway, that is 13 miles of 24-ft wide pavement, will be removed, crushed, and, after removal of mesh, will be used as aggregate in concrete for reconstructing the road. The existing pavement is 9 in. thick with contraction joints spaced at 99-ft intervals. Steel base plates at transverse joints trapped water and hastened joint decomposition. Natural gravel coarse aggregates were used in the existing pavement. Samples will be taken from the existing pavement and crushed to provide aggregates for preliminary mix design and for determining durability of the aggregates. Recycling will begin by removing the old pavement and crushing to a maximum size of 3/4 in. The material will be separated into two stockpiles; the coarse fraction containing no more than 10 percent by weight passing the No. 4 U. S. standard sieve.

Coarse aggregate in the new concrete mix will consist of recycled concrete. A mixture of natural sand and up to 50 percent crushed concrete will be permitted for fine aggregate. A Special Provision Specification for "Recycled Concrete Pavement" using crushed concrete as aggregate is the Appendix.

Conventional construction controls, such as slump and air content, and sampling will be observed. In addition, the following test samples will be taken.

Number of Sampling Sites	Type of Sample	Number Per Site	Purpose
One each mile of 24 ft pavement	6 x 6 x 20-in. beams	6	Flexural strength testing at 7, 28, and 90 days. Two beams per test.
One each mile of 24 ft pavement	6 x 12-in. cylinders	6	Compressive strength testing at 7, 28, and 90 days. Two cylinders per test.
One each mile of 24 ft pavement	3 x 4 x 16-in. beams	6	Durability testing.

Reports

An initial report will be prepared within six months after completion of construction. An additional report will be prepared after three years of service. The initial report will include the following:

Mix design

Gradation of aggregates
Absorption and specific gravity of crushed concrete used as coarse aggregate
Proportions of components of mix

Design of new pavement

Description of cross-section
Description of reinforcement and load transfer
Spacing and treatment of joints

Construction

Methods of removal and problems encountered
Problems with reinforcement
Types of equipment used and whether modifications were tried
Percent, by volume of existing pavement, that is recovered

Crushing

Types and sizes of crushers
Handling of steel
Gradation and quantities of product

Paving

Equipment used
Production rates
Problems related to recycled mix
Finishing and curing methods

Recycled concrete mix

Proportions of recycled sand in mix
Slump
Air content
Unit weights
Compressive and flexural strengths
Freeze-thaw durability factors

Cost comparisons

Actual cost vs. estimated costs of using virgin aggregates. Hauling and disposing of old pavement will be considered as will hauling costs for virgin aggregates.

Conservation of resources

Estimated quantities of virgin aggregates conserved
Disposition of steel
Disposition of old pavement materials not used in the new pavement

Conservation of energy

Energy consumption of construction using recycled materials will be compared to that using virgin materials.

Riding quality

Measured using the Department's Rapid Travel Profilometer

Traffic control

Efficiencies and problems in closing both lanes of a roadway rather than trying to maintain traffic while restricting the contractor to one lane.

Project Supervision

Preliminary mix design will be by the Testing Laboratory of the MDOT. Samples from the recycled pavement will be tested, and data analyzed by the Research Laboratory of the MDOT. Riding quality measurements will be by the Research Laboratory. Construction will be supervised in the conventional manner by the Construction Division.

Open House

The Department will cooperate with the FHWA and the Michigan Concrete Paving Association in holding an "open house" seminar for public officials, consultants, contractors, and other members of related industries. The seminar will last no more than one day and will probably be held after the first roadway has been repaved and while the second roadway is being removed and crushed.

Cost Estimate

	1983	1984	1985	1986
Salaries and Wages	$6,000	$4,000	$1,000	$1,000
Travel and Subsistence	2,000	1,000	---	---
Total	$8,000	$5,000	$1,000	$1,000

REFERENCES

1. Buck, A. D., "Recycled Concrete," Highway Research Board, Record No. 430, 1973.

2. Ray, G. K., "Recycling Portland Cement Concrete," Recycling Pavements Institute, University of Wisconsin-Extension, April 1978.

3. "Old Pavement Recycled Into New Subbase," Concrete Constructions, October 1975.

4. Bergren, J. V., "Portland Cement Concrete Utilizing Recycled Pavement," Iowa Department of Transportation, January 1977.

5. Buck, A. D., "Recycled Concrete as a Source of Aggregate," ACI Journal, May 1977.

APPENDIX

MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
PAVEMENT CONCRETE USING CRUSHED
CONCRETE AS COARSE AGGREGATE

7.01 Description.-This Special Provision covers the requirements for the concrete to be used for pavement, incorporating crushed concrete as the coarse aggregate. Except as otherwise specified herein, the provisions of Section 7.01 of the 1979 Standard Specifications shall apply.

7.02 Materials.

7.02.01 Crushed Concrete Coarse Aggregate.-The coarse aggregate for the pavement concrete shall be made from old concrete which has been crushed after being removed from the project. The crushed concrete coarse aggregate shall have 95-100% passing the 3/4 inch sieve, and 0 to 10% passing the No. 4 sieve. Only minor amounts of reinforcing steel or bituminous material will be permitted in the final product. Bituminous overlays, if any, and bituminous patches at existing pavement joints shall be removed before salvaging the concrete. The salvaged concrete and crushed product shall be handled so as to prevent contamination by clay from the roadway, or in processing or stockpiling. If salvaged concrete made with slag coarse aggregate is encountered on the project, it shall be removed, crushed, handled, and stockpiled separately from salvaged concrete containing natural aggregate (gravel or stone).

7.02.02 Crushed Concrete Fine Aggregate.-Fine aggregate resulting from the crushing of old concrete removed from the project may be used as a partial replacement for 2NS fine aggregate. The crushed concrete fine aggregate shall have 100% passing the 3/8 inch sieve, and substantially all passing the No. 4 sieve, but shall otherwise be the grading resulting from the crushing operation. The crushed concrete fine aggregate shall not be contaminated with clay.

7.03 Concrete Mixture.-The concrete mixture shall conform to the requirements for Grade 35P concrete in Table 7.01-1 of the 1979 Standard Specifications, with the following exceptions:

a. The entire coarse aggregate shall be crushed concrete coarse aggregate as described above. If the project contains some salvaged concrete with natural coarse aggregate (gravel or stone), and some with slag coarse aggregate, the resulting crushed concrete aggregates shall not be intermixed, but the crushed concrete with slag aggregate shall be used on a different portion of the project from that using the crushed concrete with natural aggregate.

b. The fine aggregate shall be entirely 2NS natural sand, unless the Contractor elects to use a blend of crushed concrete fine aggregate as described above and 2NS fine aggregate. The proportions of crushed concrete fine aggregate and 2NS fine aggregate in each batch shall be as agreed upon by the Contractor and the Engineer, but not more than 50% crushed concrete fine aggregate. The plant shall be capable of weighing and batching both fine aggregates for each batch, if the Contractor chooses the option of using the crushed concrete fine aggregate/2NS fine aggregate blend.

If the quantity of crushed concrete coarse aggregate is insufficient for the needs of the project, 6A coarse aggregate conforming to the requirements of Section 8.02 of the Standard Specifications shall be used as necessary, but 6A coarse aggregate shall not be mixed with the crushed concrete coarse aggregate.

The Engineer reserves the option of increasing the cement content of the concrete to permit earlier opening of the pavement to traffic.

7.04 Measurement and Payment.-The concrete will be included in the payment for concrete pavement as described in Section 4.50.24 of the 1979 Standard Specifications. Concrete containing crushed concrete coarse aggregate will be included in the item, Concrete Pavement Special--Reinforced ______ in.; concrete containing virgin 6A coarse aggregate will be included in the item, Concrete Pavement--Reinforced ______ in. No distinction will be made whether the fine aggregate is a blend of crushed concrete fine aggregate and 2NS fine aggregate, or entirely 2NS fine aggregates. There shall be no adjustment in unit bid prices regardless of the amount of increase or decrease from the estimated quantities of Concrete Pavement Special and Concrete Pavement.

Where concrete with an increased cement content is required by the Engineer, the additional cement over that specified for the standard strength concrete will be measured in tons for the number of square yards directed by the Engineer to be constructed with an increased cement content.

T/R:RHV
1/12/83

P1304(N12/81)

PROPOSAL 83-05613

SET 1
PAGE 1

RECEIVED AT LANSING	ON MAY 18 1983	AT 10:30 A.M.	
WORK TYPE & LOCATION	**FEDERAL PROJECT NO.**	**CONTROL SECTION**	**JOB NO.**
5.712 MI OF DUAL CONC PAV'T RECYCLING ON	IR 94-3(162)88	IR 39025	20737A
I-94 FR 4,622' E OF 40TH ST E'LY TO			
3387' W OF HELMER RD, CITY OF BATTLE CRK			
KALAMAZOO & CALHOUN COUNTIES. 10%MBE &			
3%WBE			

TABULATION OF BIDS

I hereby certify that this is a true and correct copy of the bids received, read, and tabulated for this project.

ACTING Contract Officer

WORK ITEM DESCRIPTION	CODE	QUANTITY	EISENHOUR CONSTRUCTION CO INC AURORA, COLORADO 80044 0081 UNIT PRICE	AMOUNT	JOHN CARLO INC MT CLEMENS, MI 48043 0629 UNIT PRICE	AMOUNT	ENGINEER ESTIMATE UNIT PRICE	AMOUNT
01								
REMOVING PAVEMENT	2070002	159,930.00 SYD	4.0000	639,720.00	4.5500	727,681.50	3.0000	479,790.00
EARTH EXCAVATION	2080001	12,645.00 CYD	3.0000	37,935.00	3.0000	37,935.00	2.0000	25,290.00
TRENCHING	2080012	1,180.00 STA	75.0000	88,500.00	165.0000	194,700.00	35.0000	41,300.00
EMBANKMENT (LM)	2080020	270.00 CYD	3.0000	810.00	1.1500	310.50	1.2500	337.50
EMBANKMENT (CIP)	2080021	2,527.00 CYD	2.0000	5,054.00	1.4500	3,664.15	1.2000	3,032.40
SUBGRADE UNDERCUTTING TYPE III	2080032	2,000.00 CYD	2.0000	4,000.00	3.4000	6,800.00	3.0000	6,000.00
SUBBASE (CIP)	2110002	12,226.00 CYD	1.5000	18,339.00	4.0000	48,904.00	3.5000	42,791.00
AGGREGATE BASE - CONCRETE (3" IN PLACE)	3010020	8,378.00 SYD	.9000	7,540.20	.7500	6,283.50	1.5000	12,567.00
AGGREGATE BASE - CONCRETE (4" IN PLACE)	3010021	5,521.00 SYD	1.1000	6,073.10	.9000	4,968.90	1.7500	9,661.75
CONDITIONING AGGREGATE BASE METHOD NO. 1	3010031	600.00 STA	150.0000	90,000.00	115.0000	69,000.00	150.0000	90,000.00
CLASS A SHOULDERS (LM)	3090003	1,076.00 CYD	8.0000	8,608.00	8.0000	8,608.00	8.5000	9,146.00
REMOVING BITUMINOUS SURFACE	4000001	757.00 SYD	2.0000	1,514.00	3.0000	2,271.00	3.0000	2,271.00
BITUMINOUS APPROACHES	4210001	170.00 TON	50.0000	8,500.00	50.0000	8,500.00	50.0000	8,500.00
CONCRETE SHOULDERS	4250004	91,652.00 SYD	8.2000	751,546.40	8.1500	746,963.80	12.0000	1099,824.00
CONCRETE PAVEMENT - REINFORCED 10"	4500005	159,890.00 SYD	9.5400	1525,350.60	11.8000	1886,702.00	16.0000	2558,240.00
MISCELLANEOUS CONCRETE PAVEMENT REINFORCED 10"	4500034	4,428.00 SYD	20.0000	88,560.00	14.3000	63,320.40	16.0000	70,848.00
TEMPORARY CONCRETE PAVEMENT NONREINFORCED 8"	4500062	5,854.00 SYD	30.0000	175,620.00	14.8000	86,639.20	14.0000	81,956.00
CEMENT	4500090	500.00 TON	57.0000	28,500.00	60.0000	30,000.00	100.0000	50,000.00
CONCRETE DRIVEWAY - REINFORCED	4500095	5.00 CYD	70.0000	350.00	100.0000	500.00	100.0000	500.00
LOAD TRANSFER ASSEMBLY, CONTRACTION JOINT	4500100	30,998.00 LFT	3.5000	108,493.00	3.8000	117,792.40	5.0000	154,990.00
LOAD TRANSFER ASSEMBLY, EXPANSION JOINT	4500101	4,560.00 LFT	2.4000	10,944.00	5.8000	26,448.00	7.0000	31,920.00
CONTRACTION JOINT C, 1 1/4" PREFORMED SEAL	4500102	48,613.00 LFT	4.0000	194,452.00	3.0000	145,839.00	2.8000	136,116.40
EXPANSION JOINT E2, HOT-POURED SEALANT	4500106	4,591.00 LFT	2.4000	11,018.40	1.8500	8,493.35	2.2500	10,329.75
EXPANSION JOINT E3, HOT-POURED SEALANT	4500107	2,690.00 LFT	2.4000	6,456.00	2.6500	7,128.50	2.0000	5,380.00
PLANE-OF-WEAKNESS JOINT D1	4500110	676.00 LFT	1.5000	1,014.00	1.0500	709.80	1.0000	676.00

P1304(N12/81)

PROPOSAL 83-05613

SET 1
PAGE 2

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WORK ITEM DESCRIPTION	**CODE**	**QUANTITY**	**UNIT PRICE**	**AMOUNT**	**UNIT PRICE**	**AMOUNT**	**UNIT PRICE**	**AMOUNT**
01								
EXTERNAL LONGITUDINAL PAVEMENT JOINT	4500115	118,320.00 LFT	.6000	70,992.00	1.0500	124,236.00	1.2500	147,900.00
CONTRACTION JOINT SPECIAL	4507003	96.00 LFT	10.0000	960.00	3.0000	288.00	30.0000	2,880.00
PLANE OF WEAKNESS JOINT D2	4507005	40,528.00 LFT	1.5000	60,792.00	1.2000	48,633.60	1.2500	50,660.00
12" CLASS B CULVERT (CONCRETE)	5110133	48.00 LFT	20.0000	960.00	11.8000	566.40	15.0000	720.00
CULVERT END SECTION GRATE	5111006	266.00 LBS	2.0000	532.00	1.0000	266.00	1.0000	266.00
2' DIAMETER DRAINAGE STRUCTURE	5140034	2.00 EACH	500.0000	1,000.00	450.0000	900.00	450.0000	900.00
DRAINAGE STRUCTURE COVERS	5140042	400.00 LBS	2.0000	800.00	.6000	240.00	.8500	340.00
RECONSTRUCTED BEAM GUARD RAIL, TYPE C	6130013	526.00 LFT	11.0000	5,786.00	10.0000	5,260.00	8.0000	4,208.00
STRUCTURE GUARD RAIL ANCHORAGE, TYPE B	6130044	2.00 EACH	400.0000	800.00	350.0000	700.00	350.0000	700.00
STRUCTURE GUARD RAIL ANCHORAGE, DETAIL C	6130047	5.00 EACH	400.0000	2,000.00	425.0000	2,125.00	350.0000	1,750.00
TEMPORARY BEAM GUARD RAIL	6130070	1,026.00 LFT	12.0000	12,312.00	9.0000	9,234.00	3.0000	3,078.00
SALVAGED BEAM GUARD RAIL	6130073	350.00 LFT	4.0000	1,400.00	1.0000	350.00	2.0000	700.00
REFLECTORIZED WASHERS	6130080	51.00 EACH	3.5000	178.50	3.0000	153.00	3.0000	153.00
TERMINAL END SHOES	6130086	10.00 EACH	50.0000	500.00	25.0000	250.00	40.0000	400.00
GUARD RAIL ANCHORAGE, CABLE-MODIFIED	6137001	10.00 EACH	775.0000	7,750.00	600.0000	6,000.00	650.0000	6,500.00
FIELD OFFICE	6220001	5.00 MOS	500.0000	2,500.00	100.0000	500.00	275.0000	1,375.00
DELINEATOR REFLECTOR	6260110	226.00 EACH	4.0000	904.00	1.7500	395.50	3.0000	678.00
DELINEATOR POST	6260111	191.00 EACH	12.0000	2,292.00	9.0000	1,719.00	10.0000	1,910.00
REMOVING PAVEMENT MARKINGS	6310003	10,000.00 LFT	.4000	4,000.00	.4000	4,000.00	.5000	5,000.00
LIGHTED ARROW, TYPE A, FURNISHED	6310011	4.00 EACH	960.0000	3,840.00	3300.0000	13,200.00	1000.0000	4,000.00
LIGHTED ARROW, TYPE A, OPERATED	6310012	4.00 EACH	1000.0000	4,000.00	1500.0000	6,000.00	500.0000	2,000.00
BARRICADE, TYPE II, LIGHTED, FURNISHED	6310026	100.00 EACH	30.0000	3,000.00	30.0000	3,000.00	25.0000	2,500.00
BARRICADE, TYPE II, LIGHTED, OPERATED	6310027	75.00 EACH	37.5000	2,812.50	37.5000	2,812.50	15.0000	1,125.00
BARRICADE, TYPE III, LIGHTED	6310036	8.00 EACH	150.0000	1,200.00	150.0000	1,200.00	150.0000	1,200.00
TEMPORARY CONCRETE BARRIER	6310049	500.00 LFT	17.0000	8,500.00	25.0000	12,500.00	12.0000	6,000.00
SIGN, TYPE A TEMPORARY	6310056	489.00 SFT	2.7500	1,344.75	2.7500	1,344.75	5.0000	2,445.00
SIGN, TYPE B TEMPORARY	6310057	1,082.00 SFT	2.7500	2,975.50	2.7500	2,975.50	5.0000	5,410.00
TEMPORARY PAVEMENT MARKING, TYPE R	6310080	10,000.00 LFT	1.4200	14,200.00	1.4000	14,000.00	.9000	9,000.00
FAST DRY PAINT-WHITE	6317001	135,000.00 LFT	.0600	8,100.00	.0500	6,750.00	.0500	6,750.00

P1304(N12/81)

PROPOSAL 83-05613

SET 1
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RECEIVED AT LANSING	ON MAY 18 1983	AT 10:30 A.M.		
WORK TYPE & LOCATION		FEDERAL PROJECT NO.	CONTROL SECTION	JOB NO.
5.712 MI OF DUAL CONC PAV'T RECYCLING ON I-94 FR 4,622' E OF 40TH ST E'LY TO 3387' W OF HELMER RD, CITY OF BATTLE CRK KALAMAZOO & CALHOUN COUNTIES. 10%MBE & 3%WBE		IR 94-3(162)88	IR 39025	20737A

TABULATION OF BIDS

I hereby certify that this is a true and correct copy of the bids received, read, and tabulated for this project.

[signature]

ACTING Contract Officer

			EISENHOUR CONSTRUCTION CO INC AURORA, COLORADO 80044 0081		JOHN CARLO INC MT CLEMENS, MI 48043 0629		ENGINEER ESTIMATE	
WORK ITEM DESCRIPTION	CODE	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
01								
FAST DRY PAINT-YELLOW	6317003	120,000.00 LFT	.0400	4,800.00	.0500	6,000.00	.0500	6,000.00
FLEXIBLE POST 36"	6317005	298.00 EACH	25.2500	7,524.50	25.2500	7,524.50	10.0000	2,980.00
FLEXIBLE POST 36" WITH VERTICAL PANEL	6317007	298.00 EACH	25.2500	7,524.50	25.2500	7,524.50	11.0000	3,278.00
MAINTAIN FLEXIBLE POST 36"	6317009	1,226.00 EACH	13.0000	15,938.00	13.0000	15,938.00	5.0000	6,130.00
MAINTAIN FLEXIBLE POST 36" WITH VERTICAL PANEL	6317011	1,226.00 EACH	13.0000	15,938.00	13.0000	15,938.00	5.0000	6,130.00
RAISED PAVEMENT MARKERS	6317013	3,212.00 EACH	2.7500	8,833.00	2.2000	7,066.40	3.0000	9,636.00
CLASS B SODDING	6530002	2,597.00 SYD	1.8000	4,674.60	1.7000	4,414.90	1.5000	3,895.50
ROADSIDE SEEDING	6530006	212.00 LBS	3.7500	795.00	3.0000	636.00	3.0000	636.00
CEREAL RYE SEEDING	6530008	30.00 LBS	1.5000	45.00	1.0000	30.00	2.0000	60.00
CHEMICAL FERTILIZER NUTRIENT	6530010	513.00 LBS	1.5000	769.50	1.0000	513.00	1.2500	641.25
TOPSOIL SURFACE, 3"	6530014	10,302.00 SYD	1.0000	10,302.00	.6500	6,696.30	.7000	7,211.40
MULCH	6530030	6.00 TON	250.0000	1,500.00	180.0000	1,080.00	200.0000	1,200.00
ANCHORING MULCH	6530031	3.00 ACRE	300.0000	900.00	200.0000	600.00	200.0000	600.00
REMOVE WOOD POLE	6900015	28.00 EACH	100.0000	2,800.00	100.0000	2,800.00	150.0000	4,200.00
#4 ALUMINUM TRIPLEX WITH #4 ACSR NEUTRAL	6900223	3,600.00 LFT	.5000	1,800.00	.5000	1,800.00	.7500	2,700.00
TWO LUMINAIRE ON SPAN WIRE	6900234	10.00 EACH	588.0000	5,880.00	588.0000	5,880.00	500.0000	5,000.00
35' CLASS 4 WOOD POLE	6900252	8.00 EACH	350.0000	2,800.00	350.0000	2,800.00	400.0000	3,200.00
45' CLASS 4 WOOD POLE	6900262	20.00 EACH	420.0000	8,400.00	420.0000	8,400.00	500.0000	10,000.00
FIT-UP WOOD POLE AS ELECTRIC SERVICE POLE-PHOTO CONTROL	6900304	2.00 EACH	1605.0000	3,210.00	1605.0000	3,210.00	1800.0000	3,600.00
ON THE JOB TRAINING	6920000	5.00 EACH	800.0000	4,000.00	800.0000	4,000.00	800.0000	4,000.00
MOBILIZATION	6230001	1.00 LSUM	300000.0000	300,000.00	216000.0000	216,000.00	75000.0000	75,000.00
HAZARD LIGHT, FURNISHED	6310045	1.00 EACH	100.0000	100.00	100.0000	100.00	150.0000	150.00
HAZARD LIGHT, OPERATED	6310046	1.00 EACH	100.0000	100.00	200.0000	200.00	130.0000	130.00
MINOR TRAFFIC DEVICES	6310054	1.00 LSUM	7950.0000	7,950.00	8000.0000	8,000.00	14000.0000	14,000.00
FLAG CONTROL	6310055	1.00 LSUM	10000.0000	10,000.00	2000.0000	2,000.00	8000.0000	8,000.00
	PART 01 SUBTOTAL			4,471,913.05		4,838,913.85		5,380,392.95
		TOTAL		4,471,913.05		4,838,913.85		5,380,392.95