RECYCLING PORTLAND CEMENT CONCRETE
AND
ASPHALTIC CONCRETE

by George Calvert
Materials & Research Engineer
Iowa Department of Transportation

The Iowa Department of Transportation has found itself in the same position as other highway construction agencies in that we are facing shortages of many of our road building materials. The shortages that are the most costly are related to gasoline, fuel oil and other fuel products. Great quantities of fuel are consumed in the smelting and refining of steel. Large quantities of fuel are used to manufacture cement. The asphalt in the asphaltic concrete is a fuel in itself with a very high BTU value. The Iowa Department of Transportation is making every effort to devise ways of conserving fuel. We also recognize that we have shortages of other materials just as costly and just as difficult to solve, therefore, we are working on the shortage problem associated with aggregate at the same time that we are working on the fuel shortage. In many cases they are one and the same.

This last year a research project was constructed on Highway 75 immediately south of Rock Rapids in which we removed and crushed asphaltic concrete and portland cement concrete and recycled these materials as aggregates in portland cement concrete. At approximately the same time that this project was going on, Kossuth County was constructing a project in which 80,000 tons of old asphaltic concrete and bituminous treated base was being recycled and reused as asphaltic concrete base and surface course.

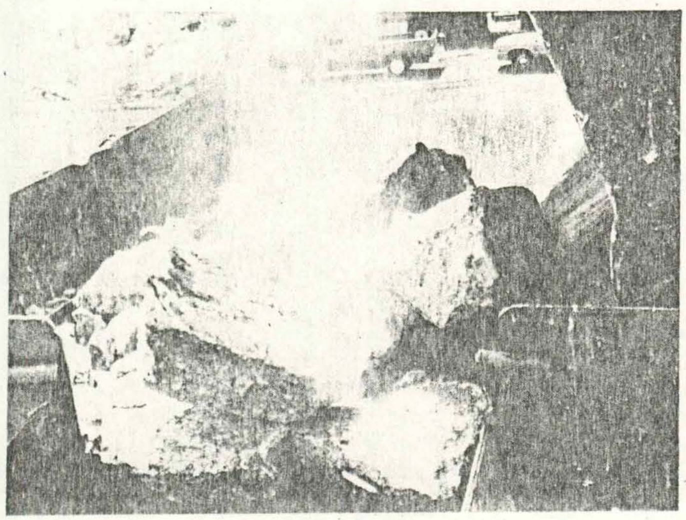
We have already let the grading phase of a reconstruction project where the old P.C. concrete will be removed and crushed for aggregate in the new roadway. This project is approximately 15 miles long. It will be completed in 1978. It is located in Southwestern Iowa on Highway 2 between Bedford and Clarinda. We anticipate receiving some very worthwhile cost data from a project this size. We are also recycling a short section of P.C. paving on I-680 north of Council Bluffs and using it in the subbase and P.C. shoulders.

Aggregates are becoming very scarce in this and other areas of Iowa. In some locations we are having to remove over burden that is 80' or more in depth. This is costly in terms of fuel and raises the selling price of the aggregate considerably. Even then many of the aggregates that are uncovered are undesirable in one or more respects. Approximately the southern one-third of the state has only "D" cracking limestone as coarse aggregate for portland cement concrete. These aggregates are not expected to last more than 20 years in portland cement concrete pavements.

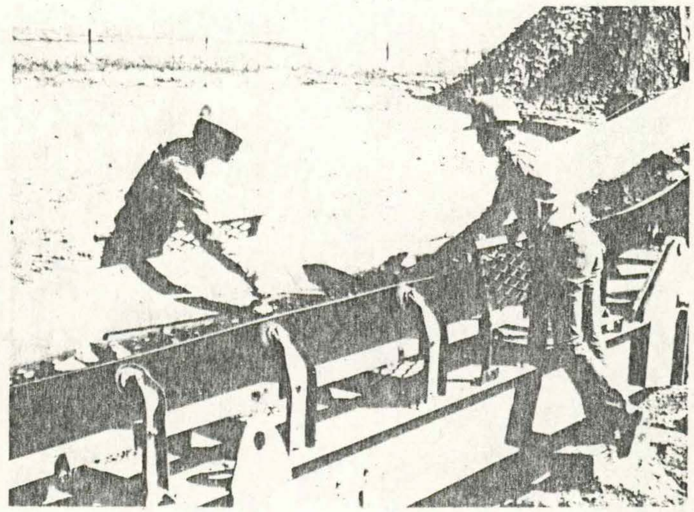
The recycling project in Lyon County was immediately south of Rock Rapids on Highway 75. This was an old portland cement concrete paving construction in the early 1930's. It was constructed 18' wide with integral curb. In the early 1950's the curb was removed and the roadway was widened with portland cement concrete to 24' wide. Then about 1964 the roadway was overlaid with 3" of asphalt concrete. This section of roadway was being removed at two separate locations in order to raise bridges to provide for adequate drainage capacity. This provided us with four separate test sections; one section at the end of each of the two bridges. The contractor used a backhoe to remove the asphaltic concrete and load it for hauling to the plant site. The portland cement concrete was then broken up with a pneumatic punch or chisel into large chunks 2-3 square feet in area. These were hauled to the same plant site for further crushing. We estimated that approximately 80-85 percent of the broken concrete was recovered from the breaking operation. The finer pieces were left on the grade because of the danger of picking up high percentages of soil with the small pieces of concrete.

The major problem encountered on this project was the removal of reinforcing steel from the broken concrete. These were two longitudinal #5 bars in the area of the curbs on each side of the roadway and two longitudinal bars running parallel near the centerline. The contractor used hydraulic powered shears to clip off all protruding steel during the removal and loading of the concrete on the grade. Some additional steel was removed from the concrete prior to crushing at the plant site.

The contractor used a 42" jaw crusher to break up the large chunks of concrete. This operation broke out most of the remaining steel which was then hand picked off the conveyor belt as the 5-6" size particles were conveyed to the stockpile. On this 1.4 mile project the calculated quantities of steel in the old slab was 52 ton. Each piece of steel was handled at least once by individuals on this project. This is a challenge that must be met by equipment manufacturers and contractors in the future. The removal and crushing contractor, L. G. Everist of Sioux City, Iowa, experienced very little trouble in the primary crushing operation. The material was reduced to grapefruit size particles.



Chunks of concrete 2-6 sq. ft. in area are crushed in this 42 inch primary Jaw Crusher.



No. 5 reinforcing steel is hand picked from the conveyor belt after crushing.

The final crushing to 1½" size was even more easily performed by a secondary crusher which employed a small jaw and a secondary roll crusher. Two separate products were produced in this crushing operation; one was crushed portland cement concrete reduced to 1½" maximum size with approximately 25 percent passing the #4 and about 1 percent passing the 200. The other product which was stockpiled separately was a blend of crushed asphaltic concrete and portland cement concrete which was 1½" maximum size, contained about 22 percent passing the #4 and approximately 1 percent passing the 200.

Three separate mixes were designed using these materials. The first of these was Mix "A" in which 35 percent of the aggregate was retained in the #4 sieve and 65 percent passed the #4. These proportions were obtained by adding concrete sand to the crushed portland cement concrete. A water reducing agent was employed to disburse the fines in the unwashed aggregate. Six percent air was entrained and six sacks of cement were utilized. The net result was a very strong and workable mix which looked and behaved much like any other concrete made with virgin aggregate. The water-cement ratio was about 0.5 and the compressive strength was in excess of 5000 PSI.

In order to gain as much knowledge as possible from this project, we designed another mix employing the crushed portland cement concrete and concrete sand. This time we increased the amount of aggregate retained on the #4 to 45 percent, reduced the total fine aggregate to 55 percent and held the cement, entrained air and water reducing agent constant. The net result was again a very satisfactory mix with the same water-cement ratio as Mix "A". The concrete constructed using both of these proportions was very strong and durable. We tested specimens constructed utilizing these proportions for durability. We used ASTM test Method C 291 to evaluate their durability. The specimens constructed using crushed portland cement concrete exhibited very good durability in the 80 range. We see no reason why the concrete constructed from these materials should not give us an additional 40 years of good service.

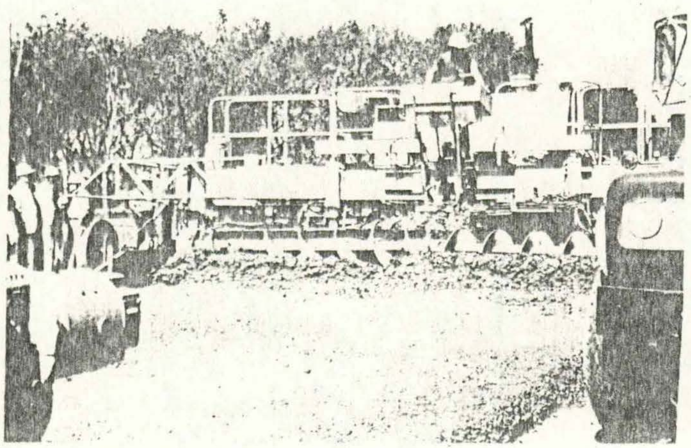
The next mix, the "C" mix, was constructed using crushed asphaltic concrete and crushed portland cement concrete with five sacks of cement, entrained air and a water reducer. The strength obtained here was slightly more than 2000 PSI which is very adequate for the use for which it was intended. The specimens constructed from these proportions were slightly less durable than those constructed from portland cement concrete alone.

Mixes "A" and "B" looked, behaved and tested so much like conventional concretes that we chose to try them in conventional concrete sections. The north and south ends of the southern most bridge were paved utilizing these mixes. The cross section was 24' wide and 9" deep. The only steel employed was the 30" tie bars at centerline.

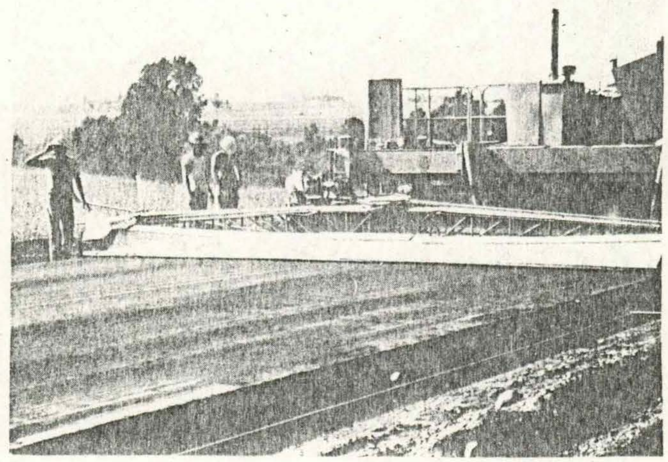
The new and innovative cross section employed at the north bridge is commonly referred to as Econocrete in that the lower 7" of this section was constructed utilizing the lower quality, less durable Mix "C". It was constructed 7" deep and was overlaid immediately with 4" of the higher quality crushed portland cement concrete with six sacks of cement.

One of the main thrusts of this project was to determine if the contractor could use his present conventional mixing and paving equipment to mix and pave these recycled materials. The Irving F. Jensen Company of Sioux City, Iowa utilized a Rex 7½ yard central mix plant to proportion and mix these materials. No insurmountable problems developed. We did have some difficulty with segregation of the recycled aggregates. This was crusher run, 1½" maximum size material. In the future we will have these materials separated on the 3/8" sieve. This should not increase our costs any appreciable amount and should increase our ability to control both air and slump. We will then have two materials produced from the recycling process; one will be 1½" to 3/8" size, and the other would be 3/8" to dust.

The contractor chose to use two slip form pavers. The lead paver spread and consolidated the lower quality 7" section. The second paver which also utilized automatic guidance systems was used to spread the 4" high quality surface course. The material was hauled to the grade in agitor trucks. The 7" thick lift was spread with a Maxon side delivery spreader. This 7" lift was spread and consolidated 23½" wide and 7" deep. The surface was intentionally left very open texture to assure maximum bond between this and the surface course thus obtaining a monolithic section. The first lift constructed with the crushed P.C. and A.C. materials proved to be very harsh and unworkable. We later added natural sand to this mix to gain workability and maintain a reasonable air content. The final surface course was spread in front of the second paver by chutes from the agitor trucks. The second paver had no difficulty spreading and consolidating this mix. The finished product was indeed a very acceptable appearing roadway. The edges stood unusually well. The surface was textured by longitudinally dragging indoor/outdoor carpeting over the surface of the roadway. A very good appearing end result was obtained. All in all this was a very successful research project. I feel sure that contractors and equipment manufacturers will devise and use different equipment which will cut the costs even further on future projects.



Four inches of "A" mix is spread and finished over 7 inches of Econocrete.

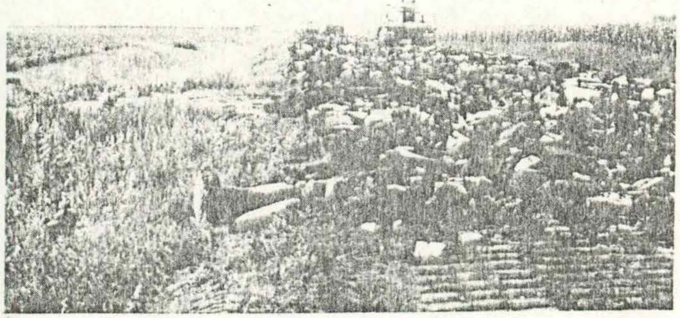


Completed section of 11 inch deep composite recycled concrete.

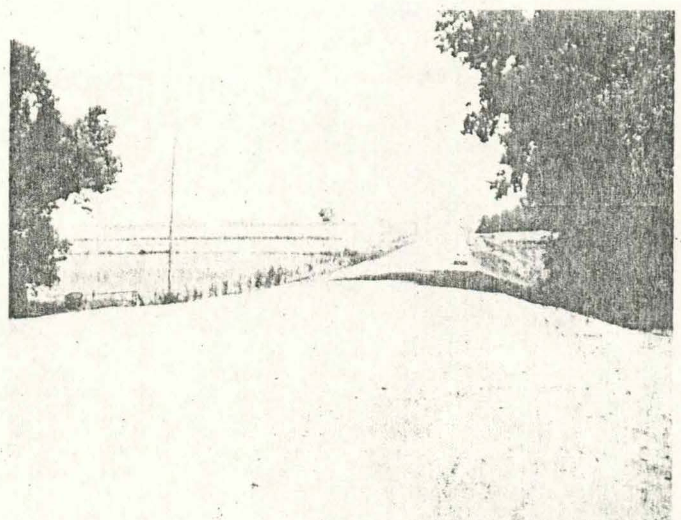
Recycling of asphalt is not quite as new or revoluntionary as recycling portland cement concrete. Many different methods have been tried. The benefits from recycling of asphaltic concrete materials may be greater than for recycling portland cement. This would be primarily true because in this instance we are recycling the bonding agent as well as the aggregate.

The 80,000 tons of asphalt materials which were recycled this year in Kossuth County was the largest single recycling project constructed in the United States to date.

For those of you who are not familiar with Kossuth County's problem I ask you to envision an old roadway which consists of a high, narrow grade with no shoulders, 3" of bituminous treated aggregate base and varying thicknesses of asphalt surface course. Most of this old asphaltic construction is 15-20 years old and has served very well. It was not designed however for the heavy farm machinery or the heavy loads of grain that are being hauled to market across these routes. Therefore, we have extensive failure on many of these relatively thin sections. This research project was designed to rip up the old asphaltic concrete, haul it to a plant site for crushing, and then lower and widen the high, narrow earthfill. Removal was accomplished with a ripper on the drawbar of a crawler tractor. The ripping operation also accomplished considerable pulverization. The asphaltic materials were then loaded with an end loader into trucks and transported to the plant site. The huge stockpile of asphaltic material at the plant was a combination of rather fine pit run sand with 2.9 percent asphalt in it, and asphaltic surface course material which contained 5-3/4 percent asphalt cement and the same fine pit run aggregate. The contractor succeeded in keeping these materials from segregating. The next step involved the crushing of this material to a 2" maximum size. The contractor, Maudlin Construction Company, was able to process in excess of 3,000 tons daily.



Roadway is broken up for removal and recycling.

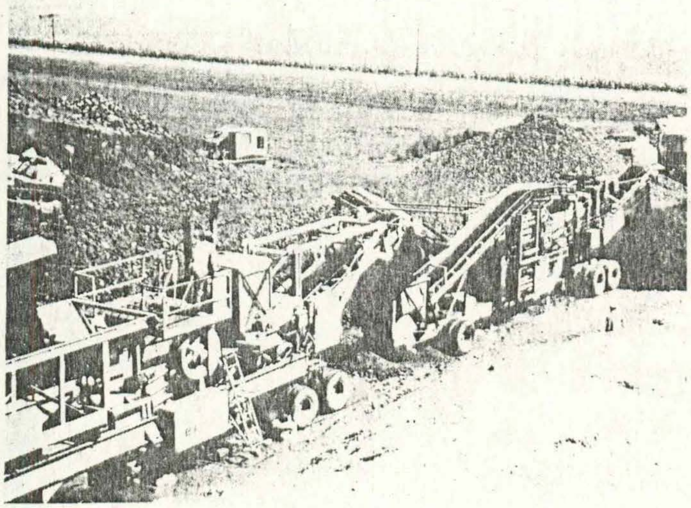


Roadbed is lowered and widened.

These materials were stockpiled adjacent to the dryer drum mixing plant as were the gravel and crushed limestone materials that were to be used in various proportions to control stack emission and improve gradation for the surface course mixes. The crushing contractor experienced very little difficulty in processing these materials. A very minor problem was encountered with a few fatty maintenance patch areas that built up in the crusher. There was some shale present in the material which did break down during the recycling process. The gradation of the finished product normally had more than 10 percent past the 200 screen.

Varying amounts of additional asphalt cement was added to try to evaluate the impact on the finished product and to assist in the control of stack emission. Our laboratory mix design had a target value of 8.25 percent which required us to add an average of slightly over 4 percent of new asphalt.

Everds Brothers Construction Company of Algona, Iowa and manufacturers of equipment tried hard to control stack emissions. Extensive modifications were made to the wet stack control system as well as the dryer burner. Inspite of all these efforts no sure fire method of emission control was developed on this project. This was not because the contractor did not try nor because we did not have completed cooperation from the environmental protection people. This does seem to be a monsterous problem that must be continually attacked by the industry.



Reclaimed asphaltic materials are crushed to 2 inch maximum size.

Asphaltic materials are recycled thru drum dryer mixer plant.

There were other research projects in progress at this time throughout the United States which claim to have mastered the emission problem. Unfortunately, all of them seem to be limiting the plant capacity to an unacceptable low level.

The mix produced from this dryer drum operation was trucked, spread and compacted in a very conventional manner. A bottom 4" lift was placed and consolidated without any difficulties that were mix oriented. The remaining 2" of the base was placed in the second lift. Some of this recycled base material was blended with virgin limestone and used to overlay another road. Three sections of new road were constructed using recycled material blended with gravel aggregate.

I feel this research project was a success in that we found and were able to isolate many of the problem areas. Also it was possible to estimate the possible financial savings on this type of construction which according to the Kossuth County Engineer, Dick Henely, is in excess of $20,000 per mile. He concedes, however, that these savings must be calculated for each project and that they are good only for the same set of circumstances.

We are very aware that escaping particulate matter must be reduced from its present value of 0.31 grains per cubic foot to less than 0.15 as required by Iowa E.P.A. and D.E.Q. The problem of hydrocarbon emission, which was evident at times as a blue haze, must be greatly improved in future recycling.

Kossuth County has programmed slightly over 1 million dollars for recycling asphalt construction in 1977. This includes some 58,000 tons of asphalt recycling on six projects.

From what has already been learned from previous attempts to recycle asphalt pavements, the following changes or experiments will be attempted:

(1) A concentrated effort will be made to leave the existing bituminous treated base on the roadway for incorporation in the new sub-base. It is thought that this very fine material containing a large concentration of asphalt is causing most of the emissions as it burns during heating of aggregates.

(2) A combination of 50% virgin aggregates and 50% recyclable aggregates will be used as part of the design mix. If pollution standards are met using these percentages, we will increase the percentage of recyclable material, hopefully reaching a point where all aggregates incorporated are recyclable.

(3) If pollution standards cannot be met under Specifications for Type B Class II, we will then use specifications for Bituminous Treated Base. This change will allow a 35° lower temperature in the mixing process.

(4) If these changes do not reach required pollution standards, we hope to use two heating and drying drums operating together - one to superheat virgin aggregates and the other to mix the super-heated aggregates, the recycled material, and the asphalt cement. This condition will likely defeat the project objective in that it does add an extra dryer to the contractor equipment requirements.

(5) In addition to the above, we are sure the equipment maufacturers and the contractor will have some ideas of their own on how to meet pollution standards.

Specific Research Objectives

The specific research objectives are:

1. To determine the effectiveness of drum mixing plant modifications specifically designed to control air pollution within the limits specified by the Iowa D.E.Q. when the plant is processing recycled asphalt concrete under field conditions. The first trial is to be conducted with the proportions to be 50 percent recycled asphalt concrete and 50 percent virgin material, the plant operating at standard mixing temperatures and at the manufacturer's recommended initial production rate.

2. To assess the impact of varying proportions of recycled and virgin material.

3. To assess the impact of varying the production rates of the plant.

4. To assess the impact of varying the mixing temperatures.

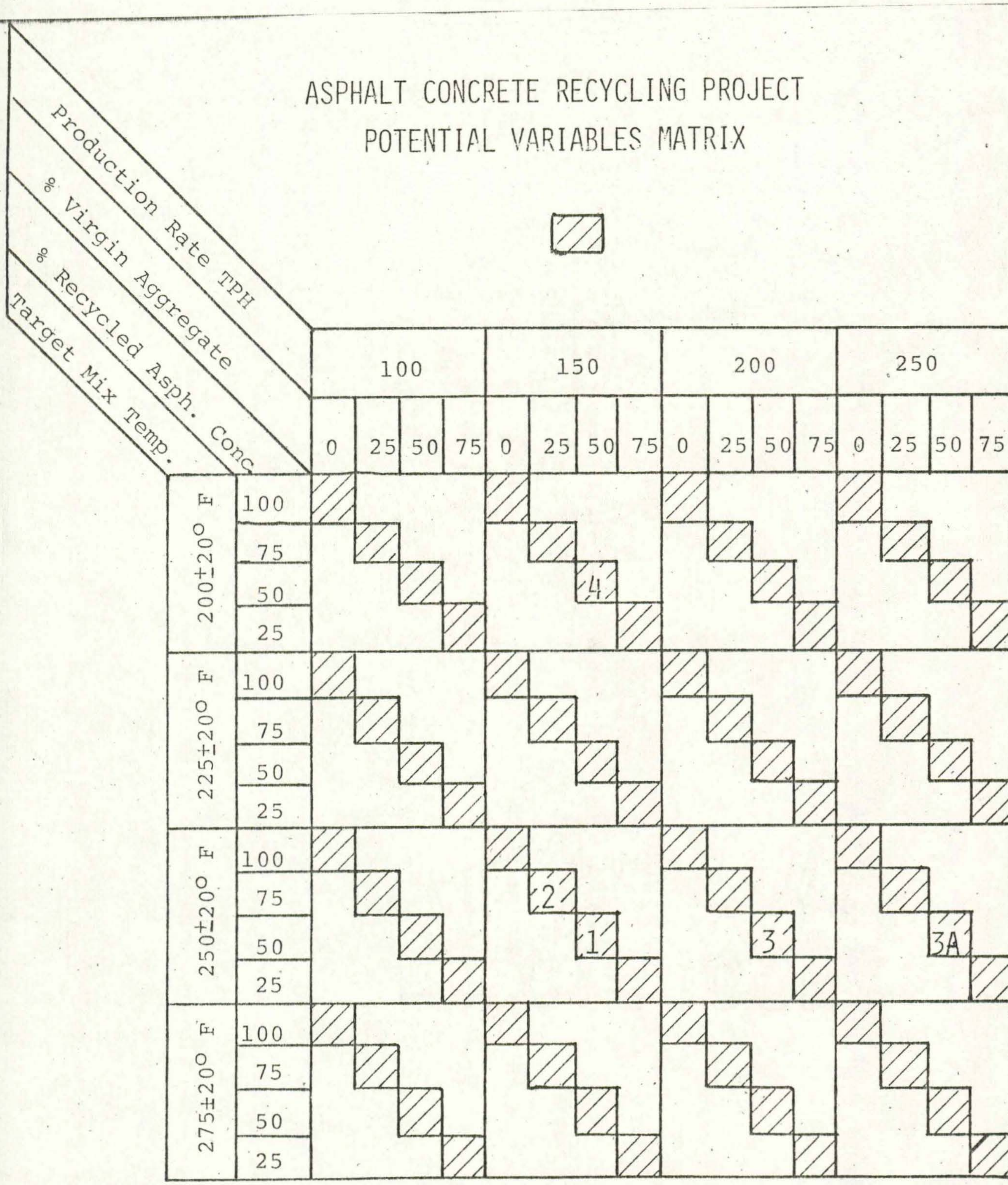
The following table demonstrates how many potential combinations of production rates, recycled asphalt concrete percentages, virgin aggregate percentages, and mixing temperatures that could be considered for evaluation on the project. The table does not include asphalt content as a variable. Asphalt content was not included because it is dependent on the combined material characteristics and will therefore, be subject to design criteria.

The tentative plan for pursuing the foregoing objectives is indicated by the numbered boxes contained in the table. This approach permits conceptual direction changes; for example, if the first (No. 1) trial does not yield satisfactory results, another preplanned combination can be tried (proceeding directly from Number 1 to 4).

I do not consider recycling to be a solution for all road construction projects. It is however another tool that the design engineer should consider particularly when the old material has to be removed. Other factors that would tend to lead you to conclude that recycling is feasible would be shortages of local available aggregates or unusually high prices for aggregates that are available. Ths probably would be influenced by the length of truck or rail haul which normally increases the price at 10¢ per ton mile or more. If you have to maintain surface drainage, overhead clearance under existing bridges, or match numerous existing intersecting grades you should consider recycling as a possibility. At this stage we should possibly not pay a premium for recycled aggregate. In my opinion we should look long and hard at recycling most all asphaltic materials. One choice that is available to the engineer is the accummulation of waste materials at some central location until the quantities become large enough that you can afford to let a recycled project. Think twice before you throw away any old portland cement concrete or asphaltic concrete materials. The Lord provided us Americans a super abundance of raw materials but we seem to have used up many of these materials at an alarming rate. We must recycle to conserve our limited resources and keep construction cost down. This is a major challenge to our generation.

We must learn how to recycle highway materials if future generations are to have highways. With the help of GOD our grandchildren will recognize this problem as only another troublesome inconvenience that American Know How overcame.

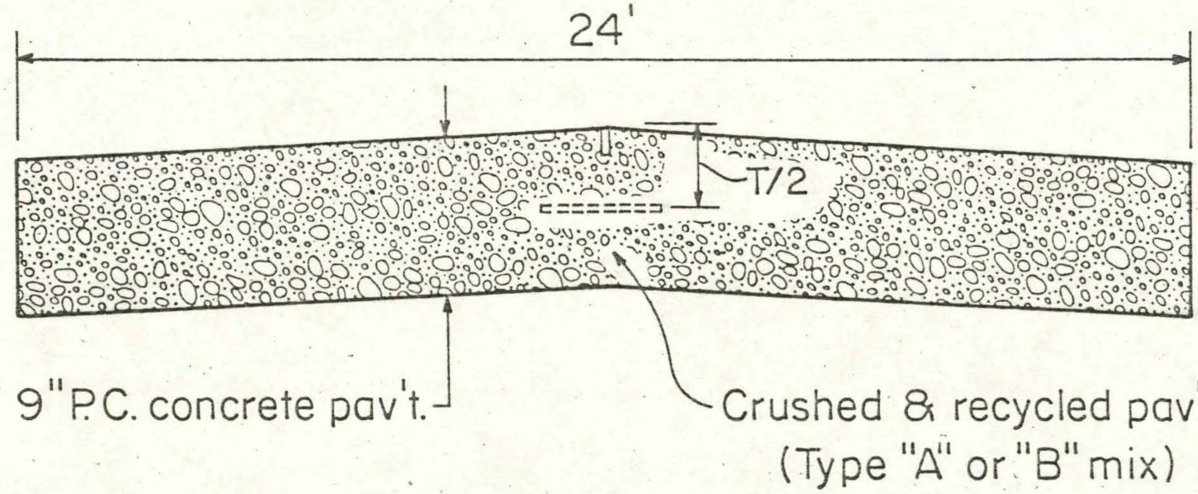
ASPHALT CONCRETE RECYCLING PROJECT
POTENTIAL VARIABLES MATRIX



IOWA D.O.T.

Recycled Pavement Project

U.S. 75



IOWA D.O.T.

Recycled Pavement Project

U.S. 75