GRADED MIX ROADS IN MISSOURI

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The construction of "graded mix" type roads in Missouri during 1937–38 was confined to providing bases for thin bituminous wearing course treatments. The availability of materials for such mixes was the determining factor for employing this type of construction in particular localities. The materials included local crushed limestone, chert gravel and chert mine tailings. There has been no opportunity to use plant mixed materials. From general observation in the conduct of work of this kind, a fairly standardized method for the purpose has developed.

Prior to 1937 stabilization design specified a thickness of approximately 3 in. and a plastic index of about 10. The minus No. 40 fraction was held to 30 percent or slightly higher but a few trial sections soon showed that better results could be obtained when both the P. I. and the percentage of fines were designed for lower limits.

Further developments indicated that a greater thickness was desirable and subsequently the depth of stabilized compacted material was increased to 6 in. mixed in one course and compacted in thin increments by sheepsfoot tampers. This increase in thickness gave indications of value which more than balanced the extra cost of additional material because of the better support provided for the thin armor coat. Approximately 40 miles were built on which the one course method of construction was used with a thickness of about 6 in. of compacted material. The indications are that this type of construction will give continued service as a satisfactory low cost base.

However, it was felt that considerable economy could be effected in a great area of the State by utilizing the gravel contained in the subgrade. Wherever this rock or gravel occurs it is brought to the surface by scarifying, the oversize is crushed, more aggregate is added if necessary and all the granular material is mixed with the binder and compacted at optimum moisture. This method is used successfully in the southern part of Missouri because of the prevalence of suitable subgrade material. In other areas of the State, such favorable conditions are not often found and it is necessary to stabilize the subbase by incorporating into the scarified subgrade designated quantities of granular material, and compacting.

The earlier design was based on the existing thickness of gravel mat and the necessary additional thickness of closely specified clay-aggregate mixture was required to be constructed in one course. The mixing, spreading and compaction of this amount of added material, between 40 and 60 cu. yd. to the station, was a difficult construction problem and later work was designed to provide for first incorporating additional aggregate in the existing scarified grade in order to build a five to six inch subbase of satisfactory gradation and density. Careful preliminary sampling of the roadbed was required in order to determine the character and amount of material to be added as well as to provide for the correction of any local unstable conditions. The mixing in this step was accomplished in much the same way as cement is incorporated in cement stabilization. The manipulation and road mixing of bulky windrows was not necessary. The subbase material was finished off and compacted to grade and section at its determined optimum moisture. The standard density obtained at optimum moisture was required

for the final density in the completed subbase.

The next step was to mix, spread and compact a 3-in. course of closely controlled graded mix. This amount of material was easily and efficiently manipulated on the compacted subbase and after compaction and rolling produced a uniformly textured and stable surface.

The Missouri State Highway Department has found this method of construction to be very satisfactory. Exact control of the subbase design is not as essential as is the case with the top course but it has been found that, in general, test results will closely approximate those on the surface layer.

Two particular jobs in Carter County, constructed of the same materials, but differing in design and construction methods, offer a particularly interesting study of the relative values of the stabilization methods.

Construction of a monolithic aggregate-clay stabilized surface course 22 ft. wide on Route 103-AP, Carter County, extending from Van Buren south to Big Springs Park, a distance of 4.1 miles, was begun in May, 1937. Just prior to the design of this particular project a condition survey of the existing road surface was made. From Van Buren south the first three miles of the route lie over unusually rough topography. Fourteen to eighteen percent grades are common and imposed no small handicap in both mixing and compacting operations. Over the same three miles a highly plastic, rocky, red clay subgrade underlies a wearing course averaging 2.7 inches in thickness. The remaining 1.1 miles lie along a stream flat, the subgrade consisting of a non-plastic sandy loam under a wearing course approximately 3 in. thick.

Locally produced chert gravel from Current river was windrowed along the route at the rate of approximately 32 tons per station, a quantity which together with the added clay was estimated to produce a compacted thickness of 3.5 in. Immediately upon beginning aggregate production it became apparent that due to the coarseness of material in the stream bars, it would be extremely difficult to hold the aggregate gradation within the limits of the specified guide.

A low percentage of minus No. 40 material made it necessary to add an unusually large amount of clay or clay and sand in order to bring the final mixed material well within the specified gradation so that a high resultant base density would be possible. It was estimated that 420 lb. of material passing the No. 40 sieve per ton of aggregate must be added and this was to be of low plasticity since the amount of non-plastic fines in the aggregate was extremely low. Fortunately, a bank of sandy clay located nearby with a plastic index of 11.0 was available and made it possible to design a mix which, when compacted at an optimum moisture content of 8 percent, gave a dry weight of 120 lb. per cu. ft. and in which the minus No. 40 material ranged in plasticity from 5.0 to 8.0.

TABLE 1

Final Mix Specification		Average Obtained
	%	%
Passing 1-in. Screen	not less than 100	100
Passing ¾-in. "	" " " 85	92
Passing No. 4 Sieve	40-75	55
Passing No. 10 "	30-55	43
Passing No. 40 "	20-35	25
Passing No. 200 "	10-20	13
Plastic Index	4-12	6

When aggregate production was well under way the addition of clay to the gravel windrow at the rate of 6.4 tons per station was begun. Pulverizing the clay was found to be unnecessary since the intimately mixed sand and clay of low plasticity did not appear to form clods when handled at the field moisture content, approximately 17 percent.

Shortly after the materials had been

windrowed along the south flat section a heavy rain permitted mixing at almost the consistency of a slurry. After bringing the surface of the existing road to a typical section, two units, a motor grader and a tractor and blade quickly and efficiently obtained a uniform mix. Materials on the north 3.0 miles were mixed dry by the same two units and it was here that due to the steep grades mixing became extremely difficult.

As soon, however, as an acceptable mixture was obtained it was evenly spread, water was applied until the optimum was reached and compaction begun with a sheepsfoot tamping roller. Here again considerable difficulty was experienced in obtaining a well compacted base on the steep grades. There was a tendency for the feet of the roller to slip in the semi-loose material and promote segregation, rather than compaction. This was particularly true on superelevated curves on grade. Traffic and construction trucks furnished the necessary compaction on these spots.

At that time contracts for bituminous surface work and base stabilization were let separately and in this instance the surface was left unsealed through the dry months of June and July. The combination of slightly inferior compaction in spots, intensification of surface abrasion by extreme grades and low plasticity of the dry base produced excessive raveling. Shallow potholes developed in the surface. Immediately prior to application of the prime coat, an attempt was made to fill the depressions and smooth the surface. This was done, however, with loosened material somewhat variable in gradation and in most instances a perfect bond with the stable base was not achieved.

Soon after completion of the thin armor coat, the shallow filled depressions loosened, breaking the seal coat and giving the surface a rough pitted appearance. This was true only on the rolling 3-mile section. After these initial surface failures had been resealed no others appeared and none could be classified as sort developed on the short section along true base weaknesses. No failures of any the stream flat which had been mixed wet, well compacted and which suffered less abrasion before sealing.

The construction difficulties experienced in attempting to road mix the large yardage of material required for the base, within the narrow limits of shoulders and on the grades encountered on this project, were felt to be responsible for the raveling and pitting. This suggested a change in method, as described later, which, while involving two course construction, shortened the mixing time, produced a good finished mix and compacted the material to a dense and stable condition.

A contract let in December, 1937, called for the construction of a stabilized surface course 24 ft. wide and a bituminous surface treatment 22 ft. wide on Route 34 from Van Buren to Keeney's Corner, a distance of 3.7 miles.

Work was begun in the late winter and carried through an unusually wet spring. The stabilized subbase was laid directly upon a raw subgrade chiefly of rocky, heavy red clay, the grading having been completed that summer. Chert aggregate for the subbase conforming to the following specified gradation was spread on the existing surface of the road-bed at the rate of 40 tons per station.

Subbase Aggregate	
Passing 1½-in. Screen	100%
Passing ¼-in. screen not more than	65%
Passing ¼-in. Sieve	15–45%

After the aggregate was spread over the roadbed from shoulder to shoulder the existing surface was scarified to a depth sufficient to loosen enough binder material for the subbase. The loose material in place was then thoroughly bladed until it was well mixed and contained sufficient binder, in the opinion of the engineer.

Shortly after a considerable section had been scarified a heavy snow fell and upon melting saturated the loose material and underlying subgrade. Subsequent rains held up operations several times and made it very difficult to control the amount of clay binder in the mix. The rains also saturated the subgrade to such an extent that compaction of the stabilized material was impossible until it was bladed off and the roadbed allowed to dry. In several instances rubbery spots developed in the compacted surface days later as a result of saturation of the subgrade.

Compaction of the subbase was performed with sheepsfoot tamping rollers at a moisture content that would insure proper compaction. At least 90 percent of standard compaction was required. Maximum weights obtained ranged from 111 to 129 lb. per cu. ft. The wide range was due no doubt to the wide variance allowed in aggregate gradation and the lack of control in supplying a uniform binder content as well as to a somewhat variable quality of subgrade soil. It was not desired to eliminate all tamper marks from the surface of the compacted subbase as it was the intention to leave the top of the subbase in such shape as to aid in bonding the stabilized surface course. This, however, allowed subsequent traffic which was carried over the job during construction to loosen the surface of the subbase slightly, particularly the larger particles of aggregate. Thus in mixing the surface course considerable material over 1 in. in size was incorporated in it.

After completion of the subbase, aggregate for the surface course produced from the same bar as that used on Route 103-AP, and of approximately the same gradation was windrowed along the project at the rate of 25 tons per station. The same mix design was used and clay from the same clay pit was windrowed with the gravel at the rate of 5 tons per station.

After thorough mixing by blading back and forth across the road while dry the following average gradation was obtained:

Passing 1-in.	98%
Passing ¾-in.	87%
Passing No. 4	50%
Passing No. 10	39%
Passing No. 40	27%
Passing No. 200	14%
Plastic Index	8

This course, too, was compacted by means of a sheepsfoot roller at optimum moisture. Densities of approximately 122 lb. per cu. ft. resulted. A flat steel roller was used for final compaction and smoothing.

Immediately upon completion of the base course an armor coat was applied. Even at this late date soft spots appeared in the base as a result of saturation of the subgrade by the spring rains and it was found necessary in places to reopen the base and allow it to dry before recompacting and sealing. This corrected the spongy condition and a fine, smooth riding surface was obtained and to date only one failure has occurred.

While clay-aggregate stabilization was being developed in Missouri the primary consideration was to obtain a plastic index of about 10. It was thought that a clay content that would give such a result would provide sufficient binder to produce a tightly bound and serviceable all weather road. At present, however, it is felt that more importance should be attached to the density of the mixture.

It has been found that a thin bituminous armor coat will, in Missouri, give best service when placed on a clay-aggregate stabilized base which has been designed for maximum density when compacted at optimum moisture, which has a plastic index of 4 or less and a minus No. 40 content of 20 to 25 percent. In such circumstances the base can be primed

immediately after complete compaction and the armor coat applied when the prime is cured. Thus, regardless of the low P.I., little or no ravelling occurs and the resultant riding surface is smooth, tight and weather resistant.

The distribution of easily available, local granular material in Missouri is such that this type of construction fits into the construction of low cost roads for at least one-half of the area of the State. In some localities, water-bound macadam bases constructed with much the same density control, and only slight variation in method, may be an improvement over this type.