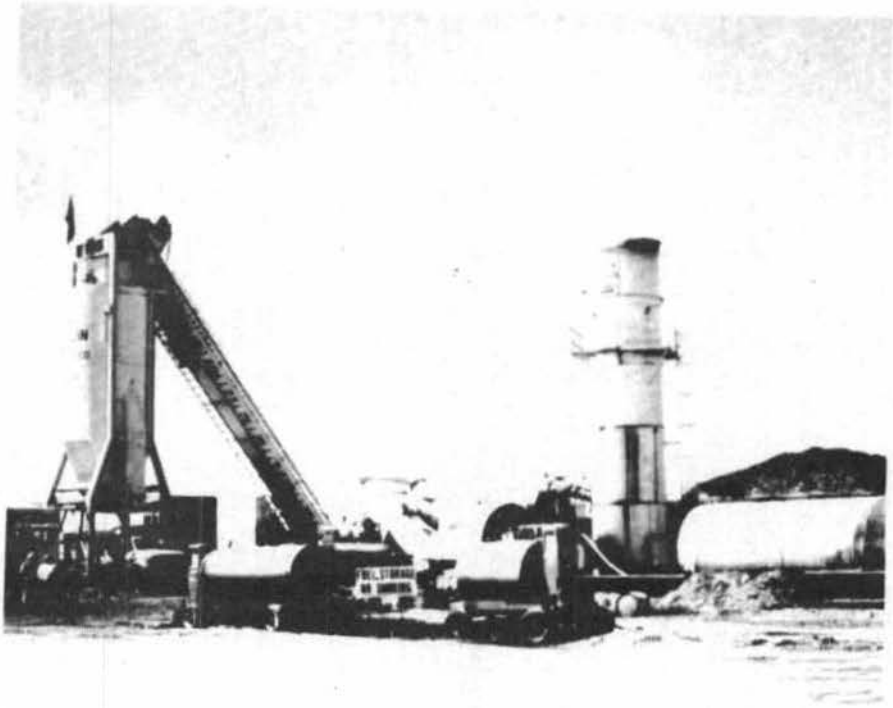
EVALUATION OF
AIR POLLUTION CONTROL DEVICES
FOR
ASPHALT PAVEMENT RECYCLING OPERATIONS



PROGRESS REPORT

FOR

IOWA HIGHWAY RESEARCH BOARD

PROJECT HR-188

Richard P. Henely, P.E.
Kossuth County Engineer
December 1977

HIGHWAY DIVISION

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EVALUATION OF AIR POLLUTION CONTROL DEVICES FOR ASPHALT PAVEMENT RECYCLING OPERATIONS

Prepared For
the
IOWA HIGHWAY RESEARCH BOARD

Submitted By
RICHARD P. HENELY, P.E.
KOSSUTH COUNTY ENGINEER
December, 1977

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Introduction

"Don't waste that old broken-up asphalt pavement!" With the successful conclusion to HR-188, that broken up pavement can now be reused in pavement construction, reconstruction, or on a pavement maintenance operation. By recycling the old pavement both energy and natural resources can be conserved, and most likely pavement construction costs in many cases can be reduced when compared with costs incurred using all virgin aggregates.

Most significant, however, is the fact that a "as good or better" quality product is produced when incorporating a relatively high percentage of recyclable asphalt pavement in the asphalt mix aggregates. The author is convinced that the recycled asphalt pavements are "better" for three reasons: (1) the old asphalt pavement has been completely oxidized due to years of weather exposure, (2) if the shale content of the original aggregates was near the upper limits allowed, the negative affects of shales on pavement life has been neutralized by their residual asphalt content and weather exposure, (3) in future trial design mixes, a better design mix will result because we should be able to control the aggregate gradations in any manner we desire.

Whether some engineers and contractors like it or not, the recycling of asphalt pavements must be considered in future project cost estimates because of the potential savings in costs, which is important, and also the conservation of energy which now a days is of prime importance. It gives the asphalt pavement industry somewhat of an edge over the portland cement concrete pavement advocates because the asphalt pavements are easier to reuse than portland cement concrete. Also, the <u>total energy</u> used in producing an asphalt pavement is considerably less than that absorbed in the production of portland cement pavements.

As inflation continues to rise and our energy sources are depleted, recycling of asphalt pavement will become more and more feasible. The residual asphalt cement in those old asphalt pavements will become "black gold" at such time

in the near future when the price of asphalt cement reaches $150 per ton.

In a report to the Federal Highway Administration relative to Kossuth County's recycling work in 1976, the author reported an energy savings of 14,000 to 15,000 gallons per mile of fuel conserved by complete reconstruction of the old road grade and pavement. Approximately 3,500 gallons per mile of this can be attributed to the asphalt heating, mixing, and paving operation.

As we all know, many rapid changes are taking place in today's world. Highway engineers must now look at those old asphalt pavements as a source of materials - conserve them, salvage them, and recycle them.

Kossuth County Recycling

Asphalt pavement recycling was first thought of in Kossuth County as early as 1970. It was at this time that many miles of Kossuth County's asphalt pavements required extensive patching and overlays to the tune of a one million dollar pavement repair expenditure. This situation resulted from many miles of under designed pavement depth and the fact that many of these pavements had been in use for twenty years. During this period, many tons of broken up asphalt pavement were wasted in erosion washouts, spoil banks, and inactive gravel pits. Today this should be considered extremely wasteful and improper from the environmental standpoint.

In 1973, it was suggested to the author by Charles Foster, then director of Engineering Research for the National Asphalt Pavement Association, that someone should seriously consider developing an experimental asphalt pavement recycling project. Such an opportunity did not properly present itself to Kossuth County until 1975.

Early in 1975 the author, who was also Kossuth County Engineer, and his engineering staff, working with Mr. Foster and the Iowa Department of Transportation developed a proposed asphalt pavement recycling project. The experimental

project was presented to the Iowa Highway Research Board as Project HR-175 in an effort to obtain financial assistance in the construction. The proposed project was approved by the Highway Research Board and the Board agreed to pay one-half the cost of the project up to a limit of $50,000 total contribution.

HR-175, "Recycled Asphalt Pavements, Kossuth County", was not one hundred percent successful. However, enough was learned from the project that Kossuth County was determined to continue experimenting with its recycling efforts.

Some of the items learned from Project HR-175 are as follows:

(1) That the total tonnage constructed in the project, 3,000 tons, was too small an amount to allow the proper amount of experimentation.

(2) That something had to be done to correct the excessive air pollution caused by the burning asphalt in the heating and mixing operation.

(3) That by incorporating 85-100 penetration virgin asphalt cement in the recycled mix, the resulting pavement would be brittle and hard with high viscosity values.

(4) That the recycled mix produced looked very similar to a conventional mix, and that it did have good pavement laying and compaction qualities.

(5) That, with some pavement design adjustments, a good quality pavement could be constructed.

(6) That it would be easier to incorporate a percentage of virgin aggregates with the recycling aggregate in effort to correct the pollution problem.

Encouraged by the results of HR-175 and aware now of some of the problems related to recycling asphalt pavements, Kossuth County programed 16 miles of recycled asphalt pavements and road widening in its 1976 road construction program. Estimated costs for this work totaled $1,100,000 and involved approximately 80,000 tons of recycled asphalt pavement. This work was to be let in three different projects; two of which were three miles in length and the third ten miles long.

The Federal Highway Administration was interested in the ten mile project, SN-1179(6), and contracted with Kossuth County to invest $29,750 toward inspection and pavement testing. The FHWA did require a construction report as part of the contract. This report was written by the author and is entitled "Evaluation of Recycled Asphalt Concrete Pavements" and can be obtained from the FHWA or the Iowa Highway Research Board.

It was during Kossuth County's 1976 preliminary planning of recycling work that the Iowa Department of Environmental Quality was contacted and asked for their input and parameters to legally permit us to further experiment with the recycling work. The Iowa D.E.Q. then aroused the interest of the Federal Environmental Protection Agency to the extent that the Federal E.P.A. agreed to monitor and pay for the air pollution testing costs.

At this juncture in time our efforts to successfully recycle asphalt pavements were somewhat disorganized. While all concerned knew what our final goal was, no one knew how to go about getting the job done. Only one contractor, Everds Brothers, Incorporated, and one equipment manufacturer, Barber-Greene Co., were sincerely interested in doing the work. The Iowa Department of Environmental Quality was unsure of its position in approving a variance or special permit; and, the Iowa D.O.T. and Kossuth County Engineer could not tell any equipment manufacturer or contractor how to proceed with the problem. All that was certain was that we wanted to recycle asphalt pavement without excessive air pollution and with currently existing asphalt plants with economical modifications.

Eventually, the Iowa D.E.Q. did establish some recommendations and parameters whereby they would grant an experimental permit to proceed with Kossuth County's proposed work. These recommendations and parameters are shown in

Exhibit A. The actual experimental permit as finally issued by the Iowa D.E.Q. is shown as Exhibits B and B-2 and spells out what the contractor awarded the projects was to expect.

The main requirement of the Iowa D.E.Q. was that the contractor awarded the work must present an experimental test plan to the D.E.Q. and have it approved before a special experimental permit would be issued. The experimental test plan, (Exhibits C, C-1 and C-2), was submitted by Barber-Green Company acting on behalf of the low bidder, Everds Brothers, Incorporated.

The 80,000 ton project, let in 1976, proved to be too large a volume, within the contract period, to allow the contractor to do much experimenting. On top of that, due to having other contracts, the contractor moved in to do the work well beyond the "critical date" of his contract starting time. During construction, some minor changes were made in the method of operation; but none of these had any significant affect on the pollution problem. The Iowa Department of Environmental Quality, realizing the financial risk the contractor had taken, permitted the work to go to completion; this, even though the best air pollution results obtained were 0.31 grains per dry cubic foot and opacity of about 20 - 30% coming out of the stack.

Several things were learned from the 1976 work which would prove to be useful in future attempts to recycle. These were as follows: (1) That a much smaller, more experimentally controlled project should be proposed, (2) That the recycled pavement should be crushed to a one-inch maximum size if less than a four-inch lift of pavement were to be laid, (3) To assist in controlling air pollution, a higher percentage of virgin aggregates should be incorporated in the mix, (4) That a higher penetration asphalt cement should be added to raise the in-place pavement residual asphalt penetration to the 80-100 area, (5) That more interest and input should be solicited from other equipment manufacturers

and contractors, and (6) That the quality of recycled pavements was still very acceptable.

Not only were the above items learned or verified by the 1976 work, but a vast amount of interest, national and worldwide, was created. This was evidenced by the two days of "open house" at which time visitors from all over the United States and some from foreign countries visited and inspected both the plant and lay-down operations. These open houses were sponsored by the Iowa Department of Transportation and the Federal Highway Administration.

The author, members of the Iowa D.O.T. and FHWA, more equipment manufactures, and additional contractors were convinced that additional recycling work should be attempted as everyone thought we were getting close to solving the pollution problem. Kossuth County was still highly interested from an economical and highway safety standpoint. Many of the county's paved roads were deteriorating rapidly, and the narrow widths of these roads presented a highway safety problem.

Development of HR-188

Encouraged by the limited success obtained in the 1975 and 1976 pavement recycling projects, Kossuth County programmed 58,000 tons of recycled asphalt in 1977. In two years Kossuth County had spent $1,300,000 in its attempt to recycle successfully. This was about 95% of all the monies spent in Iowa on the recycling effort. Other monies contributed were $46,000 by the Iowa Highway Research Board in 1975 and $29,750 by the Federal Highway Administration in 1976.

Speculating that Kossuth County had more than carried its share of the experimental cost, the County Engineer contacted other sources for financial participation. Finally, realizing the inequity of Kossuth County shouldering

all further experimental costs, the Iowa Department of Transportation suggested that the County propose another project to the Iowa Highway Research Board for 1977. Working closely with Bernard Ortgies, C. L. Huisman and Vernon Marks of the Iowa D.O.T., the Kossuth County Engineer compiled a research proposal and presented it to the Iowa Highway Research Board. The proposal entitled "Evaluation of Air Pollution Control Devices for Asphalt Pavement Recycling Operations" was accepted and approved by the Research Board. Thus, HR-188 emerged.

General Project Objectives

Simply stated, the general project objective was to meet or exceed Federal and State air pollution standards while in the process of heating and mixing recyclable asphalt pavements; further, to meet or exceed these standards using inexpensively modified conventional equipment. It is desirable in many cases to reuse old asphalt pavements if project economics dictate that costs are lower and if the pollution problem can be brought within current standards. Generally, the economics of a specific project would not permit a large investment in additional sophisticated equipment.

To accomplish the general and research objectives of the project, emphasis was to be placed on experimentation during construction. It was also anticipated that the Kossuth County Engineer, Iowa Department of Transportation, equipment manufacturers, and the contractor awarded the work would cooperate fully with the Iowa Department of Environmental Quality in monitoring the air pollution aspects of the process.

From experience gained in recycling efforts in 1975 and 1976, several changes were proposed by the Iowa D.O.T. and County Engineer. It was hoped that these changes would assist the contractor in bringing the pollution problem within acceptable standards. These changes were as follows: (1) A

definite effort was to be made to leave as much as possible of the finely graded bituminous treated base on the roadway in the pavement salvaging operation. It was thought that fine material, containing a high concentration of asphalt, might be causing most of the emissions as they burned in the heating of aggregates; (2) The recycled asphalt pavement was to be crushed to a maximum size of one inch and mixed with virgin gravel of a three-quarter inch maximum containing a high percentage of fines. In previous work, when the recycled aggregate was crushed to a two-inch maximum, there was some difficulty in laying the mat in less than four inch thickness; (3) In previous projects a combination of 70% recyclable and 30% virgin aggregate was part of the design mix. Thinking that such a high concentration of recyclable aggregates might be contributing to the pollution problem, it was planned to specify a 50% - 50% combination of aggregates; (4) If pollution standards could not be met with Specifications for Type B, Class II, Asphaltic Concrete requiring a lay-down temperature of 225°F, we would then apply specifications for Bituminous Treated Base requiring a lay-down temperature of 190°F. It was thought that the 35°F lower temperature would help the pollution problem.

Specific Research Objectives

The proposal prepared for consideration by the Iowa Highway Research Board contained four specific research objectives. These specific objectives included: (a) To determine the effectiveness of drum mixing plant modifications designed to control air pollution within limits specified by the Iowa Department of Environmental Quality, (b) To assess the impact of varying the proportions of recycled and virgin aggregates, (c) To assess the impact of varying the production rate of the plant, (d) to assess the impact of varying the mixing temperature.

It was thought that it was not necessary to include asphalt cement content as a variable because it is dependent on the combined material characteristics. Also, that, regardless of the percent of virgin asphalt cement added, such low percentages (3% - 5½%) of asphalt cement added would contribute very little to the heating of the combined material and would not affect the pollution problem.

Proposed Use of Research Funds

To accomplish the project purpose, the contractor would have to invest in special equipment appurtenances, provide operational adjustments and interruptions, and set aside time for experiments and tests. Also, due to the nature of the work and the environmental restrictions, the risk of project cancellation would be significantly increased.

The research funds would therefore be utilized to provide incentives to acquire necessary equipment appurtenances, assume the risks and responsibilities, develop the designs and techniques needed to construct environmentally acceptable asphalt recycling projects, and document the success and failures encountered.

Financial assistance was requested from the Iowa Highway Reseach Board to help reduce, as much as reasonably possible, the element of financial risk which the contractor would be taking when awarded the recycling work. Funds were also sought to cover the expense of Iowa D.O.T. and County testing and inspection and for increased County project mangement. An itemized request for financial assistance was as follows:

(1) Contractor's mobilization cost	$20,000
(2) Cost of air pollution testing	10,000
(3) Cost of Iowa D.O.T. and County inspection	5,000
(4) Increased County project management	5,000
(5) Contractor equipment and operational adjustments	10,000
Total	$50,000

Item one preceding was to be the amount paid to the contractor when his initial appurtenances had been installed and operational at project start-up time. As soon as the County Engineer and Iowa D.E.Q. approved the beginning asphalt plant installation, the contractor was eligible to receive a $20,000 mobilization cost.

Item two was sought to recover the cost of air pollution testing according to the Federal Environmental Protection Agency Method V. It was thought that a minimum of five such tests would be required during construction at a cost of $2,000 each.

Item three was an estimated cost of testing and inspection recoverable by the Iowa D.O.T. and Kossuth County. It was to cover field testing and inspection by the County and the use of the Mason City and Ames Laboratories and personnel.

Item four was sought to cover the increased County project management expenses associated with monitoring and documenting equipment designs, process techniques, and production operations.

Item five was asked for to help cover the potential down-time loss of the contractor due to shut-downs for equipment or operational changes. It was calculated that five possible shut-downs would occur at $2,000 per shut-down.

Project Location and Description

Kossuth County project designation LRS-575 was proposed as Iowa Highway Research Board Project HR-188. It consisted of the construction of 2.11 miles of new recycled asphalt pavement. The project connected two North and South pavements and would serve a Kossuth County Conservation Board recreation park and handle an excess of 500 ADT on weekends.

The project was located one-quarter mile South of Whittemore, Iowa as indicated on Exhibit D.

Construction was to consist of seven inches of recycled asphalt pavement twenty-two feet wide. The recycled pavement, involving about 10,000 tons, was to be placed on the existing gravel-clay calcium-treated surface. The existing road had been graded for pavement in 1968 and met all current design standards.

It was planned to use 50% recycled pavement and 50% virgin 3/4 inch crushed gravel from a County owned gravel pit located in Section 11-95-29. This gravel pit was also to be used as the asphalt plant location and was furnished by the County. The average truck haul to LRS-575 was 15 miles.

The recycled asphalt pavement material was to be obtained by salvaging old asphalt pavement from three projects which were planned for repaving in 1978. These projects were let early in 1977. They involved salvaging the old pavement as well as widening the roadway while the pavement was removed. Separate contracts were awarded for: (1) salvaging and widening, (2) crushing both virgin and recycled aggregate, (3) the recycled paving.

Project Planning Conference

A project planning and organization meeting was held March 8, 1977, at the Central Materials Laboratory Building in the Iowa Department of Transportation Compound, Ames, Iowa. At this meeting, full cooperation in finding a solution to the pollution problem was assured by all those in attendence. Represented at the meeting were personnel of the Iowa Department of Environmental Quality, the Iowa Department of Transportation, the Kossuth County Engineer's Office, three asphalt paving contractors including Everds Brothers, Inc., Rohlin Construction Company and Komatz

Construction, as well as two equipment manufacturers, Barber-Greene Company and Iowa Manufacturing Company. At a later date, The Boeing Company, manufacturer of drum mixers, became highly interested in this work. Each individual attending the meeting had some input into the proposed project.

The most significant part of this meeting was that the Department of Environmental Quality established definite parameters and goals by which its department would cooperate fully. The Iowa D.E.Q. specified that the following conditions be met if its cooperation was expected.

(1) A project of 10,000 to 20,000 tons would be proposed for experimentation.

(2) Before a bid proposal was issued to a prospective bidder, each bidder or his equipment representative would submit to the D.E.Q. a satisfactory plan for controlling pollution.

(3) The maximum allowable particulate concentration in grains per dry standard cubic foot (grains/scf) would be 0.15 for existing source standards and 0.04 for new source standards. Existing source standards were applicable to any existing or old asphalt plants whereas, new source standards applied to new asphalt plants which had not previously been checked for pollution.

(4) They agreed to monitor pollution testing to be sure such testing was done correctly and to D.E.Q. standards.

As a result of this meeting, everyone in attendence knew what to expect from the D.E.Q. and were aware of how far the D.E.Q. would go before stopping further progress on the project.

During the course of the meeting, the Iowa Department of Transportation volunteered the services and personnel of both the Central Office Laboratory in Ames and the District Two Laboratory in Mason City. These tests included laboratory density tests, asphalt content, residual asphalt penetration, stability and viscosity tests, pavement design mixes, and in-place pavement tests. In addition, one Iowa D.O.T. employee was to be available at all times

during construction to give advice and monitor project progress. This position was eventually handled by Bernard Ortgies.

The Kossuth County Engineer was responsible for preparing project plans and specifications, performing all field construction staking, inspection, field testing, and developing a final construction report on all aspects of the project.

The real purpose of the meeting was to explain to the contractors and equipment manufacturers the experimental nature of the project and to make certain that such things as D.E.Q. involvement, mobilization and shut-down payments, and pollution testing payments were clearly understood. This was a highly productive planning meeting and it contributed considerably to the eventual success of the project.

Plan Development

Immediately after the project planning conference, the Kossuth County Engineer and his staff began to develop plans and specifications for the proposed recycling work. Kossuth County had actually programmed four recycling projects involving a total of 40,000 tons of asphalt paving. Because of the Iowa D.E.Q.'s request that a 10,000 to 20,000 ton project be considered for experimentation purposes, the 10,270 ton Project LRS-575 (HR-188) was chosen as the primary experimental project, and Project LFM--1142 involving 8850 tons was selected as a secondary experimental project.

It was decided to let the other two paving projects, LRS-329 and LRS-507 involving a total of 23,735 tons, as Type B, Class II, Asphaltic Concrete using all virgin aggregates. It was planned that the latter two projects would be changed to recycled asphalt resurfacing if the two experimental projects proved successful and if the prices bid for recycled asphalt were lower than the conventional mix.

Hoping to obtain vigorous and competitive bidding on these projects, all elements not related to the actual paving operation were eliminated from the paving project letting. By furnishing the plant site area and all crushed aggregates in stockpiles at the plant site, no subcontract by the prime paving contractor was necessary.

A project quantity sheet, typical cross-section, notes, footnotes, and project special specifications and provisions are shown as Exhibit E for the primary experimental project LRS-575 (HR-188). A detailed examination of Exhibit E will reveal quite clearly how the project was to be done and what was expected of the contractor and/or his equipment representative.

To make provision for further experimentation, Kossuth County Project LFM-1142 was tied in the bidding procedure to LRS-575. You will note in Exhibit F that award of this contract as a recycled asphalt pavement resurfacing project was contingent upon the success obtained in controlling air pollution on project LRS-575. Letting these two projects tied together, as was done, permitted the possibility of experimenting with a total of slightly over 19,000 tons of recycled pavement.

Bid Letting

Prior to being issued bid proposals, three contractors and their equipment representatives submitted air pollution control plans to the Iowa Department of Environmental Quality to qualify for bidding. The plans approved by the D.E.Q. were submitted by the following three consortiums: (1) Everds Brothers, Inc. and Barber-Green Co., (2) Rohlin Construction Co. and Iowa Manufacturing Co., (3) Komatz Construction Co. and the Boeing Company.

Bids were let by the Iowa Department of Transportation on June 21, 1977. Project completion date was set as of October 1, 1977.

At the time of bidding, only two bids were received on the work. Because of other contract commitments, the most experienced contractor of the three who were qualified did not submit a bid on this work. This fact was somewhat regrettable because to that date, Everds Brothers, Inc. and Barber-Greene Company had considerable financial investment in the recycling process.

A table of bids received and the engineer's estimate for Projects LRS-575 and LFM-1142 are shown in Exhibits G and G-1. As anyone can see by these exhibits, the engineer's estimate was very optimistic with relation to the actual bids. But, we must still remember that these projects had a "high risk" nature to them, and perhaps the bidders were making certain that they had an adequate safety factor in their bids.

Contracts for the two experimental recycling projects and the two other projects involving all virgin aggregates were awarded by the Kossuth County Board of Supervisors to the Rohlin Construction Company of Estherville, Iowa on June 29, 1977.

Asphalt Plant Configuration

Exhibit H is a schematic diagram of the plant set-up as proposed to Rohlin Construction by the Iowa Manufacturing Company. The one major difference in the schematic and the actual plant configuration was that the location of the virgin and recycled aggregates were in reversed positions. From the diagram it can be seen that the virgin aggregates are conveyed to the smaller inner drum mixer. Also, it can be seen that the recycled aggregate is conveyed to the larger outer drum mixer.

The virgin aggregate is exposed to the open burner flame and then the virgin aggregate is spilled out into the outer drum where it mixes with the recycled aggregate. Hot asphalt cement is injected into the mix about one-half way down the larger outer drum. The remaining half of the outer drum completes

the mixing operation of the recycled mix.

The exhaust gases from the heating operation proceed from the smoke box into the wet collector. These gases must pass through a water spray before entering the adjustable venturi mounted inside the collector. The spiraling airflow in the collector removes the water droplets from the airstream. The water is then cycled through a portable settling tank.

The gases proceed through two fans in series into a duct type adjustable venturi. Nozzles spray water into the inlet of the venturi section. The particulate and water are mixed together in the turbulent airstream caused by the restricted venturi throat area.

The duct venturi discharged into a ten-foot diamter exhaust stack. The slow velocity upward in the stack allows the water droplets to fall out of the airstream in the stack and drop to the bottom of the stack. The stack drain then extends out into the settling pond. (The preceding three paragraphs apply to the air pollution control features of this operation.)

After the recycled asphalt mix has completed the mixing cycle, it is conveyed to a storage silo. After being loaded into trucks, it is weighed and hauled to the paving site. It is well to mention at this point that the pavement lay-down operation was a conventional or normal process.

Actual Plant Operation

Rohlin Construction Company was ready to start production of recycled asphalt pavement material the afternoon of July 21, 1977, on Project LRS-575 (HR-188). At first, start-up stack emmissions were of sufficient amounts that it was necessary to shut-down after producing only 162 tons or approximately after one-half hour of operation. Plant adjustments were made the remainder of that day and continued on July 22nd when only 814 tons were produced.

Actually, from the very beginning it was quite evident that the recycling operation was going to be a success. The operation required very minor adjustments which the Iowa Manufacturing Company Engineers had anticipated might be necessary. Within the first 1,000 tons of material produced using 50-50 aggregates, the plant was operating nearly pollution free. And, at the same time, producing what appeared to be a highly acceptable product.

The plant began immediately to produce 300 tons per hour at a mix temperature of 250-260°F. The inner drum mixer (150 tons/hour) was being fed virgin aggregates at its maximum rate while the outer drum was being fed another 150 tons per hour. These two drums were attached together and rotated at the same rate of speed. The inner drum was 64 inches in diameter and 16 feet in length. It extended into the outer drum about one half of its length or eight feet. The recycled aggregates spilled onto the hot inner drum and were heated without being exposed to the open flame. Once past the outlet of the inner drum, the recycled aggregates were mixed and heated with the virgin aggregates. As mentioned previously, asphalt cement was injected into the combined aggregates about one-half way down the outer drum.

Why This Method is Successful

This process of controlling the air pollution problem caused by recycling old asphalt pavement is successful because it employs the basic principle of a drum mixer. That principle being never to expose the asphalt cement to an open flame. In the mixing operation and by proper flight arrangement of blades inside the drum, a protective veil of aggregates is established which protects the asphalt cement from the open burner flame.

Iowa Manufacturing Engineers were intelligent enough to adapt this principle to a recycling process. By applying heat and open flame to the virgin aggregates in the inner drum and maintaining a proper protective veil within the inner drum,

the recycled aggregates were never exposed to an open flame. As long as this protective veil was maintained in the inner drum, requiring the inner drum to operate at maximum capacity, there was no visible pollution problem. However, if the 150 tons per hour maximum capacity of the inner drum was not maintained, a dirty or polluted stack was immediately visible.

The process involves keeping the recycled aggregates from being exposed to an open flame and at the same time being heated by a transfer of heat from the sides of the inner drum and the hot virgin aggregates.

Probable Process Limitations

The process as employed on LRS-575 (HR-188) and other Kossuth County projects will never permit employing 100% recycled aggregates in the mixing operation. Some amount of veil in the inner drum must be maintained to protect the recycled aggregates. Generally, this should not be a problem because, in most cases, a certain percentage of virgin aggregates should be added to the design mix to arrive at a well graded pavement mix.

With this plant configuration, we know that we can recycle a 50-50 aggregate mix and a 65-35 aggregate mix successfully and maintain required pavement lay-down temperatures. On the basis of what we now know, I suspect that if a higher percentage of recycled aggregates are incorporated (75%-25%), then the heat transfer will not be adequate to maintain standard lay-down temperatures. This can probably be accepted if specifications for bituminous treated base are specified which require a $35^{o}F$ lower lay-down temperature. Certainly this could be used in constructing lower base courses.

From a practical standpoint, using the equipment employed on these projects, due to the heat transfer problem on the higher production rate and maintaining the protective veil on the lower production rate, we are probably limited to production rates between 250 to 400 tons per hour.

Pollution Results

It was required in the contract documents, that the contractor awarded the work would arrange and pay for a qualified air pollution testing organization approved by the D.E.Q. to do the testing. The Iowa D.E.Q. had agreed to have a representative present during the testing to monitor and approve testing procedures. Also, in the contract documents, it was specified that the prime contractor would be reimbursed by the contracting authority at the rate of $2,000 for each E.P.A. Method V Pollution Test. Rohlin Construction Company employed its equipment manufacture, Iowa Manufacturing Company, to perform the pollution tests with the approval of the Iowa D.E.Q.

After producing less than 2,000 tons of recycled mix, it was visually ascertainable that the emissions would at least meet or exceed required standards. At the outset, the Iowa D.E.Q. was very happy with the stack appearance and its negligible effect downwind.

It requires six hours of steady plant operations to perform an E.P.A. Method V Emission Test. This is true if both the existing source and new source emission results are to be determined. The new source standard is a Federal E.P.A. requirement and is established as 0.04 grains per dry cubic foot as the allowable limit. The existing source standard was an Iowa D.E.Q. requirement and had, as its upper limit, 0.15 grains per dry cubic foot.

On July 25 and 26, 1977, one complete pollution test was run while the plant was mixing 50% recycled and 50% virgin aggregates. Test results show (Exhibit I) an average of 0.0817 grains per dry cubic foot, more than meeting the existing source standard of 0.15. It also indicates an average of 0.0129 on the new source standard - easily meeting the standard of 0.04. After this test run, the asphalt plant was fully approved to produce recycled mix using 50% recycled aggregates. No more tests involving this combination of aggregates were necessary.

On August 4 and 5, 1977, another complete test was run while the plant was mixing 65% recycled aggregates and 35% virgin aggregates. Exhibit I-1 shows the results of this test. It indicates an average of 0.081 for the existing source and 0.0244 for the new source standards. With the completion of this test run, the plant was approved to produce recycled asphalt mix with 65-35 aggregates.

Cost of these tests, as invoiced by Iowa Manufacturing to Rohlin Construction Company, were $4,670 and $2,500 respectively. The cost differential in the two tests results mostly from the expense incurred by a Pretest Consultation Conference which amounted to $1,520.

Production rates while using a 50-50% combination of aggregates averaged 277 tons per hour. When 65-35% aggregates were mixed, the production rate was 349 tons per hour. You will note here that, when the percentage of recycled aggregates was increased, the production rate was increased. This was because the protective veil had to be maintained by the inner drum, and yet the inner drum had to transfer enough heat to maintain pavement lay-down temperatures. Theoretically, when mixing 65%-35%, the production rate should have been 429 tons per hour; but, lay down mix temperatures could not be maintained at this rate of production.

Though the project was geared to allow for five pollution tests, only two were necessary to satisfy the Iowa D.E.Q.

Recycled Pavement Test Results

The recycled asphalt pavement mix looked "as good" or "better" than a conventional mix. The pavement lay down and compaction characteristics were good to excellent. Field densities of 94% Marshall were obtained easily. Minor density problem occurred on only two days of operation; but, after re-rolling the following day, were brought up to specifications.

Exhibit J shows the project asphaltic concrete design mix for a combined recycled and virgin aggregate of 50-50. This design mix indicates that the final asphalt cement content of the pavement should be nine (9) percent. Further, it recommends that five and one-half (5½) percent asphalt cement should be added to the combined 50-50 aggregates. This indicates that the salvaged pavement contained seven (7) percent of re-usable asphalt. Such a high final asphalt cement content is due to the fact that the combined aggregates contained a high percentage of fine material. The fine material was present because the salvaged pavement was partly bituminous treated base with a very high percentage of fines. On a recycling project consisting entirely of a higher type of asphalt pavement, the amount of asphalt cement required in a design mix should be much less because the percentage of fines in the combined aggregates would be lower.

Exhibit K shows the characteristics and quality of the "in-place" pavement as it was tested in both the Mason City and Ames laboratories. It should be noted that the residual asphalt penetration and viscosities are in a range which would keep the pavement from becoming hard and brittle and from "rutting" under heavy wheel loads.

The results, using a combined aggregate of 65% recycled and 35% virgin were similiar to those shown in Exhibit K. There are two basic differences which should be considered when the percentage of recycled material is increased. These are:

(1) The amount of asphalt cement added as the percentage of recycled aggregate is increased should be reduced about one percent for every ten percent the recycled aggregates were increased.

(2) As the percentage of recycled aggregates is increased, the asphalt cement penetration employed should be higher, possibly in the 300-500 area, if the recycled pavement is to be soft and not "rut".

With proper pavement salvaging procedures during construction and intelligent laboratory investigation, a good quality recycled asphalt pavement can be constructed.

Cost - Virgin Vs. Recycled

There was a substantial savings realized when Kossuth County Project LRS-507 and LRS-329 were changed from a conventional mix to a recycled mix using combined 50% recycled and 50% virgin aggregates.

Further investigation shows that the salvaged pavement (recycled aggregate) was salvaged, hauled, stockpiled, crushed and re-stockpiled at a cost of $1.91 per ton. When using a 50-50 aggregate, this meant that the recycled aggregate contributed $0.96 to the cost of each ton of mix. Cost of the virgin aggregate, likewise, contributed $0.41 per ton of mix. This resulted in a total aggregate cost of $1.37 per ton of mix. However, the combined aggregate did contain 3½ percent asphalt cement, which, at $78.50 per ton, resulted in a $2.75 value in each ton of combined aggregate incorporated.

Exhibit L shows a better breakdown of costs comparing 50-50 recycled asphalt pavement with the contracts let for Type B Class I asphalt concrete. Some quick mathematics will show, when asphalt cement costs $78.50 per ton, that a savings of one percent of asphalt cement in a ton of mix means a savings of $0.785 per ton of mix produced. As the price of asphalt cement increases, as it surely will, this cost savings can be increased dramatically.

In Exhibit M, you will note that there was an asphalt cement over-run on project LRS-575 and LFM-1142 which were let as recycled base. This was due almost entirely to the fact that the project pavement design mix called for a higher asphalt cement content than was estimated in the planning stage.

Exhibit N shows a revealing indication of the amount of money that can possibly be saved when a recycled aggregate mix is used rather than a conventional mix. Even though the savings is substantial from the picture drawn in Exhibit N, the author has reason to believe that the price bid for recycled

asphalt on these projects could have been $0.20 to $0.30 per ton lower. This statement is based on the fact that Type B Class I Asphaltic Concrete required 30% limestone aggregates at about $4.00 per ton. By eliminating 30% limestone aggregates, it would lower the Type B Class I unit price to ($6.99 - $1.20) $5.77 per ton. However, the 30% limestone would have to be replaced with 15% recycled aggregates and 15% virgin aggregates. This would bring the unit price bid back up to ($5.77 + $0.41) $6.18 per ton.

Summary

Iowa Highway Research Board Project HR-188 and all other companion Kossuth County asphalt pavement recycling projects were highly successful. In the author's rather lengthy career, he has never been associated with work that was laid out on paper, as this work was, and then have the work proceed and done precisely as predicted with little or no changes. Not a single problem was encountered on any of this work.

Today, we can safely plan and let asphalt pavement recycling without fear of pollution regulations. Additional strides and improvements are being made in this field everyday. By the 1978 construction season, the author is quite certain that additional equipment manufacturers will have developed procedures by which pollution standards can be met.

One of the next steps in pollution treatment will be the use of the "bag-house" pollution control unit rather than the "wet scrubber" type. Water will not always be available as it was in this work to permit the use of the wet scrubber. From the appearance and results of the stack emissions on this work, it looks as though applying the "bag-house" will be a routine matter.

During construction only two pollution tests were required by the Iowa Department of Environmental Quality. Both far exceeded the established standards for both the 50-50% and 65-35% combined aggregates.

Production time was lost on only two occasions. Once at the very beginning of the work when the plant pollution equipment was fine tuned and once later when the combined aggregates were changed from 50-50 to 65-35 mixture. For these shut-downs or time losses, the contractor was paid $2,000.00 each. This was money well and economically spent on the project.

Gentlemen, today recycling asphalt pavements is not a speculative proposition. It is a going fact. Though the method of pollution control employed on these projects is probably patented, other manufacturers were close to solving the problem. As additional pollution control devices are developed, the equipment investment should be lower. Thus, bidding competition should be keener and prices lower.

Acknowledgments

The Rohlin Construction Company, working closely with Iowa Manufacturing Company, should be highly complimented for the job they have done. Iowa Manufacturing, in particular, should be proud of its Engineering Staff with their ingenuity used in solving this problem. As one can see in Exhibit O, a drawing of the inner and outer drum configuration, the solution to the problem was very simple. Iowa Manufacturing should be further complimented for making this equipment modification available to contractors in a "kit" form. This should further open up bidding competition.

The author would like to thank the Iowa Highway Research Board, the Iowa Deparment of Transportation, the Federal Highway Authority, the Iowa Department of Environmental Quality, the Federal Environmental Protection Agency and all the contractors and equipment manufacturers who contributed to the solution of this problem. Appreciation is also extended to Mr. Bernhard Ortgies, Charles Huisman and Lowell Zearley of the Iowa D.O.T. who assisted in the development of the project and provided technical assistance during the project.

EXHIBITS

EXHIBIT A

STATE OF IOWA
DEPARTMENT OF ENVIRONMENTAL QUALITY
DES MOINES, IOWA 50316

MEMORANDUM

To: R. A. Walker Date: January 19, 1976

From: Leo Classen, P.E.
Permits Section Re: Recycling Asphalt
Kossuth County

After reviewing Mr. Henely's letter of December 16, 1975, we offer the following comments.

1. We fully endorse the concept and offer our cooperation in solving the problem of meeting air pollution control regulations.

2. Our observations of the experimental run last September as discussed in Mr. Woll's report of September 30, 1975, and Mr. Walker's letter of December 10, 1975, point out that the process used at that time would not meet our existing regulations.

3. We can not offer a solution to the problem but will outline our recommendations for any future experiment.

4. We believe the observed emissions consisted of a high percentage of small particles one micron or less in size. In order to remove an acceptable percentage of these particles, a medium energy scrubber will be required.

5. We have calculated various venturi configurations and believe that the minimum parameters for the removal of particles in the one micron range are:

    a. A throat velocity of 200 feet per second.
    b. Water injection rates from 8 to 10 GPM per 1000 CFM
    c. An air pressure drop through the venturi in the 20 to 25 inch water gauge range.

6. Other types of scrubbers with efficiencies above 95% may be a possible substitute for a venturi. We do not believe fabric filtration or dry collection devices can be used because the asphalt-coated particles would blank-off or clog these devices in a short time.

7. We will evaluate any proposed control device but will not issue a permit other than an experimental permit with the condition that a stack test be made within two weeks of startup.

8. Any contractor who is awarded this contract should be advised of the construction permit requirements and informed to contact us as early as possible on any permit questions.

LC:mah

EXHIBIT B

iowa department of environmental quality

PERMIT TO INSTALL OR ALTER EQUIPMENT OR CONTROL EQUIPMENT

Permit No. 76-A-257
Plant No. 55-01-005B
Project No. 76-231

ISSUED TO:

FIRM NAME Everds Brothers, Inc. Attention: Doug Meyer

MAILING ADDRESS P. O. Box 520, Algona, IA 50511

EQUIPMENT LOCATION ADDRESS Kossuth County

CITY Titonka STATE Iowa ZIP 50480

PROCESS OR SOURCE INFORMATION:

TYPE Barber-Greene Asphaltic Concrete (Turbulent Mass)

MAKE AND MODEL DM-70

AIR FLOW RATE (SCFM) 70,000 CAPACITY To Be Determined After Start-up

CONTROL EQUIPMENT INFORMATION:

TYPE Variable Venturi EFFICIENCY 97.5% (Est.)

MAKE AND MODEL Barber-Greene (Throat area between 1 ft^2 and 10 ft^2)

This equipment has been evaluated for conformance with the emission standard(s) specified in rule(s) 4.4(2) & 4.3(2)d of the Iowa Air Quality Commission. A new permit required for additional or replacement equipment if field tests after installation show that the unit will not meet the specified emission standard(s).

This permit becomes void if construction is not started before August 30, 1976, and is issued subject to the standard conditions listed on the reverse side of this permit and as follows:

7. This permit is issued in accordance with the agreement that a condition of experimentation, development, and adjustment exists. The completed system shall conform to the specified emission standards.
8. Emission tests shall be performed in a manner acceptable to the State within the first 150 hours of plant operation. Plant output capacity (tons per hour of finished product) as well as a percentage breakdown of the inlet feed material shall be monitored during the tests. The Department shall be notified when 75 hours of plant operation have elapsed.
9. A copy of detailed drawings showing all modifications finally performed on the plant will be submitted to this Department. All changes to the drawings under which this permit is issued shall be noted.
10. A differential pressure sensing device to monitor the differential pressure of the venturi shall be permanently installed.

Under direction of the Executive Director
AIR QUALITY MANAGEMENT DIVISION

Leo Classen

Date July 30, 1976

Leo Classen, P.E.
Permits Section

LC:RLK:jlw

3920 Delaware Ave., P.O. Box 3326, Des Moines, Iowa 50316 • 515/265-8134

AQIT 1/30/76

STANDARD CONDITIONS

1. This permit is issued based upon the information submitted by the applicant on the Application for Permit. Any mis-information, false statement, or misrepresentation in the Application for Permit shall cause this permit to become void.

2. This permit implies no review of various engineering aspects of this installation other than the potential of the equipment involved for reducing emissions. This agency assumes no liability, directly or indirectly, for any loss due to damage to persons or property caused by, resulting from, or arising out of the design, installation, maintenance, or operation of the proposed equipment.

3. This Department shall be provided appropriate notice at least ten (10) days before the system is placed in operation.

4. Ultimate disposal of the air contaminant(s) collected by the control equipment shall meet all applicable rules administered by the Iowa Department of Environmental Quality.

5. If requested, a test shall be conducted demonstrating compliance at the expense of the owner. The test shall be in full compliance with Subsection 7.1(1) and 7.1(3) of the rules and a copy of the stack emission tests shall be forwarded to this office.

6. This permit is issued on the basis that the owner has the responsibility for assuring that the construction will conform with that shown on the plans and specifications, and that adequate operation and maintenance will be provided to the facilities installed such that no condition of air pollution will be created. The issuing of this permit in no way relieves the owner of responsibility for compliance with all local, state, and federal laws, ordinances, regulations, or other requirements applying to this installation. A copy of this permit shall be kept on the plant site.

ADDITIONAL CONDITIONS

11. A device to monitor the water flow rate to the venturi shall be in operation for the duration of the recycling project in Kossuth County, DOT Project #SN-1179(6).
12. This permit suspends Permit No. 72-A-103S for the duration of this recycling project in Kossuth County, DOT Project #SN-1179(6).
13. Should a variance be granted for this project by the Air Quality Commission, additional conditions to this permit may be added pertaining to emission testing.

PAVEMENT RECYCLING AND EMISSIONS CONTROL PROJECT
FOR VERDS BROS., DM-70, ALGONA, IOWA

EXHIBIT C

TEST PLAN (& SCHEDULE)

1. Install new equipment with plant setup. (8-9 to 8-24)
   a. New fan
   b. New venturi contactor
   c. Relocate asphalt pipe (@ 21')
   d. 14 ft. combustion chamber - seal to breeching
   e. New (larger) water pump
   f. Scaffolding for emissions tests, and test ports
   g. "Egg crate" air-flow straightener in separator.
   h. Heat radiation shield
   j. Drum @ 2° slope ($\frac{13}{32}$ - $\frac{7}{16}$" per ft.)

2. Set up Mobile Lab and instrumentation. (8-16 to 8-24)
   a. Temperature recorder and thermocouples

1) mix	5) TPH (Ramsey)	9) Silo
2) Stack A	6) Ambient (case)	10) Cold feed
3) Water in	7) Stack out	11) Outside ambient
4) Water out	8) Stack B	12) (Open)

   b. Water meter and pressure gauge.
   c. H.C. analyzer
   d. Static pressure ports
   e. Exhaust gas sample tube
   f. SO_2 analyzer (?)
   g. Fuel meter

3. Preliminary (8-25 to 8-28)
   a. Change burner to 110,000,000 BTU/hr. max.
   b. Cure new combustion chamber
   c. Test operation of instrumentation (during cure period)
   d. Calibrate feeders and Ramsey weigh belt
   e. Adjust to initial operating conditions

4. Initial start-up conditions

   a. Use max. (14 ft.) combustion chamber length

   b. Set drum @ 2^{o} slope for max. veil.

   c. 135 TPH, 600% excess air, 15" D.P. on fan, 90,000 CFM, 760^{o} flame temp.

   d. 100% recycled material

5. Initial tests

   a. Visual - opacity

   b. Exhaust (inside drum) % O_2, % CO_2

   c. Exhaust % HC

   d. Record all rates - TPH, water in, CFM, static pressures and diff. press. at all points and all temp.

   e. Sample scrubber water in and out for particulate

   f. Sample stack for particulate

   g. Sample cold feed

   h. Sample discharge (hot mix)

6. Modifications

   a. If stack too dark, reduce TPH, increase excess air. Possibly hold TPH and increase air by reducing fan D.P.

   b. If stack okay, increase TPH and decrease excess air.

   c. Repeat tests of step 5, then repeat 6.

   d. Other parameters to be evaluated later.

      1) Venturi pressure drop

      2) Add new material

      3) Percent excess air

      4) Shroud around combustion chamber (to preheat excess air)

      5) Combustion chamber length

      6) Asphalt injection point

      7) Drum slope

      8) Flights

      9) Effect of water spray (if needed)

EFFECT OF EXCESS AIR

EXCESS AIR	GAS TEMP.	MAX. EFF. 350° EXH.	EST. OVERALL EFF.	GROSS HEAT 10^6 BTU/HR.	FUEL GPH	CFM AIR IN @ 60°	CFM OUT PROD.COMB. @ 350°
50%	2700°	82%	70%	21.4	160	5400	10,300
100	2200	80	68	22.1	163	7400	13,400
200	1600	75	63	23.8	176	11900	20,700
300	1220	70	58	25.9	192	17200	29,200
400	1020	65	53	28.3	210	23600	39,300
500	880	59	47	31.9	236	31900	52,600
600	760	54	43	34.9	258	40700	66,500
800	620	44	33	45.5	337	68200	110,300
1000	520	34	24	62.5	463	114600	184,100

ASSUME: 100 TPH @ 3% H_2O
350° exhaust temp.
#2 oil @ 135,000 BTU/Gal.
1350 cu. ft. air/gal. oil
1820 cu. ft./gal. prod. comb.

NOTE:--

a. 100 TPH @ 3% H_2O, 275° mix and 350° exhaust will require net heat approx. 15 x 10^6 BTU/hr.

b. Water spray is not really practical for cooling the gas. It cools more effectively than excess air, but the air is needed as a heat trasfer medium.

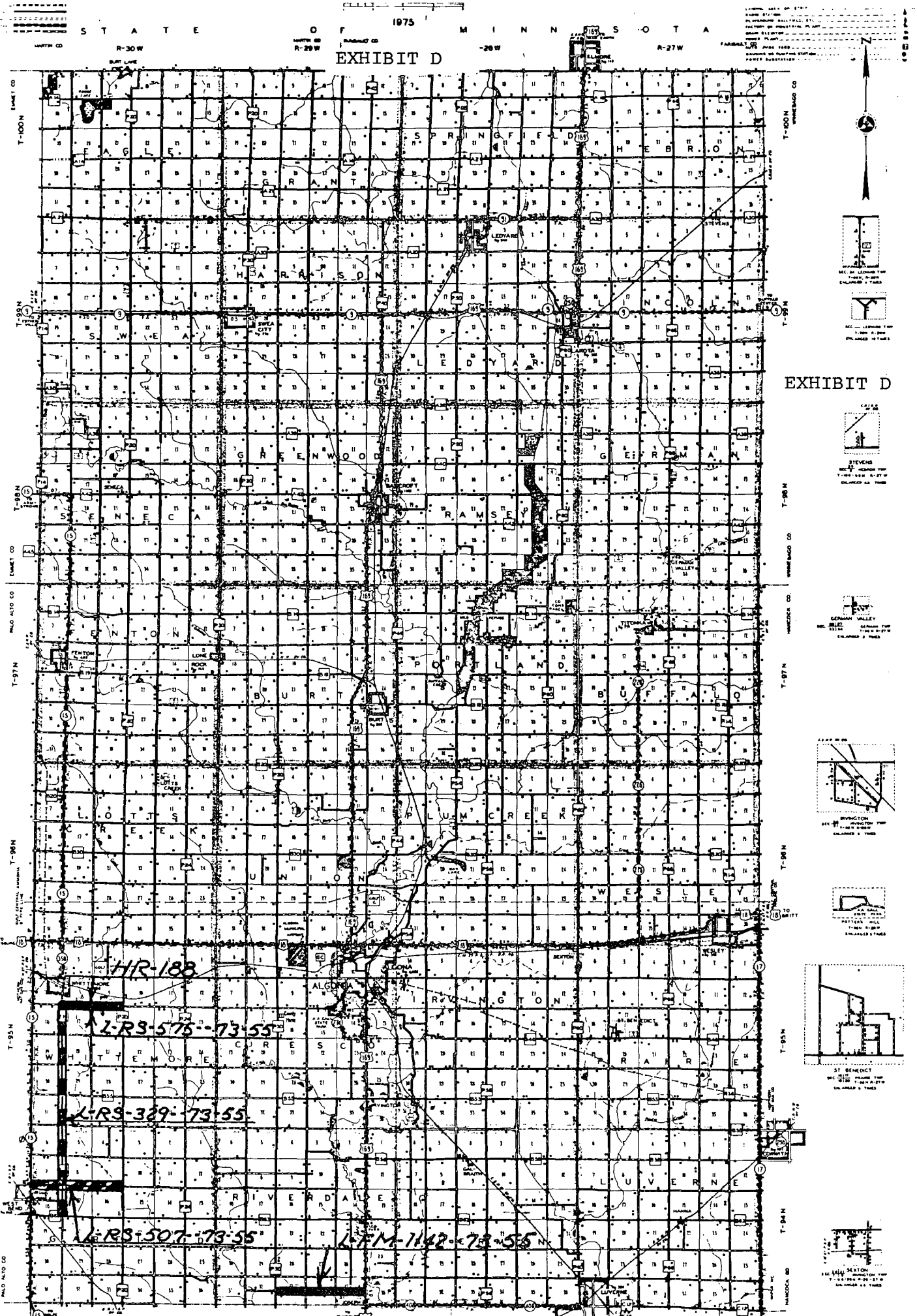
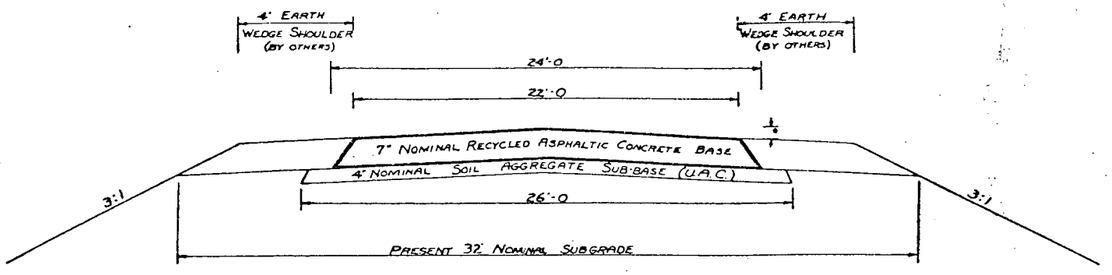


EXHIBIT D
EXHIBIT D
HR-188
L-RS-575-73-55
L-RS-329-73-55
L-RS-507-73-55
L-FM-1142-C-73-55

STA. 100+11 TO STA. 204+95.6



*THE MAXIMUM ALLOWABLE SLOPE IS 3.0% AND THE MINIMUM ALLOWABLE SLOPE IS 1.5%. SECTIONS MAY BE MODIFIED AS DIRECTED BY THE ENGINEER THROUGH AREAS OF SPECIAL SHAPING.

THE PLANT SITE WILL BE LOCATED IN THE N.W.¼ SECTION 11-94-29 ON PROPERTY OWNED BY KOSSUTH COUNTY. THE CONTRACTOR SHALL HAVE FULL USE OF THIS LOCATION DURING CONSTRUCTION AT NO COST.

CONTRACTOR WILL CONSTRUCT A 7" RECYCLED ASPHALTIC CONCRETE BASE USING A MIXTURE OF RECYCLABLE ASPHALT MATERIAL, ADDED ASPHALT CEMENT AND CRUSHED GRAVEL AGGREGATES AS DETERMINED BY JOB MIX. SECTION 2202, 1972 STANDARD SPECIFICATIONS, SHALL APPLY AMENDED AS FOLLOWS:

1. IN ANY SECTION WHERE ASPHALT TREATED BASE APPEARS, IT WILL BE ASSUMED TO READ "RECYCLED CONCRETE BASE.
2. DELETE SECTION 2202.02B AND INSERT IN ITS PLACE--THE MINERAL AGGREGATE USED WILL BE THE SALVAGED ASPHALT PAVEMENT MATERIAL, WITH OR WITHOUT VIRGIN AGGREGATES, CRUSHED OR PULVERIZED SO THAT ALL PARTICLES PASS A 1" SEIVE. THERE WILL BE NO OTHER GRADATION SPECIFICATIONS OR REQUIREMENTS. THE BEST GENERAL PRACTICE IS TO PREVAIL AND ONLY METHODS, EQUIPMENT AND WORKMANSHIP OF THE FIRST QUALITY ARE TO BE USED. CHANGES IN PROPORTIONS SHALL BE APPROVED BY THE ENGINEER.
3. DELETE SECTION 2202.02C AND INSERT IN ITS PLACE--THE ADDITIONAL ASPHALT CEMENT REQUIRED TO BE ADDED TO THE SALVAGED MATERIAL WILL BE DETERMINED BY JOB MIX OR AS MAY BE DETERMINED BY SUBSEQUENT LABORATORY TESTING. THE ASPHALT CEMENT ADDED SHALL BE MAINTAINED WITHIN PLUS OR MINUS 0.40 PERCENTAGE POINTS TOLERANCE OF THE PERCENT INTENDED. THE BEST GENERAL PRACTICE IS TO PREVAIL AND ONLY METHODS, EQUIPMENT AND WORKMANSHIP OF THE FIRST QUALITY ARE TO BE USED. CHANGES IN PROPORTIONS SHALL BE APPROVED BY THE ENGINEER.
4. FOR ESTIMATING PURPOSES THE PERCENT OF VIRGIN GRAVEL AGGREGATES TO BE ADDED TO THE SALVAGED BITUMINOUS MATERIAL IS 50%. THIS PERCENTAGE MAY BE CHANGED DURING CONSTRUCTION TO MEET THE RESEARCH OBJECTIVES.

THE CONTRACTOR AWARDED THIS WORK WILL COOPERATE FULLY WITH THE IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY AND LEND HIS ASSISTANCE IN THE FORM OF LABOR, SCAFFOLDING MATERIALS, AND EQUIPMENT NECESSARY TO PERFORM AIR POLLUTION TESTS THAT MAY BE REQUIRED BY THE IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY.

THE CONTRACTOR IS HEREBY ADVISED THAT HE MUST OBTAIN A LETTER OF PRE-QUALIFICATION FROM THE IOWA D.E.Q. BEFORE BIDDING ON THIS PROJECT AND THE SUCCESSFULL BIDDER WILL BE REQUIRED TO HAVE NECESSARY IOWA D.E.Q. PERMITS FOR OPERATION BEFORE STARTING THE PROJECT. CORRESPONDENCE WITH THE IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY SHOULD BE DIRECTED TO REXFORD WALKER, PHONE NO. 515-265-8134.

IT IS INTENDED THAT THE 7" PLANNED RECYCLED ASPHALTIC CONCRETE BASE BE PLACED IN THREE LIFTS. THE FIRST LIFT SHALL BE A NOMINAL 4" COMPACTED THICKNESS AND THE SECOND AND THIRD LIFT SHALL BE A NOMINAL 1 1/2" COMPACTED THICKNESS.

THE NON-BID ITEM FOR MOBILIZATION - RECYCLING IS A FIXED LUMP SUM OF $20,000 AND WILL PROVIDE PAYMENT TO THE CONTRACTOR FOR INITIAL MOBILIZATION EXPENSES INCURRED BY THE CONTRACTOR AS A RESULT OF THE SPECIAL EQUIPMENT MODIFICATIONS IMPOSED BY THE RECYCLING ASPECTS OF THIS PROJECT. THE CONTRACTOR SHALL BECOME ELIGIBLE FOR THE $20,000 MOBILIZATION - RECYCLING PAYMENT AT SUCH TIME AS THE MODIFIED PLANT AND ITS APPURTENANCES ARE DETERMINED OPERATIONAL BY THE ENGINEER. SUCH A DETERMINATION WILL BE MADE AFTER CONSULTATION WITH THE AUTHORIZED REPRESENTATIVE OF THE IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY.

PROJECT MOBILIZATION

THE ITEM FOR PROJECT MOBILIZATION IS A LUMP SUM BID ITEM COVERING NORMAL MOBILIZATION EXPENSES INCURRED BY THE CONTRACTOR IN SETTING UP THE EQUIPMENT AND PERSONNEL FOR THE PROJECT. THE CONTRACTOR WILL BECOME ELIGIBLE FOR PAYMENT WHEN ALL STANDARD EQUIPMENT HAS BEEN ERECTED AND IS OPERATIONAL AT THE PLANT SITE. (THIS ITEM IS INCLUDED TO SEPARATE NORMAL MOBILIZATION FROM PRODUCTION REIMBURSEMENT. PRODUCTION REIMBURSEMENT ON REGULAR PROJECTS INCLUDES PAYMENT FOR MOBILIZATION.)

POLLUTION TESTING

THIS IS A NON-BID ITEM FOR PAYMENT OF THE E.P.A. METHOD 5 TESTING REQUIRED BY THE IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY.

THE CONTRACTOR AWARDED THIS WORK SHALL EMPLOY THE TESTING SERVICES OF A PRIVATE CONCERN, APPROVED BY THE I.D.E.Q. TO PERFORM THE REQUIRED E.P.A. METHOD 5 TESTS. THE EQUIPMENT MANUFACTURER, IF APPROVED BY THE IOWA D.E.Q., MAY PERFORM THESE TESTS.

THE CONTRACTOR SHALL SUBJECT HIS PLANT OPERATION TO THE FIRST E.P.A. METHOD 5 POLLUTION TEST FOR COMPLIANCE USING THE RECYCLABLE AGGREGATES AT OR BEFORE THE PRODUCTION OF 2000 TONS OF RECYCLED ASPHALTIC CONCRETE BASE.

IF THE CONTRACTORS PLANT IS FOUND TO BE IN NON-COMPLIANCE, SUBSEQUENT E.P.A. METHOD 5 TESTING WILL BE REQUIRED (BY THE ENGINEER AFTER CONSULTATION WITH I.D.E.Q.) AFTER MODIFICATIONS HAVE BEEN MADE.

PAYMENT FOR THE METHOD 5 E.P.A. TESTING WILL BE MADE AFTER AN ITEMIZED INVOICE IS PRESENTED TO THE ENGINEER SHOWING THE ACTUAL COSTS OF THE TEST.

FIVE E.P.A. METHOD 5 TESTS MAY BE REQUIRED. A MAXIMUM PAYMENT OF $2,000 PER E.P.A. METHOD 5 TEST WILL BE ALLOWED.

PRIOR TO THE INITIAL E.P.A. METHOD 5 TEST, AND FOR SUBSEQUENT TESTS REQUIRED, THE CONTRACTOR AWARDED THIS WORK SHALL FURNISH POLLUTION CONTROL DESIGN ENGINEERING AND TESTING AT THE CONTRACTOR'S EXPENSE.

EQUIPMENT ADJUSTMENTS

THE NON-BID ITEM FOR EQUIPMENT ADJUSTMENT IS A FIXED LUMP SUM PAYMENT OF $2,000, PER WORKING DAY, IN THE EVENT THE CONTRACTOR IS SHUT DOWN FOR FAILURE TO MEET REQUIRED POLLUTION CONTROL STANDARDS AND IS MAKING MODIFICATIONS TO MEET POLLUTION REQUIREMENTS. A MAXIMUM OF FIVE WORKING DAYS WILL BE ALLOWED FOR EQUIPMENT ADJUSTMENTS AND NOT MORE THAN ONE WORKING DAY PAYMENT WILL BE ALLOWED PER SHUT DOWN.

IN ORDER TO BE ELIGIBLE FOR PAYMENT, THE CONTRACTOR MUST RECEIVE A NON-COMPLIANCE NOTICE FROM THE ENGINEER (BASED ON CONSULTATION WITH THE IOWA D.E.Q.) NOTIFYING THE CONTRACTOR THAT HE IS FAILING TO MEET POLLUTION STANDARDS.

THE DEFINITION OF WORKING DAY WILL BE THE SAME AS SECTION 1101.03 OF THE STANDARD SPECIFICATIONS EXCEPT NO PAYMENT FOR EQUIPMENT ADJUSTMENTS WILL BE ALLOWED ON SATURDAYS, SUNDAYS, OR LEGAL HOLIDAYS.

RICHARD P. HENELY
REGISTERED
3065
IOWA
PROFESSIONAL ENGINEER

RECYCLED ASPHALTIC CONC. BASE	PRIMER OR TACK COAT BITUMEN	ASPHALT CEMENT	MOBILIZATION RECYCLING	PROJECT MOBILIZATION	EQUIPMENT ADJUSTMENTS	METHOD 5 E.P. POLLUTION TESTING
TONS	GALLONS	TONS	(FIXED AMOUNT NOT A BID ITEM) LUMP SUM	(BID ITEM) LUMP SUM	(FIXED AMOUNT NOT A BID ITEM) WORKING DAY	(FIXED AMOUNT NOT A BID ITE PER TEST
①②③⑧⑦	⑦	④⑤⑦	——	——	$ 2000 EACH ⑦	$2000 EACH
10,270	2620	411	$ 20,000		$10,000 MAX.	$10,000 MAX.

FOOTNOTES:

(1) DRUM MIXING EQUIPMENT COMPLYING WITH SECTION 2001 AND MODIFIED TO PROCESS RECYCLED MIXTURE SHALL BE USED FOR PRODUCTION OF RECYCLED ASPHALTIC CONCRETE BASE.

(2) THE SALVAGED BITUMINOUS MATERIAL, CRUSHED TO A 1" MAXIMUM SIZE, WILL BE FURNISHED COST FREE TO THE CONTRACTOR IN STOCKPILE AT PLANT SITE LOCATED IN THE NW¼ SECTION 11-94-29.

(3) GRAVEL AGGREGATE TO BE ADDED TO THE SALVAGED BITUMINOUS MATERIAL WILL BE FURNISHED COST FREE TO CONTRACTOR IN STOCKPILE AT PLANT SITE LOCATED IN THE NW¼ SECTION 11-94-29.

(4) ESTIMATED AT 4% ADDITIONAL ASPHALT CEMENT.

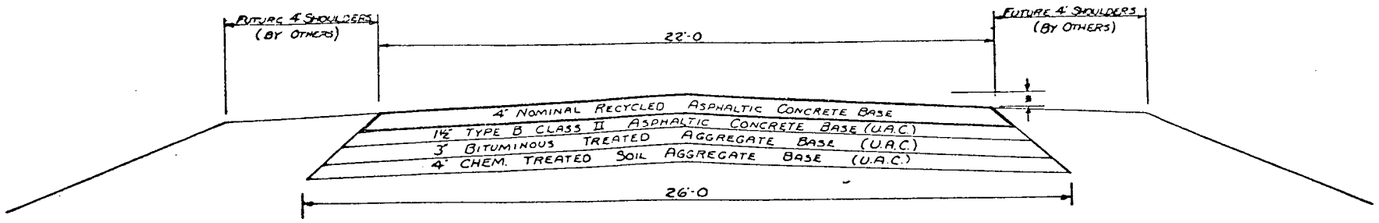
(5) CONTRACTOR SHALL USE 200-300 PENETRATION ASPHALT CEMENT COMPLYING WITH REQUIREMENTS OF SECTION 4137, 1972 STANDARD SPECIFICATIONS.

(6) CONTRACTOR SHALL SHAPE AND COMPACT EXISTING SOIL-AGGREGATE SUB-BASE TO THE PROPER CROWN AS SPECIFIED FOR THE FINISHED PAVEMENT. AT JUNCTIONS OF EXISTING PAVEMENTS AND BRIDGES THE SUB-BASE WILL BE EXCAVATED TO PERMIT THE FULL THICKNESS OF THE RECYCLED ASPHALTIC CONCRETE TO BE CONSTRUCTED. THIS WORK SHALL BE CONSIDERED INCIDENTAL TO OTHER WORK ON THE PROJECT.

(7) SECTION 1109.03 OF 1972 STANDARD SPECIFICATIONS SHALL NOT APPLY.

(8) WEDGE SHOULDERING AFTER THE ASPHALTIC CONCRETE IS PLACED WILL BE DONE BY OTHERS AND IS NOT A PART OF THIS CONTRACT.

(9) PERMANENT EROSION CONTROL WORK TO BE DONE BY OTHERS AND IS NOT A PART OF THIS CONTRACT.



*THE MAXIMUM ALLOWABLE SLOPE IS 3.0% AND THE MINIMUM ALLOWABLE SLOPE IS 1.5%. SECTIONS MAY BE MODIFIED AS DIRECTED BY THE ENGINEER THROUGH AREAS OF SPECIAL SHAPING.

THE PLANT SITE WILL BE LOCATED IN THE N.W.¼ SECTION 11-94-29 ON PROPERTY OWNED BY KOSSUTH COUNTY. THE CONTRACTOR SHALL HAVE FULL USE OF THIS LOCATION DURING CONSTRUCTION AT NO COST.

CONTRACTOR WILL CONSTRUCT A 4" RECYCLED ASPHALTIC CONCRETE BASE USING A MIXTURE OF RECYCLABLE ASPHALT MATERIAL, ADDED ASPHALT CEMENT AND CRUSHED GRAVEL AGGREGATES AS DETERMINED BY JOB MIX. SECTION 2202, 1972 STANDARD SPECIFICATIONS, SHALL APPLY AMENDED AS FOLLOWS:

1. IN ANY SECTION WHERE ASPHALT TREATED BASE APPEARS, IT WILL BE ASSUMED TO READ "RECYCLED CONCRETE BASE."
2. DELETE SECTION 2202.02B AND INSERT IN ITS PLACE--THE MINERAL AGGREGATE USED WILL BE THE SALVAGED ASPHALT PAVEMENT MATERIAL, WITH OR WITHOUT VIRGIN AGGREGATES, CRUSHED OR PULVERIZED SO THAT ALL PARTICLES PASS A 1" SEIVE. THERE WILL BE NO OTHER GRADATION SPECIFICATIONS OR REQUIREMENTS. THE BEST GENERAL PRACTICE IS TO PREVAIL AND ONLY METHODS, EQUIPMENT AND WORKMANSHIP OF THE FIRST QUALITY ARE TO BE USED. CHANGES IN PROPORTIONS SHALL BE APPROVED BY THE ENGINEER.
3. DELETE SECTION 2202.02C AND INSERT IN ITS PLACE--THE ADDITIONAL ASPHALT CEMENT REQUIRED TO BE ADDED TO THE SALVAGED MATERIAL WILL BE DETERMINED BY JOB MIX OR AS MAY BE DETERMINED BY SUBSEQUENT LABORATORY TESTING. THE ASPHALT CEMENT ADDED SHALL BE MAINTAINED WITHIN PLUS OR MINUS 0.40 PERCENTAGE POINTS TOLERANCE OF THE PERCENT INTENDED. THE BEST GENERAL PRACTICE IS TO PREVAIL AND ONLY METHODS, EQUIPMENT AND WORKMANSHIP OF THE FIRST QUALITY ARE TO BE USED. CHANGES IN PROPORTIONS SHALL BE APPROVED BY THE ENGINEER.
4. FOR ESTIMATING PURPOSES THE PERCENT OF VIRGIN GRAVEL AGGREGATES TO BE ADDED TO THE SALVAGED BITUMINOUS MATERIAL IS 50%. THIS PERCENTAGE MAY BE CHANGED DURING CONSTRUCTION TO MEET THE RESEARCH OBJECTIVES.

THE CONTRACTOR AWARDED THIS WORK WILL COOPERATE FULLY WITH THE IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY AND LEND HIS ASSISTANCE IN THE FORM OF LABOR, SCAFFOLDING MATERIALS, AND EQUIPMENT NECESSARY TO PERFORM AIR POLLUTION TESTS THAT MAY BE REQUIRED BY THE IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY.

THE CONTRACTOR IS HEREBY ADVISED THAT HE MUST OBTAIN A LETTER OF PRE-QUALIFICATION FROM THE IOWA D.E.Q. BEFORE BIDDING ON THIS PROJECT AND THE SUCCESSFULL BIDDER WILL BE REQUIRED TO HAVE NECESSARY IOWA D.E.Q. PERMITS FOR OPERATION BEFORE STARTING THE PROJECT. CORRESPONDENCE WITH THE IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY SHOULD BE DIRECTED TO REXFORD WALKER, PHONE NO. 515-265-8134.

IT IS INTENDED THAT THE 4" PLANNED RECYCLED ASPHALTIC CONCRETE RESURFACING BE PLACED IN TWO LIFTS. THE FIRST LIFT SHALL BE AN AVERAGE 2" THICKNESS LEVELING COURSE AND THE SECOND LIFT SHALL BE A NOMINAL 2" COMPACTED THICKNESS.

NOTE:

FORMAL AND FINAL AWARD OF THIS CONTRACT IS CONTINGENT UPON THE SUCCESS OF THE CONTRACTOR BEING ABLE TO CONTROL THE AIR POLLUTION PROBLEM AS MAY BE REQUIRED BY THE IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY AND THE FEDERAL ENVIRONMENTAL PROTECTION AGENCY.

FINAL AWARD OF CONTRACT WILL BE DELAYED UNTIL AN ADDITIONAL PERMIT TO PROCEED IS OBTAINED BY THE BIDDER FROM THE IOWA D.E.Q. THIS PROJECT IS TIED TO KOSSUTH COUNTY PROJECT L-RS-5/5--77-55. IF THE CONTRACTOR FAILS TO MEET THE POLLUTION REQUIREMENTS OF THE IOWA D.E.Q., THIS PROJECT WILL NOT BE AWARDED AND THE BIDDER SHALL NOT BE AWARDED ANY COMPENSATION FOR BIDDING THE PROJECT AND SECTION 1109.05 OF THE 1972 STANDARD SPECIFICATIONS SHALL NOT APPLY.

GUARD RAIL TO BE
INSTALLED BY OTHERS

RICHARD P. HENELY
REGISTERED
3065
IOWA
PROFESSIONAL ENGINEER

CLEANING AND PREPARATION OF BASE	PRIMER OR TACK COAT BITUMEN	RECYCLED ASPHALTIC CONC. BASE	ASPHALT CEMENT
MILES	GALLONS	TONS	TONS
(7)	(6)	(1)(2)(3)(6)	(5)(6)
2.979	3845	8852	354

FOOTNOTES:

(1) DRUM MIXING EQUIPMENT COMPLYING WITH SECTION 2001 AND MODIFIED TO PROCESS RECYCLED MIXTURE SHALL BE USED FOR PRODUCTION OF RECYCLED ASPHALTIC CONCRETE BASE.

(2) THE SALVAGED BITUMINOUS MATERIAL, CRUSHED TO A 1" MAXIMUM SIZE, WILL BE FURNISHED COST FREE TO THE CONTRACTOR IN STOCKPILE AT PLANT SITE LOCATED IN THE N.W.¼ SECTION 11-94-29.

(3) GRAVEL AGGREGATE TO BE ADDED TO THE SALVAGED BITUMINOUS MATERIAL WILL BE FURNISHED COST FREE TO CONTRACTOR IN STOCKPILE AT PLANT SITE LOCATED IN THE N.W.¼ SECTION 11-94-29.

(4) ESTIMATED AT 4% ADDITONAL ASPHALT CEMENT.

(5) CONTRACTOR SHALL USE 200-300 PENETRATION ASPHALT CEMENT COMPLYING WITH REQUIREMENTS OF SECTION 4137, 1972 STANDARD SPECIFICATIONS.

(6) SECTION 1109.03 OF 1972 STANDARD SPECIFICATIONS SHALL NOT APPLY.

(7) FINAL PAYMENT WILL BE BASED ON ESTIMATED PLANNED QUANTITIES WITHOUTH RE-MEASUREMENT.

(8) SHOULDERING TO BE DONE BY OTHERS.

(9) PERMANENT EROSION CONTROL WORK TO BE DONE BY OTHERS.

RECORD OF CONSTRUCTION AND MATERIAL BIDS

PROJECT - LRS-575
Recycled Asphalt Pavement

DATE OF LETTING June 21, 1977

COUNTY - Kossuth

NAME OF CONTRACTOR CONTRACTOR'S ADDRESS AMOUNT OF BIDDER'S CHECK				Engineer's Estimate		Rohlin Construction Company		Komatz Construction Company	
NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
1	Base, Recycled Asphalt	10,270	tons	5.00	51,350.00	6.35	65,214.50	6.55	67,268.50
2	Primer or Tack Coat Bitumen	2,620	gals.	0.45	1,179.00	0.52	1,362.40	0.50	1,310.00
3	Asphalt Cement	411	tons	72.00	29,592.00	78.50	32,263.50	80.00	32,880.00
4	Project Mobilization	Lump Sum	L.S.	5,000.00	5,000.00	10,000.00	10,000.00	15,000.00	15,000.00
	SUB TOTAL				87,121.00		108,840.40		116,458.50
	Non Bid Items (Fixed Amount)								
	Mobilization, Recycling	Lump Sum	L.S.		20,000.00		20,000.00		20,000.00
	Equipment Adjustments	5	each	2,000.00	10,000.00		10,000.00		10,000.00
	Method V EPA Pollution Tests	5	each	2,000.00	10,000.00		10,000.00		10,000.00
	PROJECT TOTAL				127,121.00		148,840.40		156,458.50
	This project tied to Kossuth Project LFM-1142								

EXHIBIT G

RECORD OF CONSTRUCTION AND MATERIAL BIDS

Project - LFM-1142
Recycled Asphalt Pavement Resurfacing
DATE OF LETTING June 21, 1977

COUNTY - Kossuth

NAME OF CONTRACTOR CONTRACTOR'S ADDRESS AMOUNT OF BIDDER'S CHECK				Engineer's Estimate		Rohlin Construction Company		Komatz Construction Company	
NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
1	Base, Clearing and Preparation	2.979	miles	150.00	446.85	300.00	893.70	500.00	1,489.50
2	Primer or Tack Coat, Bitumen	3,845	gals.	0.45	1,730.25	0.52	1,999.40	0.50	1,922.50
3	Base, Recycled Asphaltic Conc.	8,852	tons	4.20	37,178.40	6.35	56,210.20	6.55	57,980.60
4	Asphalt Cement	354	tons	72.00	25,488.00	78.50	27,789.00	80.00	28,320.00
	PROJECT TOTAL				64,843.50		86,892.30		89,712.60
	This project tied to Kossuth County Project LRS-575								

EXHIBIT G-1

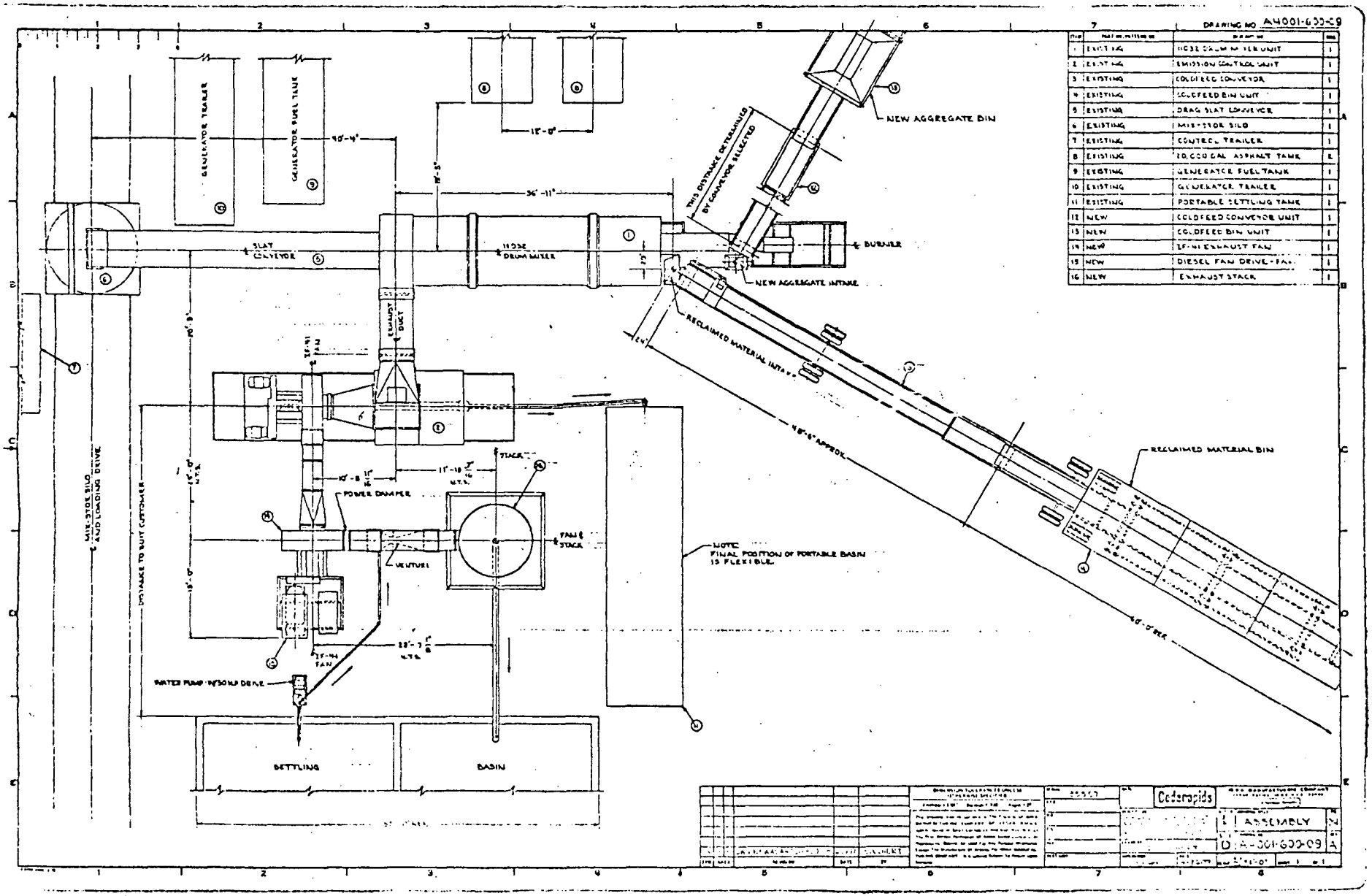

DRAWING NO A4001-600-C9
NEW AGGREGATE BIN
BURNER
NEW AGGREGATE INTAKE
RECLAIMED MATERIAL INTAKE
RECLAIMED MATERIAL BIN
SLAT CONVEYOR
DRUM MIXER
EXHAUST DUCT
POWER DAMPER
STACK
VENTURI
FAN & STACK
SETTLING
BASIN
Cedarapids
ASSEMBLY

EXHIBIT H

TEST RESULT SUMMARY 50% Rec./50% Vir.

EXHIBIT I

TEST NO.	1	2	3	Average
DATE	7-25-77	7-26-77	7-27-77	
TOTAL TEST TIME (min.)	132	132	132	
PRODUCTION RATE (ton/hr.)	277.5	283	270	
ACTUAL STACK CFM (ft^3/min)	41,657	41,885	42,261	
STACK GAS TEMP. (°F)	140	137	140	
TEST GAS SAMPLE, SCF (ft^3)	66.3	70.7	66.5	
FILTER PARTICULATE CATCH (gm.)	.0250	.0369	.0526	
FRONT PARTICULATE WASH (gm.)	.0111	.0185	.0248	
IMPINGER CATCH (gm.)	308.1	390.8	409.8	
CHLORO-ETHER EXTRACT (gm.)	.2956	.1903	.4009	
INORGANIC CATCH (gm.)	.0052	.0080	.0066	
AVG. EMISSION RATE, NEW SOURCE (lb./hr.)	2.041	3.082	4.400	
AVG. EMISSION RATE, EXISTING SOURCE (lb./hr.)	19.049	14.113	27.567	
ISOKINETIC VARIATION, Un/Us (%)	1.007	1.029	.993	
ISOKINETIC CHECK, NEW SOURCE (%)	1.001	1.016	1.006	
ISOKINETIC CHECK, EXISTING SOURCE (%)	.999	1.016	.994	
NEW SOURCE PARTICULATE CONCENTRATION (grains/SCF)	.0084	.0123	.018	.0129
XISTING SOURCE PARTICULATE CONCENTRATION (grains/SCF)	.078	.055	.112	.0817

TEST RESULT SUMMARY 65% Rec./35% Vir.

EXHIBIT I-1

TEST NO.	1	2	3	Average
DATE	8-4-77	8-5-77	8-5-77	
TOTAL TEST TIME (min.)	132	132	66 *	
PRODUCTION RATE (ton/hr.)	354	346	346	
ACTUAL STACK CFM (ft^3/min)	41,943.9	43,186.5	43,980	
STACK GAS TEMP. (°F)	139.9	139.7	139.6	
TEST GAS SAMPLE, SCF (ft^3)	64.47	65.97	35.08	
FILTER PARTICULATE CATCH (gm.)	.1135	.0649	.0387	
FRONT PARTICULATE WASH (gm.)	.0230	.0135	.0125	
IMPINGER CATCH (gm.)	391.0	421.6	214.5	
CHLORO-ETHER EXTRACT (gm.)	.3078	.1080	.1347	
INORGANIC CATCH (gm.)	.0144	.0154	.0103	
AVG. EMISSION RATE, NEW SOURCE (lb./hr.)	7.84	4.530	5.780	
AVG. EMISSION RATE, EXISTING SOURCE (lb./hr.)	26.33	11.66	22.152	
ISOKINETIC VARIATION, Un/Us (%)	.997	.999	1.003	
ISOKINETIC CHECK, NEW SOURCE (%)	.993	.989	1.009	
ISOKINETIC CHECK, EXISTING SOURCE (%)	.992	.986	1.009	
NEW SOURCE PARTICULATE CONCENTRATION (grains/SCF)	.0324	.0181	.0227	.0244
EXISTING SOURCE PARTICULATE CONCENTRATION (grains/SCF)	.1089	.046	.0871	.081

* Due to plant equipment malfunction, test 3 was limited to 1/2 the sampling time of the previous tests.

EXHIBIT J

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
ASPHALT CONCRETE MIX DESIGN
LAB LOCATION AMES

MIX, TYPE AND CLASS: RECYCLED ASPH. CONC. LAB NO. ABD7-146

INTENDED USE:

SIZE 3/4" SPEC. NO. 803 & PLANS DATE REPORTED 7-19-77

COUNTY KOSSUTH PROJECT L-FM-1142--73-55
L-RS-329--73-55
L-RS-507--73-55
L-RS-575--73-55
HR-188

CONTRACTOR ROHLIN

PROJ. LOCATION

AGG. SOURCES RECYCLED MATL. CONTAINING 7.5% ASPH.; GRAVEL-
DOLE CONST. -NE 1/4 -11-94-29, KOSSUTH CO.

JOB MIX FORMULA AGGREGATE PROPORTIONS: 50% ABC7-164(RECYCLED) 50% AAT7-372(GRAVEL

JOB MIX FORMULA = COMBINED GRADATION

1-1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.200
		100	96	89	78	65	51	33	15	7.9	6.3

TOLERANCE:

75 BLOW MARSHALL DENSITY	2.04		
ASPHALT SOURCE AND APPROXIMATE VISCOSITY	KOCH - 306 POISES (200-300PEN.)		
PLASTICITY INDEX			
% ASPH. IN MIX (TOTAL)	6.0	8.0	9.0
NUMBER OF MARSHALL BLOWS	50	50	50
MARSHALL STABILITY - LBS.	2378	2430	1868
FLOW - 0.01 IN.	10	9	8
SP. GR. BY DISPLACEMENT(LAB DENS.)	2.02	2.11	2.16
BULK SP. GR. COMB. DRY AGG.	2.552	2.552	2.552
SP. GR. ASPH. @ 77 F.	1.021	1.021	1.021
CALC. SOLID SP. GR.	2.39	2.32	2.29
% VOIDS - CALC.	15.4	9.2	5.7
RICE SP. GR.	2.45	2.33	2.31
% VOIDS - RICE	17.5	9.5	6.5
% WATER ABSORPTION - AGGREGATE	1.84	1.84	1.84
% VOIDS IN THE MINERAL AGGREGATE	25.6	23.9	23.0
% V.M.A. FILLED WITH ASPHALT	39.7	61.8	75.2
CALCULATED ASPH.FILM THICKNESS(MICRONS)	7.7	11.0	12.6

A CONTENT OF 9.0 % ASPHALT IS RECOMMENED TO START THE JOB.
THIS IS AN ADDITION OF 5.5 % ASPHALT.

COPIES:
ASPH. MIX DESIGN
PROJECTS LISTED ABOVE
R. I. BORTLE
R. C. HENELY
B. ORTGIES
C. HUISMAN
. ZEARLEY
ROHLIN
V. MARKS
DON HINES C. JONES
K. BENKE
J. BEHMER
C. SCHULOR

SIGNED: BERNARD C. BROWN
TESTING ENGINEER

EXHIBIT K

RECOVERED ASPHALTIC CONCRETE TEST RESULTS
50% Recycled - 50% Virgin
5.5% Additional Asphalt Cement

Project	Sample No.	Avg.** Pen of A.C. Added	% Asphalt Extracted	Recovered Asphalt Penetraction @ 77°F	Recovered Abs. Viscosity @ 140°F (Poises)	Recovered Kinematic Vis. @ 275°F (Centistrokes)
L-RS-575	26-8-C	296	7.5*	100	1250	331
L-RS-575	27-5-6	296	8.2*	106	1150	334
L-RS-575	27-8-C	296	7.3*	99	1220	333
L-RS-575	28-5-C	243	6.8*	84	1740	373
L-RS-575	28-8-C	243	7.1*	85	1690	366
L-RS-575	29-4-C	236	7.5*	78	1810	386
L-RS-329	29-7-A	236	8.4*	66	2350	428
L-RS-329	30-7-C	228	7.1*	82	1770	387
L-RS-329	30-5-C	228	7.0*	77	1750	373
L-RS-329	1-5-C	236	7.0*	77	1760	377
L-RS-329	1-7-C	236	6.7*	82	1690	372
L-RS-329	2-5-C	233	7.1*	77	1680	392
L-RS-329	2-7-C	233	6.8*	77	1890	405
L-RS-329	3-5-C	233	6.9*	82	1650	370
L-RS-329	3-8-C	233	7.5*	87	1650	380

*Does not include retention factor which is estimated at 1.75% due to the high shale content of materials used.

**Average Penetration determined from three samples submitted daily.

EXHIBIT K

Cost Comparison

Type B Class I
VS
Recycled Mix - 50% Virgin, 50% Recycled Aggregates

Item	All Virgin Aggregates, 6½%* A.C. added to Type B, Class I	50% Recycled 50% Virgin Agg. 5½% A.C. Added
Cost - aggregates	0.75	1.37
Cost bid - mix, lay, compact	6.99	6.35
Cost - asphalt cement	5.10	4.32
TOTAL PER TON	$12.84	$12.04

*Estimated percent - could be higher if a design mix was actually used.

Note: Price bid for asphalt cement was $78.50 per ton

EXHIBIT M

Bid Price Vs. Final Construction Cost

Project LRS-575 (HR-188)	Unit	Contract #Units	Contract Unit Price	Contract Total	Construction #Units	Construction Unit Price	Construction Total
Item No. 1 Base, Recycled Asph. Conc.	Ton	10,270	6.35	65,214.50	10,424.19	6.35	66,193.61
No. 2 Primer or Tack Coat Bit.	Gallon	2,620	0.52	1,362.40	2,730.00	0.52	1,419.60
No. 3 Asphalt Cement	Ton	411	78.50	32,263.50	586.65	78.50	46,052.03
No. 4 Project Mobilization	Lump Sum	L.S.	L.S.	10,000.00	L.S.	L.S.	10,000.00
Sub Total				108,840.40			123,665.24
Additional Fixed Costs:							
Mobilization, Recycling	Lump Sum	L.S.	L.S.	20,000.00	L.S.	L.S.	20,000.00
Equipment Adjustment	Each	5	2,000.00	10,000.00	2	2,000.00	4,000.00
Method V, E.P.A. Pollution Tests	Each	5	2,000.00	10,000.00	2	2,000.00	4,000.00
Sub Total				40,000.00			40,000.00
TOTALS				$148,840.40			$151,665.24

Project LFM--1142	Unit	Contract #Units	Contract Unit Price	Contract Total	Construction #Units	Construction Unit Price	Construction Total
Item No. 1 Base, Clean & prepare	Mile	2.979	300.00	893.70	2.979000	300.00	893.70
No. 2 Primer or Tack Coat Bit.	Gallon	3,845	0.52	1,999.40	4,057.00	0.52	2,109.64
No. 3 Base, Recycled	Ton	8,852	6.35	56,210.20	8,805.37	6.35	55,914.10
No. 4 Asphalt Cement	Ton	354	78.50	27,789.00	475.30	78.50	37,311.05
TOTALS				$ 86,892.30			$ 96,228.49

EXHIBIT M

EXHIBIT N

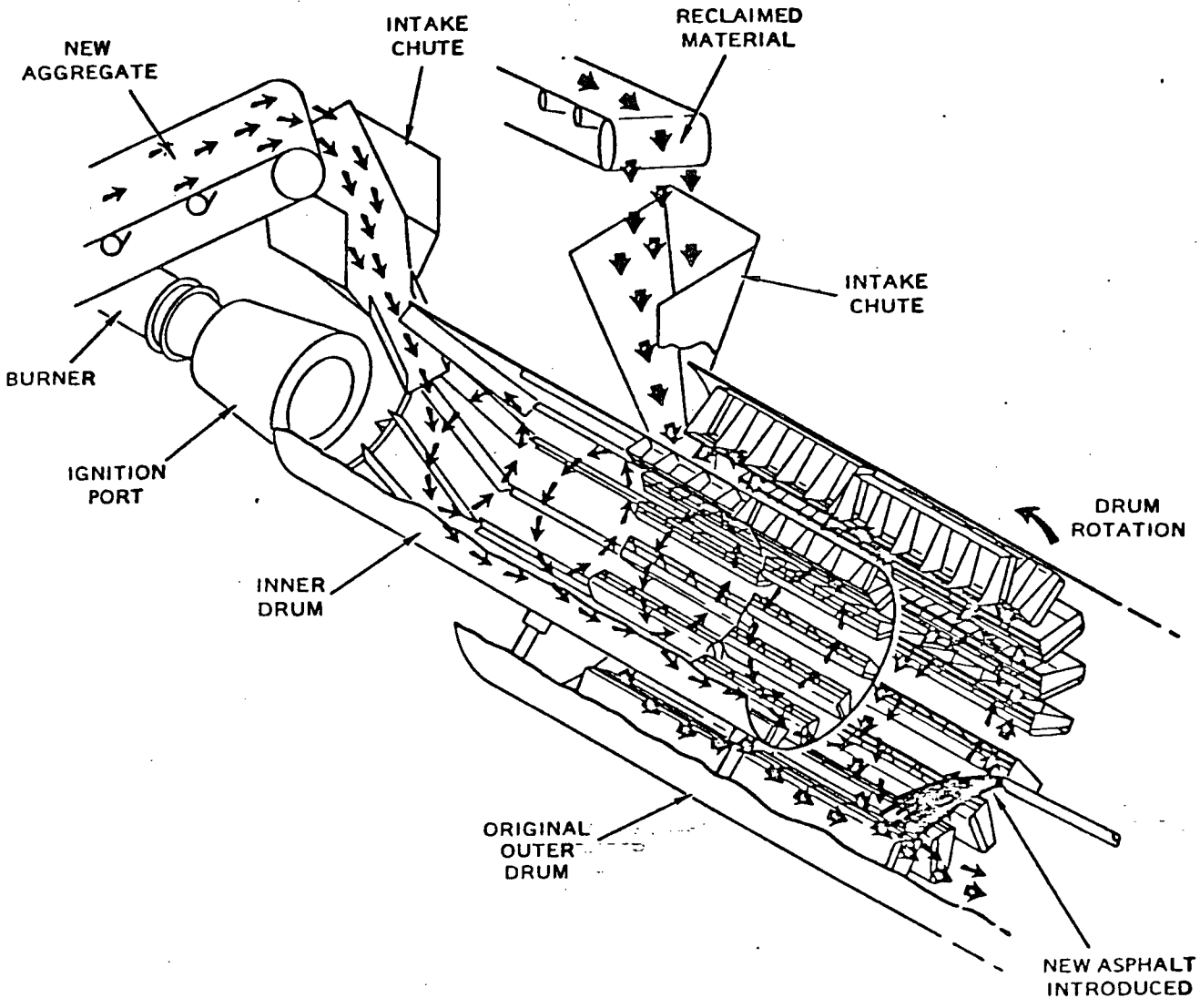
Bid Price Vs. Final Construction Cost

Project LRS-507	Unit	Contract #Units	Contract Unit Price	Contract Total	Construction #Units	Construction Unit Price	Construction Total
Item No. 1 Base, Clean & Prepare	Mile	2.979	100.00	297.70	2.977000	100.00	297.70
2 Primer or Tack Coat Bit.	Gallon	3,877	0.52	2,016.04	4,233.00	0.52	2,201.16
3 Base, Type B Class I	Ton	7,361	6.99	51,453.39	7,523.48	6.35*	47,774.10
4 Asphalt Cement	Ton	478	78.50	37,523.00	406.08	78.50	31,877.28
TOTALS				91,290.13			82,150.24

Project LRS-329	Unit	Contract #Units	Contract Unite Price	Contract Total	Construction #Units	Construction Unit Price	Construction Total
Item No. 1 Base, Clean & Prepare	Mile	6.996	100.00	699.60	6.996000	100.00	699.60
2 Primer or Tack Coat Bit.	Gallon	9,036	0.52	4,698.72	7,919.00	0.52	4,117.88
3 Base, Type B Class I	Ton	16,375	6.99	114,461.25	15,777.13	6.35*	100,184.78
4 Asphalt Cement	Ton	1,064	78.50	83,524.00	810.21	78.50	63,601.49
TOTALS				203,383.57			168,603.75

*Recycled asphalt concrete bid price

EXHIBIT N



With the installation of the asphalt recycle kit, the plant can produce paving material from re-claimed asphalt pavement and save money three ways:

First - - the aggregate costs are lower because less new material is required.

Second - - fuel costs are lower because the recycled aggregate requires less drying.

Third - - asphalt costs are lower because the recycled material enters the plant carrying asphalt that is reused.