Part II

RECYCLED PORTLAND CEMENT CONCRETE PAVEMENTS

— State-of-the-Art Summary —

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

This report constitutes a review of the literature concerning recycling of portland cement concrete pavements by crushing the old pavement and reusing the crushed material as aggregate in a number of applications. A summary of the major projects conducted by state transportation departments is included.

Crushed portland cement concrete is shown to have been successfully used in the following applications.

1. Graded-aggregate bases

2. Cement-treated bases

3. Asphalt base courses and pavements

4. Portland cement concrete bases (econocrete) and pavements

5. Source of supply for independent commercial operations selling aggregate for a variety of applications.

In any given circumstances the cost and availability of new aggregate and the cost of disposing of the old concrete play important roles in establishing whether or not recycling is a desirable alternative. Consequently, each project or the general situation for a given area must be examined separately and the decision made on the basis of local conditions.

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INTRODUCTION

A relatively large number of articles dealing with the recycling of portland cement concrete pavements have appeared in the literature in the past few years. However, a close examination of these reports reveals considerable repetition, and the overall volume of the work done is not as great as might at first be thought. Nevertheless, the successful reuse of the material from old concrete pavements in the projects reported upon is evidence that recycling offers an economical and energy-conservative alternative in a number of situations. This option is particularly attractive where there is a shortage of good aggregate in the vicinity and long hauls of new aggregate for the replacement pavement are required. It is also attractive where long hauls are necessary to dispose of the old concrete or where high costs are assessed for putting the old concrete in landfills.

Under present circumstances, the conditions surrounding each candidate project must be examined in order to determine whether or not reuse of the material offers cost or environmental benefits. The less tangible benefits of conserving the supply of good aggregate and also conserving embodied energy should also be considered. (Embodied energy is defined as the energy used in manufacturing or processing a material up to the point of its use in the project under consideration.)

The information presented here has been compiled to provide (1) a basis for determining when the recycling of concrete offers benefits, and (2) a guide for estimating the potential cost-effectiveness of recycling projects in Virginia.

USES OF OLD CONCRETE

Old concrete pavements have been used in a number of ways. These include:

1. Use in aggregate bases

2. Use as aggregate in asphalt bases and pavements

3. Use as aggregate in cement-treated bases

4. Use as aggregate in portland cement concrete bases (econocretes) and pavements

5. Source of supply for independent commercial operations selling aggregate for a variety of applications.

Circumstances vary for each type of use, and crushed material from the same source may at times be used for more than one purpose. A summary of projects reported in the literature is included in Appendix A. It is likely that some projects not included in this summary have been constructed, but it is believed that those reviewed provide a good indication of the types of use and the "pay off" that can be expected under given circumstances. The reports on these projects, as well as the additional publications referenced, have been used in preparing the succeeding paragraphs setting forth the consensus on each of the types of use.

Use in Aggregate Bases

When old concrete is crushed, it can be successfully used as aggregate in bases for either rigid or flexible pavements with a minimum of processing. The major problem that arises in this use is the need to remove any reinforcing steel in the old concrete. However, most reports indicate that after preliminary crushing, manual removal by employees stationed at the conveyor belts is not too difficult. Sale of the steel as scrap offers a means for a partial recovery of costs. For some large operations, electromagnets stationed above the conveyor belt have been used to assist in steel removal.

The use as aggregate in bases is the method of recycling most often used and the one most likely to show favorable economics. This is particularly true for projects in metropolitan areas where long hauls as well as high fees for disposing of old concrete are required. By crushing and reusing the material at or near the job site, significant savings in money and energy are possible. This type of project is exemplified by the reconstruction of the Eden Parkway now under way in Chicago. The project is described in Appendix A.

The economics of projects such as this are controlled primarily by balancing the cost of crushing and removing the steel against the cost of hauling and disposing of the old material and the cost of purchasing and hauling new material. Construction costs, i.e., the costs of placing and compacting the materials, are essentially the same for recycled aggregate and new aggregate. The contamination of the crushed portland cement concrete with asphaltic material from pavement overlays is not a problem in this type of application and, in fact, often helps in attaining good water resistance properties.

Use as Aggregate in Cement-treated Bases

When used as aggregate in cement-treated bases, crushed portland cement concrete does not create any problems. The normal construction practices for cement-treated base can be followed and good results have been attained in this type of application.

As discussed in the preceding section, the economics of using the recycled material as opposed to conventional material depend upon the relation between the cost of crushing the old pavement and delivering the material to the job site and the cost of delivering new material to the job site. The presence of an asphalt overlay does not create any problems in this application.

Use as Aggregate in Asphalt Bases and Pavements

When the crushed portland cement concrete is used for asphalt bases or pavements, the proper gradation is important. Most reports of such uses indicate that good performance is attained. For this type application, the presence of asphaltic material in the recycled aggregate creates a problem in that air pollution standards are not met when the material is dried in the usual manner. The asphaltic particles burn and create excessive smoke. Consequently, if the recycled aggregate is to be used in asphalt bases or pavements, it is desirable to remove all asphalt overlays prior to breaking up and crushing old portland cement concrete pavements.

As discussed previously, the major factor controlling whether or not the recycling process is economical will be the costs of removal and disposal of the old concrete and costs of bringing in new material. In the present case, however, the additional costs of removing any overlays and providing the proper gradation must be considered.

Use as Aggregate in Portland Cement Concrete Bases (Econocrete) and Pavements

When crushed portland cement concrete is to be used in a new portland cement concrete base or pavement, a new set of circumstances must be considered. These relate to the mix design and to the workability of the concrete mixture. Where the use is for a lean concrete base, or econocrete as it is sometimes called, strength requirements are not difficult to meet. In the California project described in Appendix A, the crushed aggregate included some asphaltic material from the overlays and this created a problem with excessive entrained air. The problem was overcome by using an air detraining agent.

In the Iowa projects, where crushed pavements were used as aggregate in new portland cement concrete pavements, it was necessary to use about 15% natural sand as a part of the fine aggregate in order to obtain proper workability. Some problems were also encountered with segregation, and these were solved by using a water reducing agent which aided in dispersing the fine material in and on the recycled aggregate.

The literature search revealed only a few studies which included measurement of the characteristics of laboratory concrete mixtures containing recycled aggregate. In a summary of European experience, Buck(1) reported the conclusions of a Russian author, Gluzhge, which were:

"a) A new concrete will be no better than the waste concrete that is used as aggregate;

b) the use of concrete fines as sand requires an undue increase in the cement content of a mixture;

c) compressive strengths are lower when concrete is used as aggregate;

d) the specific gravity of crushed concrete tends to be lower than that of the natural aggregates;

e) the cement factor can be lowered if the crushed concrete aggregate is moistened, not saturated, before use;

f) for equal compressive strengths, the flexural strength of mixtures with crushed aggregate is higher than for the control mixtures;

g) mixtures with crushed concrete aggregate stiffen rapidly but consolidate well with vibration."

Buck also conducted a laboratory investigation comparing recycled concrete that contained siliceous aggregate and recycled concrete that contained carbonate aggregate with "normal" concrete containing aggregate of the same types. He studied compressive strength, frost resistance, and volume stability, using a constant water-cement ratio. His data showed that aggregates made from old concretes tend to have a high absorption and low specific gravity. In this series of tests the recycled concretes had lower compressive strengths than the normal concrete. One significant finding of Buck's work was that recycled concrete with chert aggregate had significantly improved frost resistance over the original concrete with the same aggregate, although recycled mixtures containing carbonate-rock aggregate had essentially the same frost resistance as the original concrete. Volume changes with changes in moisture content and temperature were similar for concretes from both the original and recycled materials for each type aggregate.

In later tests, Buck studied the effect of recycling low strength concrete into aggregate. Contrary to the findings of Gluzhge, he found that it was possible for the strength of new concrete with crushed low strength concrete as aggregate to be higher than that of the concrete that was crushed.

Buck also examined the effect of gypsum added to a mixture to simulate the use of building rubble containing plaster. He found that 5% of gypsum by weight of the total aggregate was sufficient to produce harmful internal expansion in concrete made with a cement containing over 5% C_3A when the specimens were stored in a moist condition. The expansion was reduced when the specimens were allowed to dry.

The principles involved in the use of recycled concrete as aggregate in lean concrete base (econocrete) and as aggregate in pavements are generally the same. However, as is evident, properties such as abrasion resistance, resistance to polishing, and strength are of more concern in surface courses.

Relatively few projects in which recycled concrete has been used as aggregate in pavements have been reported in the United States literature, but the success of the Iowa project summarized in Appendix A indicates that this technique can attain excellent results. As previously indicated, there are some special considerations in the mix design, such as the necessity to avoid harshness and the need to assure proper dispersion of the recycled aggregate throughout the mix, but these problems can be eliminated by the proper addition of sand as a part of the fine aggregate and the use of dispersing or water-reducing agents.

Iowa constructed recycled pavements in two ways. In one system the pavement using recycled aggregate was placed as the full 9-in. (230 mm) thick pavement. In another system, a composite pavement was constructed. The lower course was 7 inches (180 mm) thick and incorporated recycled aggregate. To this was added a 4-inch (100-mm) top course with conventional aggregate. The top course was placed while the lower course was still plastic to assure good bond.

As a result of studies and experience with their projects, Iowa developed a supplemental specification for "Portland Cement Concrete Utilizing Recycled Pavement". This specification is given in Appendix B. The specification includes three mix designs that vary with respect to the ratio of coarse aggregate to fine aggregate and the amount of recycled aggregate used. The specifications permit the crushing of old pavement without removing the asphalt overlay when two-course construction is used, but the overlay must be removed prior to crushing when single-course construction is used.

As of August 1979, correspondence with the Highway Division of the Iowa Department of Transportation indicated the projects constructed were performing well and were considered successful. However, no projects other than the three constructed in 1976 and 1977 have been built.

The Federal Highway Administration is encouraging states to construct and evaluate concrete pavement projects built from recycled concrete materials. It has established Demonstration Project No. 47 for this purpose. Gary Henderson, the project leader, has reported that as of August 1979, Connecticut was participating in the project by using recycled aggregate in several sections of pavement reconstruction on Interstate Highway 84. Also, a project was being planned by the Colorado Department of Transportation, and was scheduled to begin in October 1979.

Use as a Commercial Source of Aggregate

The literature summarized in Appendix A includes several accounts of crushed concrete being processed for sale as aggregate in the construction of base course, parking lots, and other uses. In addition, a study conducted at the Massachusetts Institute of Technology (MIT), indicated that in metropolitan areas old concrete could be properly processed and sold at a profit. This work by Frondistou-Yannas and Itoh showed that in such areas enough concrete debris is generated to profitably support the operation of at least one concrete recycling plant.(2) Based on 1976 costs of equipment and manpower, they concluded that old concrete, including building rubble as well as old pavements, could be processed for $2.20 per ton ($2.00 per metric ton). Natural aggregate was estimated to cost $3.30 per ton ($3.00 per metric ton), exclusive of transportation charges. However, if the aggregate is to be used in new concrete, they assume that the concrete member containing the recycled aggregate must be at least 20% larger to account for potential differences in strength. On this basis, if conventional aggregates are available at the same, or shorter, haul distances as the recycled aggregate, they have an economic advantage. However, if the haul distance for conventional aggregates is at least 15 miles (24 km) more than the distance for the recycled material, the recycled material becomes the more economical choice. Where only equal volumes of aggregate are needed, the recycled aggregate has an economic advantage at equal or slightly greater haul distances.

In the MIT study it was assumed that the raw materials — old concrete and building rubble — would be available without charge to the processor. In several accounts of successful commercial crushing operations the contractor with old concrete to dispose of is charged for dumping at the crushing site, thus providing even a greater opportunity for the crusher operator to make a profit.

Although the MIT study included a consideration of using crushed pavements and rubble as an aggregate in portland cement concrete, no record of actual use of such aggregate on a commerical basis was found. Generally such aggregates are used in applications requiring aggregate as a part of the finished project — that is, in backfills, bases for parking lots and pavements, etc.

In a discussion of recycled concrete as a source of aggregate, Bernard and Henderson reported that where the haul distance for natural aggregate exceeds 50 miles (80 km), recycled aggregate at the work site gains the economic advantage.[3] They also pointed out that as more efficient methods of pavement breaking and removal are developed, recycling will become an even more economically attractive alternative for new aggregate. These authors discussed the problem in mix design encountered when using recycled aggregate in new portland cement concrete.

CONCLUSIONS

The conclusions given below have been drawn from this state of the art survey.

1. From the technological viewpoint, with proper consideration of design factors crushed portland cement concrete can be used as aggregate in essentially all highway applications.

2. For use in base course construction where the recycled aggregate is not heated, the presence of asphaltic particles from crushing overlays along with the portland cement concrete can be tolerated, and for such applications removal of the overlay is not necessary. The entire pavement can be broken up and crushed. This applies to lean concrete bases and cement-treated bases as well as aggregate bases.

3. For use in applications requiring heating of the crushed pavement it is necessary to either remove the asphalt overlay or to employ special equipment or techniques as in hot-asphalt recycling in order to avoid excess air pollution caused by the burning asphaltic particles.

4. When using recycled concrete in new portland cement concrete pavements, asphalt overlays must be removed to obtain adequate surface characteristics of the new concrete. In such applications, some new fine aggregate (sand) is usually required to attain proper workability. Water-reducing admixtures or other dispersing agents may also be needed.

5. Even though the technology for using recycled aggregates from crushed portland cement concrete is well established, there is only a limited use of such recycling in the United States. This is especially true with respect to utilization of the recycled material in new portland cement concrete. The reason for this is that in many cases the potential saving is borderline, and the necessary capital expenditures for equipment to break up the roadway, remove the steel, crush the old pavement, and grade the aggregate outweigh the savings unless special conditions exist. Such conditions include:

   a. Large projects where many tons of old pavement would have to be hauled away and new aggregate brought in. In such cases, for example the Jacksonville runway project(7) and the Eden Expressway reconstruction in Chicago,(8) the large amount of material that must be handled justifies the capital expenditures and provides significant savings.

   b. A long haul is required to remove the old concrete and a fee must be paid to dump it at the disposal area.

c. A shortage of natural aggregate exists in the areas so that long hauls at high cost are needed to bring in new materials.

d. In an urban area there are sufficient small jobs under way to justify consolidation of debris at a central point for crushing, processing, and sale for reuse in the area.

6. Before it can be determined if crushing an old portland cement concrete pavement for reuse as aggregate is desirable, an economic analysis of the conditions existing for the job under consideration or the surrounding area must be conducted. Such an analysis must evaluate the costs of crushing and processing the old concrete against the costs of new material. Consideration must also be given to the costs associated with disposal of pavement rubble and to the value of avoiding environmentally undesirable stockpiles of rubble. Energy considerations should also be included, although it is probable that the higher cost alternative will also require the most energy, since the hauling distances required are likely to be the controlling factor.

7. Because good aggregate is readily available in most areas of Virginia, aggregate supply will not normally be an important factor in the decision as to whether or not to recycle concrete. Disposal costs and environmental considerations are likely to bear more weight in decisions for this state.

RECOMMENDATIONS

1. In the planning stages for any project requiring the breaking up and removal of old portland cement concrete pavement or structures, an economic analysis should be made to determine if savings would result from crushing the pavement and reusing it as aggregate. In such analyses alternate uses of the recycled aggregate should be considered, including the option of stockpiling the material for maintenance work.

2. For metropolitan areas, a feasibility study should be conducted to determine if old concrete from pavements and possibly other structures could be processed at a central location and the material stockpiled for future use.

3. Where contractors desire to make use of recycled aggregate from old concrete in lieu of new materials, the state should be willing to establish special provisions based on proven successful use of such materials for the application in question.

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APPENDIX A

SUMMARY OF REPORTED USES OF CRUSHED PORTLAND CEMENT CONCRETE IN HIGHWAYS

California

On State Highway 91 (Compton)

This project was conducted in 1975. Old portland cement concrete pavements, including asphalt overlays, were crushed and stockpiled for future use. These pavements did not contain reinforcing steel.

The stockpiled material was used for Class 3 aggregate base, cement-treated base, and lean concrete base.

The lean concrete base was 50 ft (15.2 m) wide and about 5 in (130 mm) thick. It was laid in one pass of the paver. The surface pavement was portland cement concrete -- 8 in (200 mm) thick at the center and about 9-1/2 in (240 mm) thick on the edge.

Trial mixes in the laboratory indicated that the material entrained excessive air, probably because of the asphalt or oils in the aggregate. Tributyl phosphate (1/2 oz [15 ml] per sack [35 kg] of cement) was added to detrain air. The air content was thus reduced to 3 to 4%. The cement content for the lean concrete base was 8%, and a compressive strength of 500 psi (3450 kPa) at 7 days was required.

The cement-treated base containing the reclaimed aggregate with 5% cement was hauled from the plant to the grade in bottom dump trucks and then spread in 25-ft (7.6 m) widths to approximate grade. No problems were encountered in the placement or compaction of the cement-treated base.

Significant savings in aggregate costs resulted from the use of this material.

For additional information, refer to reference 4.

District of Columbia

Two recycling plants have been established, primarily to handle excavation materials from METRO construction. The crushed product of the plants is a conglomerate of materials from different sources. The product is approved by the District of Columbia Highway Department for use in subbases.

Reuse of this material avoided long hauls to otherwise dispose of rubble with a consequent cost saving. Excavation contractors found it more economical to pay to dump at these plants rather than haul 10-20 miles (16-32 km) outside the city to a landfill and still pay $8 to $9 a load for dumping.

For additional information, see references 5 and 6.

Florida

The major project in Florida involved rehabilitation of a portland cement concrete runway at the Jacksonville International Airport. The work was done in 1975.

The existing concrete runway was crushed and used as aggregate in both the subbase and econocrete base. A total of 21,500 tons (19,400 metric tons) of old concrete was crushed for the project. This supplied about 50% of the needed aggregate.

The pavement initially was broken up with two concrete pavement breakers using a round blunt breaker point. The original strike pattern was 6 in x 6 in (150 mm x 150 mm) but this was later increased to 18 in x 18 in (460 mm x 460 mm). The latter pattern resulted in 85% of the broken pavement having dimensions smaller than 18 in x 18 in x 11 in (460 mm x 460 mm x 280 mm). Breaking of 37,250 sq. yd (31,140 m^2) of pavement was completed in 21 working days with the two machines. Dowel bars in the concrete presented no serious problem at the primary screen deck. It was estimated that 80% of the bars were in excellent condition and could have been reused. The material for the econocrete base had a maximum size of 2 in (50 mm). The 6-in (150 mm) econocrete base was placed with a CMI Suburban Paver.

The conclusion reached from this project was that recycling of old portland cement concrete pavement into aggregate and new econocrete base is both an economical and feasible method of construction. The use of natural resources is also greatly reduced. At the same time, the problem of disposing of large masses of waste concrete is avoided.

For additional information, see reference 7.

Illinois

In Chicago one company has established a commercial crushing operation for old concrete at two sites. The waste rubble from buildings and old concrete pavements is accepted for a fee. The waste is then processed alternatively at each site. A portable crusher is moved from site to site depending on the need. The crushed material meets Illinois Specification CA-6 (grade 8) and is sold for use in base courses and railroad ballast.

Source of information, reference 6.

Another project in the Chicago area was reported by the American Concrete Pavement Association in its June 1979 newsletter. This project involves the reconstruction of over 15 miles (24 km) of the Edens Expressway, which connects the northern Chicago suburbs to the inner city. It is planned that 350,000 tons (317,000 metric tons) of the original portland cement concrete pavement will be crushed and recycled on site. About 83% of the crushed material will be graded for use as material for the porous granular embankment specified for backfilling undercuts. The remainder will be classified into Illinois CA-6, which is specified for a 3-in (76 mm) lift under the new stabilized subbase. The steel mesh is removed manually and with electromagnets operating above the conveyor belts. Source of information, reference 8.

Iowa

The first project in Iowa, in 1976, involved 1.4 miles (2.2 km) of old concrete in Lyon County. The old concrete was crushed and used in a new concrete pavement. In order to obtain proper workability at a water/cement ratio of 0.5, 15% natural sand was used in the new mix along with the crushed recycled aggregate. A water-reducing agent was also used to disperse fine material in and on the recycled aggregate.

The old roadway used for this project was built in 1934 and had a 3-in (75 mm) overlay of asphalt. A pneumatic punch was used to punch holes on 2- to 3-ft (.6- to .9-m) centers in the old pavement. The asphalt layer was then peeled off with a backhoe and the 3- to 4-ft (.9 to 1.2-m) pieces of concrete, which were tied together with reinforcing steel were picked up. The steel was cut with a hydraulic shear to enable the contractor to load and haul the concrete to the crusher. The initial crushing reduced the concrete to a maximum size of 6 in (150 mm) and freed almost all of the steel, which was manually removed as the material came from the crusher. Secondary crushing was by a portable crushing and screening plant that had a capability of removing material passing the No. 8 (2.36 mm) screen. The finished crushed rock for the first job went into a single stockpile. However, segregation was a problem, so subsequent materials were split into two sizes — the split being on the 3/8-in (9.5 mm) screen.

A second job in 1977 involved a 15-mile (22.5 km) section of Iowa Highway No. 2, where reconstruction was on the same alignment as the old roadway. In this case the backhoe operated from the shoulder and loosened the broken pieces of concrete by dragging a hook through them. This removed much of the reinforcing steel. Steel holding pieces of concrete together was cut by a hydraulic shear or torch. In this case, grill work at the secondary crusher caught most of the steel. The balance was removed by an electromagnet before it entered the plant. The material was then processed into two fractions, which were split on the 3/8-in (9.5 mm) screen. The maximum size was 1-1/2 in (38 mm).

A third project involved I-680 near Council Bluffs. In this case a 24-ft (7.3 m) portland cement concrete roadway was recycled for aggregate in a slip-form econocrete subbase and in portland cement concrete shoulders.

Removal, crushing, and processing the material for this project were done essentially as described in earlier projects. Paving operations were conducted the same as with any slip-form paving. The material was reported to handle about the same as concrete made with conventional aggregate. The exception was that the mix with the recycled aggregate was more harsh. Natural sand was added along with the recycled aggregate to improve workability. It was found that mixes using 40%-50% coarse aggregate with 15%-30% natural sand (in addition to recycled material passing the 3/8-in [9.5 mm] sieve) gave the most desirable result.

For additional information, see reference 9, 10 or 11.

Michigan

A contractor in Pontiac has set up a crusher inside a landfill area. He crushes old concrete from other contractors as well as that from his own jobs. The crushed material is then used on his new projects or sold as aggregate to other contractors. The material is used primarily in sewer bedding or as subbase material for parking lots, etc. This procedure results in savings and also solves problems for everyone involved. The crusher owner develops for himself a source of aggregate and a means of disposing of his rubble without charge. He also provides other contractors with essentially the same advantages. They have a close-in means of disposing of their wastes and save on both transportation costs and dumping fees. The landfill manager also benefits because the elimination of the necessity to handle large pieces of concrete in the landfill avoids considerable problems.

For additional information, see reference 12.

Texas

Fifteen miles of State Highway 36 in Burleson County were reconstructed in 1969. The existing roadway was a lightly reinforced portland cement concrete pavement with an asphaltic concrete overlay. The material was crushed at a central location and used in an asphalt stabilized base course. Heating of the crushed material in the asphalt plant during preparation of the asphalt base material caused air pollution problems, but the material compacted and performed well.

In 1972, a 10-in (250-mm) nonreinforced portland cement section of I-30 east of Greenville was crushed and the material used as aggregate in a flexible base.

Also in 1972, U. S. Highway 54 in District 4 was reconstructed using aggregate obtained from crushing portland cement concrete. Aggregate from this source was used in asphalt concrete surfacing and seal-coat cover stone on the shoulders. The performance of this pavement has been excellent. A second job in District 4 was completed in 1974 on U. S. 60 in West Texas. This involved crushing old pavement with limited reinforcing steel as in the 1972 project. The material was used as aggregate in a dense-graded asphalt concrete surface course. It was also used as cover stone for seal coats. The contractor for the project felt that he not only salvaged a valuable resource but was able to reduce hauling costs and produce an acceptable product at less cost.

District 3 of the Texas Department of Highways & Public Transportation has recycled portland cement concrete building rubble. This crushed material was used to construct a detour. The aggregate for the asphalt stabilized pavement was composed of crushed concrete rubble and field sand. Although the detour was only in temporary use, its performance was satisfactory.

For additional information, see references 13 and 14.

Wisconsin

Wisconsin used recycled material in a project on U. S. Highway No. 2 in Ashland County. The existing pavement, which consisted of paving brick, asphalt concrete, and portland cement concrete, was broken by crane and ball and then crushed. The resulting product was graded and used as a base course.

For additional information, see references 13 and 15.

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Specification 776

IOWA DEPARTMENT OF TRANSPORTATION

Ames, Iowa

SUPPLEMENTAL SPECIFICATIONS
FOR
PORTLAND CEMENT CONCRETE PAVING UTILIZING RECYCLED PAVEMENT

November 12, 1975

THE STANDARD SPECIFICATIONS, SERIES OF 1972, ARE AMENDED BY THE FOLLOWING MODIFICATIONS, ADDITIONS, AND DELETIONS. THESE ARE SUPPLEMENTAL SPECIFICATIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

Section 2301 shall apply with the following modifications:

776.01 DESCRIPTION. Concrete pavement shall consist of a single-course, or a monolithic, composite, two-course, portland cement concrete pavement, as indicated on the plans.

776.02 MATERIALS. All materials shall meet the requirements for the respective items in Part IV of the Standard Specifications, except the aggregate derived from crushing the existing pavement.

776.03 REMOVAL AND CRUSHING. All existing portland cement concrete shall be removed and crushed, except as noted on the plans. All removed and crushed pavement shall be the property of the contracting authority.

A. Where the plans indicate single-course construction, if asphaltic concrete resurfacing is present, the asphaltic concrete shall be removed before the portland cement concrete is crushed, and each shall be crushed separately. It is intended that all of the asphaltic concrete be removed from the portland cement concrete. Isolated areas of adhering asphaltic concrete up to one inch in thickness will be considered acceptable, including patches of asphaltic concrete.

B. Where the plans indicate two-course, composite construction and asphaltic concrete resurfacing is present, the contractor may break and remove the two materials together or separately. Both materials shall be introduced into the crusher at the same time and in the same proportion as they existed in the old pavement. Other means of combining the crushed product of the portland cement concrete and the asphaltic concrete in their original in-place proportions may be used with the approval of the engineer.

C. All reinforcing steel shall be removed from the existing pavement prior to or during the crushing operation and shall be disposed of by the contractor.

D. The contractor shall remove the pavement in a manner which does not develop a large amount of fines in the pavement material and which excludes subgrade and subbase material to the maximum extent practicable.

E. The pavement material shall be crushed to pass a 1½-inch sieve. Processing equipment shall include a screen by which excessive fines in the product can be controlled by removal of fines passing the No. 8 screen. Control will be as directed by the engineer, and his target will be 5 percent passing the No. 200 sieve. Aggregate washing will not be required.

F. Any excess material and fines removed during processing shall be disposed of as shown on the plans.

776.04 CONCRETE MIX PROPORTIONS. The following three (3) mix proportions will be used where indicated on the plans:

<u>Mix A</u>: (35% C.A. - 65% F.A.)

Basic Absolute Volumes:

Cement	.106611
Water	.180769
Air	.060000
Aggregate (crushed p.c. concrete)	.393822
Fine Aggregate (4110)	.258798
	1.000000

Approximate quantities of materials per cubic yard of concrete:

Aggregate (crushed p.c. concrete)	1652 lb.
Fine Aggregate (4110)	1155 lb.
Cement	564 lb. (6 bags)
Water	305 lb.

Design Water/Cement Ratio = 0.54

<u>Mix B</u>: (45% C.A. - 55% F.A.)

Basic Absolute Volumes:

Cement	.106611
Water	.180769
Air	.060000
Aggregate (crushed p.c. concrete)	.506334
Fine Aggregate (4110)	.146277
	1.000000

Approximate quantities of materials per cubic yard of concrete:

Aggregate (crushed p.c. concrete)	2124 lb.
Fine Aggregate (4110)	653 lb.
Cement	564 lb. (6 bags)
Water	305 lb.
Design Water/Cement Patio = 0.54	

Mix C:

Basic Absolute Volumes:

Cement	0.088842
Water	.181327
Air	.060000
Aggregate (crushed p.c. and a.c. concrete)	.669831
	1.000000

Approximate quantities of materials per cubic yard of concrete:

Aggregate	2765 lb.
Cement	470 lb. (5 bags)
Water	306 lb.
Design Water/Cement Ratio = 0.65	

Notes: The above quantities are based on the following assumptions:

Specific gravity of cement	3.14
Specific gravity of fine aggregate (4110)	2.65
Specific gravity of crushed P.C. concrete	2.49
Specific gravity of crushed P.C. and A.C. concrete	2.45
Approximately 42% of the crushed P.C. concrete will pass the No. 4 screen	
Weight of one cu. ft. of water	62.4 lb.

An approved water reducing admixture will be required with each of the above mixes.
Gradation of the crushed material will be evaluated at the time of processing, and changes in proportions may be required.

776.05 EQUIPMENT. Equipment used shall be subject to approval of the engineer and shall comply with the following:

A. Proportioning and Mixing Equipment shall meet the requirements of 2301.06.

B. Placing and Finishing Equipment for the first lift of composite sections shall be capable of spreading the mixture to the full width and depth of the lift and consolidation of the mixture equivalent to that specified for pavement. In addition, equipment may be required that is capable of roughening or scarifying the surface of the first lift of a composite section to a depth of 1 inch. This equipment is subject to approval of the engineer and shall be used as he directs. Placing and finishing equipment for the second lift of composite sections and for single-lift construction shall meet requirements of 2301.07.

776.06 PLACING AND FINISHING. Pavement sections requiring single-lift construction shall be placed, finished, and cured in accordance with requirements of Section 2301.

A. Composite Section. Where indicated on the plans, composite sections shall be placed and finished in accordance with Section 2301 with the following modifications:

Composite sections shall be constructed monolithically. The first lift shall be consolidated by vibration before the second lift is placed.

The surface of the first lift shall have a roughened or scarified finish to facilitate a monolithic bond with the second lift. It is not intended that any hand finishing be performed on the first lift. The surface of the first lift shall not be higher than the design elevation prior to scarifying.

The second lift shall be placed while the first lift is in a plastic condition. The second lift shall be placed, finished, and cured in accordance with Section 2301.

776.07 LIMITATIONS. The pavement may be opened for use in accordance with 2301.36 with both the single-lift sections and the composite sections considered as Class A concrete.

776.08 METHOD OF MEASUREMENT. The single-lift pavement sections will be measured by the engineer in accordance with 2301.39. Composite pavement sections will be measured as follows:

A. The first lift will be measured on a volume basis, in cubic yards, using a count of batches incorporated.

B. The second lift will be measured in accordance with 2301.39.

C. The entire composite section will be considered in the determination of pavement thickness.

D. One core will be taken for approximately each 1000 square yards of composite pavement constructed.

776.09 BASIS OF PAYMENT. Payment for single-lift pavement will be in accordance with 2301.40. Payment for composite pavement will be as follows:

A. Payment for the first lift will be at the contract unit price per cubic yard for the number of cubic yards incorporated, and no payment will be allowed for concrete in excess of the design volume.

B. Payment for the second lift will be in accordance with 2301.40 using only the percentage rates indicated for 6-inch designed depth. These percentage rates will be applied only to the second lift in the composite section.

Measurement and payment for the removal and crushing of old pavement will be as shown on the plans.

Additional coarse aggregate necessary to complete the paving operation, as ordered by the engineer, will be paid for as extra work.

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