Cold-Mix Construction Considerations With Cutback Asphalt

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•THE TERM "cold mix" is normally used in Kansas to describe the mixing process of a soil and/or an aggregate with a cutback asphalt without heating the aggregate except by the Sun. In general this process involves some or all of the following seven steps:

1. Initially placing a windrow of aggregate on the roadway to be surfaced;
2. Reducing the moisture content to a suitable value by blade mixing;
3. Equalizing it to a uniform cross section;
4. Adding a cutback asphalt by means of suitable mixing and/or distributing equipment; (The previous steps can be eliminated if nornal plant-mix methods are employed utilizing a dryer.)
5. Manipulating the material with blades and tillers to aerate the volatiles, further reduce the moisture content, and thoroughly mix the combination;
6. Spreading it over the roadway in thin lifts; and
7. Compacting it by suitable rolling equipment.

There are, however, other problems that result from the aggregate selected, the types of equipment used, and the prevailing weather during the course of construction. These are the problems with which this paper is concerned.

AGGREGATE SELECTION

Of primary importance is the availability of suitable material in the immediate vicinity of the proposed project. A thorough knowledge of prospective locations and related characteristics enables economic aggregate selection, reduction of unexpected aggregate problems, and accurate engineering estimates.

Most Economic Aggregate Selection

The physical characteristics of the material, such as gradation, plasticity, wear, soundness. absorption, and specific gravity, dictate the type of surface design, probable thickness based on given conditions, and the economics of its use. The criteria for the determination of the relative worth of a particular material with regard to these properties for use in bituminous stabilized mixes have been reasonably well established in Kansas as it has elsewhere. Existing specifications (3) differentiate between the best cold-mix material and the poorest by varying properties to fit local aggregate conditions. In general, revisions to the specifications vary only the gradation, screen spread, and plasticity index (PI) for all classes of cold-mix material while maintaining other quality requirements at a constant value. The decision to be made with regard to use of a local deposit must be based on its economy in relation to the thickness needed for a given traffic volume and the amount of asphalt required. This must be compared to the use of less thickness of a higher grade material with a resultant saving in asphalt but increased cost in material and, possibly, transportation if the material is not local in origin.

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In Kansas the determination of surface thickness is predicated on the triaxial method of design (1), which has been used continuously since 1945 and includes the testing of each component of the roadbed structure. The subgrade and the proposed surfacing materials are each tested separately to determine the thickness of the selected surface course through the use of the following modification of a formula presented by Palmer and Barber (2):

$$T = \sqrt{\left(\frac{3Pmn}{2CS}\right)^2 - a^2}\;\sqrt[3]{\frac{C}{C_p}} \qquad (1)$$

in which

T = thickness required,
C_p = modulus of deformation of surface course,
C = modulus of deformation of subgrade or subbase,
P = basic wheel load (single wheels),
m = traffic coefficient based on volume,
n = saturation coefficient based on rainfall,
a = radius of area of tire contact corresponding to P and m, and
S = permitted deflection of surface.

The stress-strain curve is used for determining the modulus of deformation of the material being tested and is the secant modulus between the two points on the stress-strain curve limiting the range of stress determined or the stress difference divided by the strain. Typical triaxial modulus of deformation values for the surfacing materials used in Kansas range from 5,000 psi for the fine-graded, cutback-asphalt stabilized-base courses to 25,000 psi for the most densely graded surface courses mixed with an asphalt cement.

The traffic coefficient, m, is assigned a value in accordance with anticipated traffic volume as forecast by traffic studies for the number of years the pavement is designed to serve without heavy maintenance. It varies in increments of $\frac{1}{8}$ from a minimum value of $\frac{1}{2}$ corresponding to a traffic volume of 50 to 400 veh/day to a maximum value of $\frac{12}{8}$ representing 13,501 to 20,000 veh/day.

The saturation coefficient, n, is based on the average annual precipitation in the area of the proposed project. Inasmuch as all designs are based on test results from saturated specimens, the design formula must be modified by the appropriate coefficient. This value varies in increments of 0.1 from a minimum of 0.5 corresponding to a precipitation range of 15.0 to 19.5 in. in the western part of the State to a maximum of 1.0 representing 40.0 to 50.0 in. in the southeastern counties.

With this system, the structural thickness of any type of flexible surface course, base course, or subbase may be computed, once the basic data have been obtained from tests, by means of the following formula when the term, T, from the basic formula has been computed:

$$t_t = (T - t_p)\sqrt[3]{\frac{C_p}{C_t}} \qquad (2)$$

in which

t_t = thickness of base course or subbase,
T = thickness of flexible pavement required directly on the subgrade,
t_p = thickness of flexible pavement desired in the combination,
C_p = modulus of deformation of flexible pavement, and
C_t = modulus of deformation of base course or subbase.

TABLE 1

EQUIVALENT THICKNESSES AND TRIAXIAL MODULUS VALUES OF VARIOUS BITUMINOUS STABILIZED MIXES

Surface Course	C_p (psi)	T (in.)
Hot mix	25,000	6
Cold mix:		
Dense-graded	15,000	7
Fine-graded	5,000	10

This formula establishes the relationships given in Table 1 for various types of presently used bituminous stabilized pavement components.

A number of specifications has been adopted in Kansas (3) to fit the wide range of materials utilized in both cold-mix and hot-mix asphalt stabilization projects. The specifications considered here are those presently used for the construction of new surfaces or resurfacing projects on both the State and county highway systems, by contract, as well as those dealing with acquisition of bituminous patching aggregate by contract. In addition to specific grading bands or limits, provisions have also been included to allow the use of special aggregates such as dune sand or other economical materials occurring on or adjacent to a project site. In many instances such an aggregate exists at a particular location and is well suited to a road mix but is not universal enough to be included as a standard specification. Efforts have also been made to determine how and where some of the marginal materials, such as those which have a high PI or a high absorption value, may be used.

Reduction of Unexpected Aggregate Problems

The physical properties and the extent of the deposit can be determined by obtaining samples from pits or probe holes and submitting them to the laboratory for analysis. However, to date, only by experience can the engineer or the contractor know the problems which a given material may present as a result of characteristics not always measurable by the laboratory or controlled by specifications. One of the most important of these concerns the degree of pulverization of the mix that is obtainable with ordinary mixing and pulverizing equipment. The result of pulverization is the production of "effective fines," generally considered to be that portion passing the No. 200 sieve. Material of this size is necessary to obtain stability, and fines introduced as dry, hard clods or tightly cemented to the coarse aggregate will not produce effective fines by normal mixing methods. The present Kansas Highway specifications require that a percentage of the total minus No. 200 mesh material as determined by washing and dry screening pass the No. 200 mesh sieve by dry screening before washing. Because these characteristics are not always apparent without moisture, the material may appear highly satisfactory if the deposit is dry and may meet the gradation and PI requirements, but if subjected to a series of rains before addition of asphalt, the problem of pulverization may be of utmost concern. This is usually brought about by an aggregate which has a thin, highly plastic clay coating on the coarse aggregate to which the granular fines adhere. In wash tests, both the clay coating and the granular fines appear as effective fines, whereas the PI of the clay coating may considerably exceed the specification value. Because the PI is determined by percentage of material which passes the No. 40 mesh sieve, that of the clay may be reduced to an acceptable figure if sufficient fine sand is present in the material. This possibility is not indicated by the PI nor can these conditions be readily duplicated in the laboratory. Some of the detrimental aspects of this condition are as follows:

1. The necessity for and the cost of adding additional mineral filler because the minus No. 200 mesh material in the mix cannot be made effective by normal means of pulverization;
2. The cost of repairing failures due to the stripping of the asphalt from the coarse aggregate, because it is coated with clay and fines which prevents the asphalt from directly contacting its surface; and
3. The "raveling" and degradation of the riding surface of the roadway resulting from the loss of aggregate by the poor bond between the coarse and fine particles.

Accurate Engineering Estimates

A thorough knowledge of local aggregate deposits and their characteristics provides the only means of making an accurate engineering estimate of the cost of a proposed project for budgeting or bidding purposes.

The attempt has been made to emphasize aggregate selection as a major consideration in the construction of any asphalt-stabilized surface.

MIX DESIGN

The first cold-mix asphalt surface in Kansas was constructed on US 50 in Stafford County near Zenith in 1930. It was constructed 3 in. in depth and 22 ft wide and performed very satisfactorily with normal maintenance for 28 yr. It was constructed in part from gravel existing on the roadway plus a graded washed gravel, a pit-run sand, and volcanic ash as a mineral filler. In general, the mix was considerably coarser than any cold-mix mat or base built under present Kansas specifications. Both laboratory and field results indicated an average of 35 percent of the material retained on the No. 8 sieve with 5.5 percent passing the No. 200 sieve. Current specifications for cold-mix surface course material in Kansas allow a minimum of 25 percent retained on the No. 8 sieve, whereas some of the bituminous-stabilized bases require only 15 percent. These reductions in over-all coarseness of present-day specifications were made to adjust them to more nearly fit existing aggregates for economy as well as to conserve deposits of material.

The information used in the construction of the first cold-mix surface was obtained from New Mexico, and present-day methods of mix design and determination of the proper asphalt content have changed very little. From time to time changes have been made in grading requirements, but this was done, primarily, to make the specifications meet the gradation of an existing aggregate deposit rather than to improve the stability or life of the mix. Recently, however, increased emphasis has been placed on the effective fines aspect of each specification with a marked improvement in the immediate stability of the compacted surface. This does not imply that no attempt has been made to improve the design method but rather that very little has been learned which would make any radical or obvious change.

Kansas was one of the first States to adopt the triaxial compression test for the determination of rigid and flexible pavement thicknesses and of stability of soils. It was on the basis of results obtained from triaxial tests that the PI was limited to a maximum value of 6 for the individual aggregates as well as the combined material for bituminous mats. This PI value was determined from a comparison of the moduli of deformation of specimens molded from bituminous-stabilized cold-mix materials submitted to the laboratory from projects throughout the State. In each case, a minimum of two specimens were molded, and one was saturated with water before testing. In any mix with a PI value greater than 6, the modulus of deformation of the saturated sample was greatly reduced as compared to the sample which was not saturated.

Efforts have been made for years to use the modulus of deformation as an indication of optimum asphalt content in bituminous-stabilized mixes, but, in general, no peak occurs. Instead, a very flat curve results which cannot be utilized to indicate this point, but if extended by additional samples at higher asphalt percentages, a sharp drop in the curve takes place indicating the maximum asphalt content which can be tolerated in a particular mix. A comparison of the moduli of deformation values (Table 2) provides a means for increasing or decreasing the proposed surface thickness based on results obtained from cold-mix specimens tested over a period of years.

Attempts have also been made to adapt Marshall equipment to cold-mix design problems without much success even though the specimens were tested at room temperature. It was necessary to modify the practice of placing Marshall specimens in a 140 F waterbath for 20 min before testing because specimens molded with cutback asphalts will either slump or show no stability at this temperature.

Uniform aeration of the volatile portion of a bituminous material stabilized with cutback asphalt is of major importance in all mix stability determinations in the laboratory. Because the volatiles act as lubricants, the aeration time must be increased with

TABLE 2

TRIAXIAL MODULUS VALUES FOR TYPICAL GRADINGS[a]

Type	Percent Retained on Sieve													Asphalt Content[b] (%)	Density[c] (pcf)[3]	Triaxial Modulus 100 F (psi)
	Inch			Number												
	1	3/4	3/8	4	8	16	30	40	50	80	100	200				
BC-1	0	2	8	15	27	41	54	63	73	83	85	89		4.2	131.2	6847
BC-1	0	5	17	21	31	47	66	75	82	87	88	89		3.6	133.0	6973
BC-4	0	5	9	14	22	36	54	65	77	88	89	92		3.3	129.7	5343
BC-4	0	0	3	8	21	38	57	—	76	85	87	90		3.8	130.8	5483
BC-5	0	0	1	6	18	36	54	65	77	86	87	88		3.9	131.6	4800
BC-5	0	0	2	7	21	42	59	69	79	85	86	88		3.3	132.5	4927

[a]Samples were removed from windrows at completion of aeration and mixing. All were mixed with MC-4 grade cutback asphalt.
[b]Based on dry weight of aggregate and determined by a reflux-type extractor.
[c]Value is 95 percent of Marshall density obtained on same material (50 blows to each side of specimen at 140 F).

the asphalt percentage to maintain a constant relationship of the percent volatiles retained between all specimens. This is difficult to accomplish with small samples where an oven is used as a heat source and where the volatiles retained must be determined by distillation. It is probable that this is a part of the answer for the variations which result in using either the triaxial or Marshall equipment to determine the stability of a mix.

For the bituminous-stabilized surface and base courses utilizing cutback asphalt which are constructed under present Kansas specifications, the use of either or a combination of the results of the Nebraska or the New Mexico formulas (Appendix) generally provides a reasonable starting point for field determination of the proper asphalt content. These formulas are based on the surface area of the material. For extremely fine mixes, the only source of information as to asphalt content is previous experience with these materials because they are too fine for either formula to give a satisfactory answer. Either of these formulas could possibly be corrected to make suitable allowance for the increased surface area.

The preceding discussion indicates that very little guidance or positive answers to cold-mix design problems can be given by the laboratory with regard to the optimum asphalt content.

CONTROL OF MATERIALS

The success of any well-designed surface or base course depends on the uniformity of construction, particularly with regard to the materials involved. The two components, aggregate and asphalt, present individual problems which are considered separately in the following discussion:

Aggregate Distribution

The fundamental concept of most multiple-aggregate mix designs is based on the various materials being combined on a weight basis. The actual methods employed for distributing aggregates in their proper proportions are well known by anyone who has ever been concerned with this type of construction; however, they are rather crude as are many other aspects of cold-mix construction.

In asphalt-stabilized mixes gradation is usually considered to contribute a major part to the stability. Stability is generally conceded also to be some measure of the load-carrying capacity of a surface. Each type of asphalt-stabilized mat or base has a particular load-carrying ability which is used in determining the thickness requirements for a particular proposed surface. As a result, it becomes imperative that if uniform stability is to prevail, every means within reason must be employed by both engineer and contractor to produce the material uniformly from the deposit and combine it on the road as accurately as possible. This can only be done by cooperation on the part of both parties involved, and by an understanding of each others problems.

The engineer must accurately sample the materials which the contractor has selected for use and determine their physical properties before a combination can be calculated which will meet the specifications.

The engineer must keep in mind at all times that the contractor had obviously made some preliminary calculations using these same aggregates in order to establish a bid price and that his success or failure, economically, depends to a certain extent on using these same percentages. The greatest percentage of the cheaper material should always be used in mix calculations unless it will impair the quality of the mix or a mutual agreement concerning the addition of a more expensive material has been reached with the contractor.

The lower cost material is generally a pit-run aggregate, and although cheap to produce, it could be more expensive in the end for the contractor unless the deposit is very uniform in grading and is worked properly. Once the various percentages of the individual aggregates have been determined, it becomes the contractor's responsibility to continue to produce material with uniformity and of the same quality and grading.

Some of the combined windrow samples may fail to meet the specification requirements unless the material is thoroughly mixed at the pit, a fairly elaborate screening plant is used to process the aggregate, and/or exceptional care is taken in placing the individual aggregates on the roadway. An additional problem results from the tendency to produce individual materials with only the minimum amount of coarse aggregate required to meet the lower specification limits because of the cost involved.

The cost of additional material to correct any discrepancy, determined by windrow sampling, must be borne by the contractor if the surface being constructed is one in which the total plan thickness is being laid in one lift, or the tonnage already on the road equals plan quantities. A representative windrow sample must be obtained to prevent a serious loss to the contractor of both time and money. If the engineer is satisfied in all respects that the material does not meet specifications, it should be determined whether the error is of sufficient magnitude to require correction. At this point it is well to know that specification limits were established: (a) to provide a means of control, (b) to maintain a gradation range which will produce a stability satisfactory for design thickness, (c) to fit local aggregates, and (d) to provide a common basis for competitive bidding in the case of projects constructed by contract. If the deficiency can be justified on the basis of these reasons, the contractor should be allowed to proceed. The difficulty of producing and combining the various aggregates into a suitable mixture emphasizes the necessity for the cooperation of all personnel engaged in this type of construction.

Asphalt Distribution

Whether the asphalt percentage calculated for a particular mix has been determined by the laboratory, by formula in the field, or from experience alone, control of asphalt content must be as strict as possible. The argument of whether the asphalt content is too high or too low for a particular mix will probably continue until an absolutely accurate means for its determination under all conditions has been found. In any case, close supervision of a number of operations is a necessity to produce a finished surface uniform in asphalt content. Areas or sections with an excess of asphalt must be removed because a surface constructed of this material is unstable and will eventually corrugate or rut.

The windrow of material must first be absolutely uniform in cross-sectional area, as well as gradation. This condition is a necessity for proper operation of most equipment used to add asphalt to the aggregate. The types of machines used may be the ordinary asphalt distributor, a traveling plant which picks up the entire windrow and runs it through a closed pugmill where the asphalt is introduced, an open-bottomed traveling pugmill which straddles the windrow and adds the asphalt during the mixing process, or a rotary tiller-type mixer with an attached spray bar. In all cases, constant speed on the part of the machine is absolutely necessary to obtain a consistent asphalt percentage. If constant speed is not maintained, sections with an excess of asphalt will be produced. Speed is most often interrupted by an extremely large windrow which causes the machine to slow down momentarily due to overload.

These machines are, in general, equipped with positive displacement asphalt pumps which deliver constant volume at any constant pump speed; however, asphalt content is calculated on the basis of a percent of the dry weight of the aggregate. This makes it necessary to have an accurate calibration of the pump output through its speed range in order to make corrections for the variations in temperature of the asphalt used during the course of construction.

MIXING

Aggregate and asphalt mixtures are generally either road mixes, plant mixes, or a combination of both procedures. Because each method has its own unique problems, they must be considered separately.

Road Mix

Nearly all cold-mix material in Kansas is mixed on the roadway by motor graders and rotary tillers. The initial mixing is usually accomplished by the particular machine used to add the asphalt to the windrowed material, but it may be added to a uniform lift (spread over the roadway) by a conventional asphalt distributor in not less than three applications per inch of base thickness. Initial mixing, if properly performed, can be the most effective period of all. However, it is often felt that as long as the proper amount of asphalt is distributed per unit length of windrow, the blades and rotary tillers will break up the oil balls and complete the mixing. When the weather is extremely hot and dry, this procedure generally works satisfactorily, but the question arises as to whether a black windrow is evidence of satisfactory mixing. By past and present standards satisfactory mixing is gaged only by visual inspection based on uniform color; however, some of the coarse aggregate which is always difficult to coat may only be discolored and not have a sufficient asphalt film thickness to provide a satisfactory bond. The asphalt is at its highest temperature during this particular part of the mixing phase, and as a result, its viscosity is lowest. Lowered viscosity results in a reduced film thickness, which allows a greater number of aggregate particles to be coated. A windrow of a size which allows all material to be agitated by the pugmill blades will further the success of this operation.

In addition to coating all aggregate particles throughout the entire windrow, the mixing phase releases the volatile portion of the cutback asphalt and the moisture. The cutbacks generally used in Kansas for road-mix construction are medium curing type. The diluent added to the base stock serves to lower its viscosity, allowing it to be fluid at normal summer temperatures. A portion of this diluent or volatiles must be removed by aeration before the asphalt will become tacky enough to develop a bond between aggregate particles sufficient for mix stability. For practically all road-mix construction in Kansas, an MC-4 grade of cutback asphalt is specified. The present specifications limit the diluent to a maximum of 15 percent by vol and require that at least 30 percent by wt of the volatiles present in the cutback asphalt at the time of mixing with the aggregate be removed before the actual laying and compacting of the mix can begin.

Because the percentage of volatiles in cutback asphalts can vary widely, it may be more desirable to limit the amount of volatiles which may remain in a mix rather than to specify the percent which must be removed. The percentage selected must be less than any volatile content supplied by the cutback producers to be any more significant than that established by the present specifications inasmuch as all grades of cutback asphalt will require some aeration.

Over a period of years, the specifications for cutback asphalts have become more stringent. This has been accomplished by more rigid controls of the distillation requirements affecting the diluents that may be used and by limiting the variation of penetration of the base stock from any one producer to 50 points during a construction season. These changes have produced more consistent results from project to project where the cutback is supplied by different producers.

Road-mixed projects, quite frequently, are also plagued by the weather. The specifications allow asphalt to be added to the windrowed material when the moisture content is 4 percent or less of the dry weight of the aggregate for predominantly sand mix or 3 percent plus one half the moisture absorption of the aggregate for other aggregates. After the asphalt has been added, the mix cannot be laid until the moisture content is less than 1 percent of the total weight of the mix. When projects are subjected to a series of rains, the cost of drying out the windrow each time quickly reduces the profit in the job for the contractor. In many instances additional material must be hauled to supplement that which was washed away by a torrential rain.

Each time the windrow is aerated to reduce the moisture content, volatiles are released. This condition is desirable initially but may be detrimental to the success of the job if enough volatiles are lost to make the mix brittle and difficult to lay. Rain and cold weather make road mixing hazardous in cost to the contractor and in the quality of the finished product.

Plant Mix

Although plant-mixed cold-laid materials are rapidly becoming common place throughout the highway industry, Kansas has had relatively little long-term experience in this field.

Two projects have been built utilizing the continuous-mix type of hot-mix plant; one approximately 15 yr ago on the county secondary system and the other nearly 10 yr ago on the State system. With the advent of the Interstate Highway System, this type of construction has been utilized for bituminous-stabilized base course material on approximately 20 mi of Interstate 70 in Trego and Gove Counties during the past 3 yr. These were not cold mixed, however, because the aggregates were heated, but a cutback asphalt was used as the bitumen. This type of mix must be further subdivided by the method employed in lay-down operations.

Plant Mixed (Finisher Laid). —The first plant-mixed mat was constructed in May 1948 on Halstead Street at the east edge of Hutchinson, Kansas, as a county secondary project. It utilized a BMA-1 type of aggregate (similar in grading to the BC-1 specification) and MC-5 cutback asphalt and was laid 3 in. thick. The asphalt and the aggregate were both heated to 250 F. The New Mexico formula was used to determine the asphalt content, calculated to be 5 percent of dry weight of aggregate. The mixed material was placed on the roadway with a conventional laying machine, but the contractor was unable to compact the mix immediately because of its fluffy condition caused by the volatiles remaining in the mix. Various types of equipment were used to manipulate and aerate the material. After 2 days the material became tacky and was compacted by pneumatic-tired and flat-face rollers. Aeration checks during construction indicated a loss of only 14 percent of the volatiles. Repeated aeration checks made during June, July and August indicated a maximum loss of 23 percent of the volatiles contained when shipped from the refinery. This project has been highly successful and has required very little maintenance although most traffic is of heavy industrial type.

The second project was constructed in Rush County on US 183 within LaCrosse, Kansas, in 1953. An aggregate meeting the AA (Special) requirements (similar in grading to the BC-4 specification) and an MC-5 cutback asphalt were mixed and laid 6 in. thick by a conventional laying machine. This mix acted much the same as the previous project and required approximately 2 days of manipulation by a farm cultivator before it became tacky enough to be compacted. It has required relatively little maintenance and has satisfactorily carried both local and through traffic of approximately 1,700 veh/day.

It is evident from these two projects that the heating of both aggregate and cutback asphalt does not eliminate the need for additional aeration of the volatile fraction before compaction can begin.

Plant Mixed (Blade Laid). —The plant-mixed cold-laid material used on a portion of Interstate 70 differed primarily from the previously discussed project in that the plant-mixed material was hauled to the job site, dumped in a windrow, and blade mixed and laid by means of motor graders rather than the conventional bituminous pavement finisher. However, an automatic batch-type hot-mix plant and/or a stabilization mixer with conveyor-connected dryer were used for blending and mixing the aggregate and asphalt. This type of operation lends itself to high-volume production in keeping with the quantities involved in the usual interstate project. This system eliminated the problem of aeration encountered with the previously described projects and alleviated the drying hazard normally associated with road mixing.

LAYING AND COMPACTING

Though all other problems have been dealt with successfully, the final test of any type of roadway surface is how it rides. Most cold-mix asphalt in Kansas in laid by a motor grader. The subgrade, base or existing surface on which the mix is being laid dictates how smooth the finished surface is unless crown and longitudinal irregularities are corrected. Localized or spot leveling plus a leveling course to correct the crown is generally standard practice before the final lift is applied.

Until recently, the success of any motor grader-laid surface depended entirely on the skill of the operator. This situation was improved by the adaption of an electronically operated, constant slope control device to the blade of a motor grader. By means of this control the surface may be trimmed quite accurately to conform to any desired crown.

It has been suggested that a compaction requirement should be established for cold-mix laid base and mats to assure a uniform density in the finished surface as required in hot-mix specifications. Information from laboratory tests conducted at Oklahoma State University (4) indicates that it may not be desirable to compact materials stabilized with cutback asphalts to a particular density requirement unless the amount of moisture and volatiles can be accurately controlled. Tests indicate that maximum stability and maximum density do not occur at the same moisture-volatile point. Any control of the compaction of a cutback asphalt-aggregate mixture by a density requirement must be accompanied by a limitation in the amount of water and volatiles in the mixture. These results may not be applicable in the field and to Kansas mix designs, but they indicate that other agencies are interested in the same problems.

APPLICATION

The simplicity of production and economy of construction makes cold-mix material adaptable to a wide range of applications and appealing to many engineers and contractors. This type of asphalt stabilization is commonly used for bituminous surfacing, resurfacing, base, and stabilized shoulders, and for maintenance patching.

The reasons for the selection or consideration of cold mix vs hot mix may be any of the following:

1. Construction is more economical;
2. Small volume needed makes plant-mix prohibitive in cost;
3. Equipment normally used for routine highway maintenance is all that is normally required to produce cold mix;
4. New construction involving realignment may permit road mix without traffic interference;
5. A relatively wide range of temperatures can be tolerated during construction without detrimental effects;
6. Many marginal aggregates may be acceptable for a road mix but unsuitable for plant production; or
7. Maintenance patching material may be prepared in advance and stockpiled until needed with little danger of deterioration or loss.

USE AND COSTS

In Kansas, the use of cold-mixed materials for base and surface courses prepared by road mixing is on a steady decline in favor of plant-mixed materials whenever possible. This applies not only to surfacing projects being constructed by contract but also to maintenance work performed by State Highway personnel. Such a change has been the result of an effort to reduce the weather hazard always present during road-mixing operations. A comparison of the road-mixed and plant-mixed material costs

TABLE 3

ANNUAL TOTAL OF COLD-MIXED AND HOT-MIXED ASPHALT STABILIZED MATERIALS USED IN KANSAS

Year	Cold Mix				Hot Mix			
	MC-4 Asphalt BC-Type Agg.[a]		MC-3 Asphalt BPA-Type Agg.[b]		AC-7 Asphalt BC-Type Agg.[a]		AC-5 Asphalt HM-Type Agg.[a]	
	Tons	Cost[c] ($/ton)	Tons	Cost ($/ton)	Tons	Cost ($/ton)	Tons	Cost ($/ton)
1960	1,146,072	2.45	—	—	597,112	3.47	536,456	5.82
1961	862,893	2.47	—	—	756,597	3.60	416,393	5.63
1962	504,570	2.40	1,000,000	4.06	1,358,257	3.65	419,831	4.98

[a]Used for surfacing and resurfacing projects by contract.
[b]Used by Maintenance Department.
[c]Includes manipulation and lay-down costs.

and quantities utilized in the construction and maintenance of the Kansas Highway System by contract indicates this change and provides a means of estimating the expense involved. These values are given in Table 3. The data, which have been correlated from laboratory tests, do not indicate any gain in stability to justify the increased cost of using plant-mixed materials with an asphalt cement as compared to the same aggregate mixed on the road with a cutback asphalt. However, in many cases, this additional cost can be justified where a roadway must be resurfaced under traffic, thereby reducing the traffic hazard for the workmen and relieving the congestion by needing less equipment as well as eliminating the windrow of material.

Although the use of cold mix is decreasing each year, Table 3 indicates that it is still a major construction item in the Kansas Highway Program.

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Appendix

ASPHALT PROPORTIONING FORMULAS

Formula A (New Mexico)

$$P = 0.02a + 0.07b + 0.15c + 0.20d$$

in which

P = percent of bituminous material by weight of dry aggregate,
a = material retained on No. 50 sieve in percent,
b = material between No. 50 and No. 100 sieve in percent,
c = material between No. 100 and No. 200 sieve in percent, and
d = material passing No. 200 sieve in percent.

Formula B (Nebraska)

$$P = AG\,(0.02a) + 0.06b + 0.10c + Sd$$

in which

P = percent of bituminous material by weight of dry aggregate;
A = absorption factor, equal to 1 for sand-gravel and to 1 + ⅔ the approximate net water absorption of other aggregates;
G = gravity correction factor, equal to 1 for sand-gravel and inversely proportional to other average specific gravities on the base of 2.61 as the gravity of river sand-gravel (retained on No. 50 sieve);
a = material retained on No. 50 sieve in percent;
b = material retained between No. 50 and No. 100 sieve in percent;
c = material retained between No. 100 and No. 200 sieve in percent, plus c_1;
d = percent of fines determined by average of percent passing the No. 200 sieve dry screened and that passing the No. 200 on wash test in separate determinations;
c_1 = percent of material equal to difference between percent of material passing No. 200 sieve on wash test and d; and
S = 0.2 except when volcanic ash is used as a mineral filler, in which case S shall be determined by laboratory tests.

The quantity, d, in the Nebraska formula shall be found by separate determination on two similar samples of combined material; one sample shall be dry screened only, and the other sample shall be tested by the wash test plus dry screening after washing.

In both formulas, cutback oils of MC and RC types should be increased in quantity by the amount of diluent which is expected to be lost during aeration and curing.