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PAVEMENT AND METHOD OF MAKING PAVEMENTS

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Fig. 1.

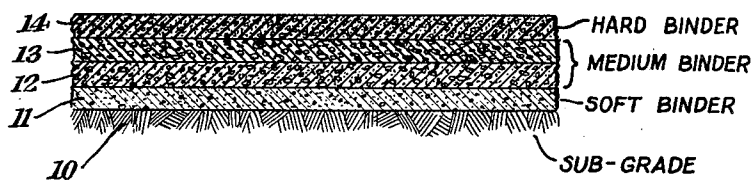
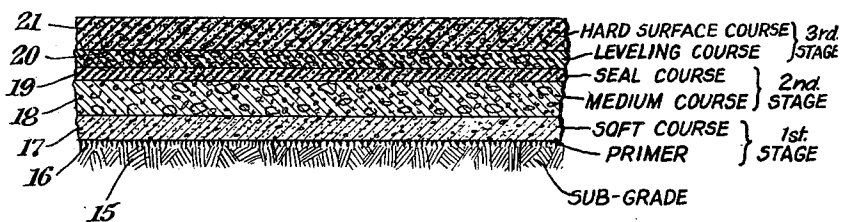


Fig. 2.



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PAVEMENT AND METHOD OF MAKING
PAVEMENTS

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16 Claims. (Cl. 94—23)

This invention relates to pavements and to method of making pavements. It relates particularly to pavements primarily intended for roads, highways, sidewalks, platforms and the like.

It is an object of this invention to afford a bituminous pavement which has increased resistance to disintegration due to subbase movements, the action of water and frost, and the like. A further object of this invention is to afford a pavement which has the property of being in large degree self-healing and which is resistant to cracking and disintegration. It is a further object of this invention to provide a pavement which has the above desirable properties and which is adapted in composition and method of laying to conform to traffic increases over a period of years.

Further objects of this invention relate to providing a road which can be laid immediately in a plurality of differing courses affording the advantages of this invention or can be laid over a period of years while maintaining traffic on the individual courses as they are laid. Thus any one course can be made according to this invention so that it will have permanent utility as a foundation for subsequent courses whether the subsequent courses are laid immediately or at a later date. Moreover such courses have utility not only as a foundation course but also as a surface adapted to withstand certain traffic conditions. As traffic density increases, such courses without preparatory reconstruction are adapted for the superposing of courses adapted to carry traffic of increased density. If the traffic density does not increase a preliminary course may be maintained indefinitely at a low cost of maintenance. It is an object of this invention to afford a new type of road such that a program of road construction and maintenance can be employed which is adapted to conform to traffic increases over a period of years at a very low total cost per mile per year. The completed road is fully competitive with reinforced Portland cement concrete both as to cost and quality. However, a road made according to this invention can be used for many years prior to completion and the cost of completing the road can be spread over a number of years.

It is a feature of this invention that a pavement is laid in courses or layers containing bituminous binding material having different degrees of hardness. It is a further feature of this invention that a pavement is provided having a wear-resisting and deformation-resisting

surface course in combination with one or more sub-courses containing binders which are softer than the binder for the surface course. A further feature of this invention resides in employing a plurality of sub-courses made up with binders of increasing softness so that the softer binder or binders are at the base of the road.

It is a further feature of a pavement embodying this invention that it comprises courses containing aggregate materials coated with bituminous binders having definitely different penetrations, the difference in penetrations being such as afford new results in the way of permanence of the finished composite road. Further features of this invention reside in employing bituminous binders which have a penetration ranging from about 30 to 300 and in employing certain intermediate penetration binders e. g. from 85 to 150. According to this invention, such bituminous binders are employed preferably in graduated courses to afford definite advantages as will appear more in detail below.

Further features of this invention reside in the grading and size of aggregate contained in the various courses and the employment of the same with bituminous binders of different penetrations.

Features of this invention reside in the control within certain limits of the void content in the various layers of the completed pavement and in the thoroughness of the coating of the aggregate as by suitable mechanical agitation.

In practicing the novel method of stage or course construction of this invention while permitting traffic to pass over the various stages during intervals in the manufacture of the road, it is a further feature and advantage of this invention that road making materials, both aggregate and bituminous binder, used in the manufacture of preliminary courses are not lost or wasted but are used in their entirety. Heretofore it has been a common practice to spread aggregate material on roads for the purpose of allowing the aggregate to become fixed in the surface of the road and form a desirable subgrade for a later application of paving materials. However, there is great loss by ravelling of the aggregate which is thus spread upon a road.

Further features of this invention reside in combining adjacent courses of different particular character, controlling the thickness of the different courses, and the like.

It is one of the objects and advantages of this invention to employ in certain courses or stages of road construction bituminous binders which

are softer than those heretofore employed in making bituminous concrete but yet which are hard enough to be susceptible to the penetration test. Courses made with such binders are designed to be permanent in the practice of this invention. In a surface course the soft binder is adapted to withstand light traffic and a course bound thereby may be used indefinitely by relatively cheap maintenance. As an underlying course, where increased traffic warrants the superposing of a course containing a harder binder, such a course containing a soft binder is available without preparation as a base for the superposed layer and the soft binder of the sub-course affords healing properties to the superposed course containing a harder binder. Such permanent courses containing soft binders susceptible to the penetration test are to be distinguished from temporary roads such as oiled or untreated metal roads wherein no bituminous binder susceptible to the penetration test has been used. The latter type of road is unduly costly on an annual basis due to loss of metal.

Further purposes, features and advantages of this invention will appear from the following description in connection with the accompanying drawing, wherein

Fig. 1 is an embodiment of this invention adapted for a road or highway, and

Fig. 2 is another embodiment of this invention.

It is to be understood that the following description in connection with the drawing is confined to certain specific examples of this invention which are given merely for the purpose of illustration and for convenience in description.

Referring to Fig. 1, the reference character 10 indicates a sub-grade which may be of any suitable character such as graded dirt, sand-clay mixture, gravel worked in by traffic, primed sub-grade, old road in poor condition, and the like.

In the embodiment of this invention shown in Fig. 1, a first course 11 is laid as by spreading and rolling the same upon the sub-grade 10. The course 11 contains medium to fine aggregate such as sand, small stones and the like coated and mixed with about 6% to about 8% of a soft bituminous binder of about 150 penetration. The layer 11 is about 1 to about 2 inches in thickness. In coating the aggregate it is subjected to mechanical agitation so as to cause it to become coated as thoroughly as possible with the binder. It is more advantageous to use aggregates so graded that the voidage of the finished course is less than about 8%, but the benefits of this feature of this invention can be obtained with void-ages up to about 12%.

A second course 12 overlies layer 11. The layer 12 contains graded aggregate mixed with a bituminous binder which is harder than the binder in course 11. The binder in course 12 contains about 6% to about 9% of bituminous binder having, for example, a penetration of about 100. In the manufacture of layer 12 graded aggregate is used, the larger particles thereof being not more than about one-half the thickness of the layer and the aggregate is thoroughly coated with the binder. The layer 12 may be about one to two inches thick and preferably contains less than about 8% of voids.

A third course 13 overlies course 12 and contains a bituminous binder which is still harder than the bituminous binder used in course 12. In course 13 about 6% to about 9% of a bituminous binder having a penetration of about 85 may be used, for example. The size and grading of the

aggregate, the void content, and the thickness of course 13 may correspond in other respects to course 12.

The last or top course 14 contains a binder which is still harder than the binder in any of the underlying courses. The binder (about 7% to about 11%) in the top course has a penetration which is sufficiently high to resist the action of traffic in the climate where the pavement is laid. Thus in very hot climates a penetration as low as 30 to 50 is desirable while in a very cold climate a penetration as high as 60 to 70 will be satisfactory. In the temperate climates it is usually desirable to use a bituminous binder having a penetration of about 50 to 60.

It is preferable in the practice of this invention to use a somewhat finer aggregate in the top layer than in subjacent layers 12 and 13. The top layer may be of any desired thickness such as one to two inches and preferably contains less than about 5% of voids.

A road such as the one described in connection with the foregoing example has certain distinct advantages. The laying of the very plastic layer adjacent the base or subgrade of the road results in greatly minimizing the damage consequent upon subsidences and upheavals in the subgrade brought about by the action of water, frost, etc. The effects of base failures usually evident as cracks, potholes or progressive disintegrations from the bottom are greatly lessened. In the completed pavement, the thickness of the least flexible layer is reduced according to this invention without sacrificing resistance to horizontal displacement by traffic action at the surface.

It has also been found that the construction above described results in a pavement which is more permanent due to the fact that the softer asphalts in the lower strata maintain the road in better condition under varying conditions of traffic. When a road is made of sufficient thickness to be durable using only an asphalt cement of from about 40 to 70 penetration, constant traffic is required to maintain it in perfect condition. The employment of soft subcourses under a relatively thin hard top course, serves to preserve the top course.

When stage construction is employed as will be described below, the soft layers or courses adjacent the subgrade before the superposing of additional courses thereon conform readily to subsidences or upheavals without cracking and the foregoing remarks relating to self-healing, resistance to disintegration, etc., are applicable to any preliminary number of the courses that have been laid in place. Moreover, when such preliminary courses using soft asphalts are thrown open to the traffic, less traffic is necessary to keep the asphalt in good condition than where harder asphalts are used.

A modified form of this invention is shown in Fig. 2 and is illustrative of the manufacture of a road in stages, there being intervals of time between the laying of the various courses during which the courses may be thrown open to traffic. In Fig. 2, the reference character 15 indicates a foundation for a road which, as in the case of the road shown in Fig. 1, may consist of ordinary dirt foundation, sand and clay, gravel, old road in poor condition, and the like.

The modification shown in Fig. 2 is illustrative of a sub-grade which is primed with a road oil, for example. The use of the road oil as a primer is desirable in preventing water from rising into the wearing course and in preventing

dust from working up through the pavement. A road oil of about 40 to 150 viscosity Furol at 122° F. may be spread on the foundation, for example, using about one-third of a gallon of oil to each square yard of foundation.

On the primed foundation indicated by the reference character 16, a layer 17 of aggregate and binder is laid. This layer may consist largely of sand and fine aggregate coated with about 6% to about 8% of bituminous binder having a penetration of about 150. The course 17 may be laid to a thickness of about one to two inches. The aggregate is preferably thoroughly coated by mechanically mixing the aggregate and bituminous cement and preferably contains less than about 12% of voids.

While the asphalt used in the layer above described is very soft, it has been found that the layer will resist light traffic for a short period. As the aggregate is relatively fine and as there is a relatively large amount of binder employed, there will be very little ravelling due to traffic. Moreover, the layer has sufficient flexibility and softness to conform to subsidences or upheavals in the sub-grade without breaking and disintegration. While the layer 17 is not particularly well adapted for use as a permanent pavement for heavy traffic, it does afford a desirable surface for light traffic and may be used to great advantage for subsequent combination with an overlying course or overlying courses containing aggregate coated with bituminous binders which are successively harder and more permanent than the binder in course 17.

After a suitable interval of time, during which the course 17 may be open to traffic, a course 18 may be laid over course 17. The course 18 is preferably laid before the course 17 has become disintegrated to a marked degree. If the traffic continues to be light on course 17 an additional course corresponding to course 17 can be laid and used for several years prior to laying course 18. The foregoing remarks are also applicable to the laying of subsequent courses overlying course 18, namely, any of the intermediate courses may be repeated and used for an additional period of time if the circumstances warrant so doing.

In the layer 18, a bituminous binder is used having a penetration of about 100, for example. The layer 18 is about two to three inches in thickness and comprises graded stone from about one to one-quarter inch in size together with about 15% to about 40% of sand and fines. The graded aggregate is thoroughly coated with about 6% to about 8% of asphalt and when laid in place contains less than about 8% of voids.

If the course 18 is to be thrown open to traffic, it may be desirable to provide a wearing surface for the layer 18 in the form of a relatively thin layer 19. The layer 19 may comprise about 10% of bituminous cement having a penetration of about 30 to about 70 mixed with sand or other relatively fine aggregate so as to contain less than about 5% of voids. This layer 19 serves the additional purpose of waterproofing layer 18 which in effect seals the top of the layer from the action of weather.

When the courses 18 and 19 are thrown open to moderate traffic conditions, the road will give good service for a number of years. The asphalt in the layer 18 is of sufficient softness to conform to subsidences and upheavals in the subgrade and the layer 18 is so flexible that the road will not crack and disintegrate.

The final stage of the completed road may be laid in two courses or layers 20 and 21. The layers 20 and 21 are preferably manufactured using a bituminous binder having a penetration of about 30 to 70. Layer 20 is primarily intended as a leveling course and preferably comprises about three parts of stone and one part of sand coated with about 5% of the bituminous binder. The layer 20 is preferably somewhat thinner than the layer 21.

The layer 21 comprises a somewhat larger proportion of finer material than the layer 20 and contains increased proportion of binder, e. g. approximately 7% or more. The final stage of pavement comprising layers 20 and 21 is hard and is adapted to resist very severe traffic.

By the stage construction above illustrated, a method of road construction is afforded whereby one or more preliminary stages may be laid which are adapted to resist light or moderate traffic for a considerable time and after the last stage is laid a road is afforded which is of a very permanent character and is highly resistant to the most severe traffic. As a result, a road is kept in good condition for a very large number of years at relatively low cost. The method of construction can be used to great advantage in the manufacture of side roads or feeders to main traffic arteries when it is contemplated that the traffic borne by the road will increase gradually over a period of several years. All of the preliminary courses or stages are used in their entirety and without loss and are peculiarly adapted to afford self-healing properties and resistance to disintegration in the completed road. Moreover, as the asphalt used in the preliminary courses is soft and plastic, it does not deteriorate under light traffic conditions as would be the case if a hard asphalt were used. Moreover, during the interval of time between the laying of different stages, the sub-grade will have opportunity of becoming settled to permanent position and any subsidences or upheavals in the sub-grade can be corrected on laying the succeeding courses. Any subsequent movement in the sub-grade will be met by the improved road without causing cracking or disintegration because of the increased flexibility and healing power afforded by the soft sub-courses in combination with a relatively thin surface layer.

Hereinabove certain specific examples of pavements embodying this invention have been given for the purpose of illustration. It is to be understood, however, that the specifications given can be departed from considerably within the scope of this invention.

Broadly speaking, the construction of pavements laid in courses differing in hardness, the softer courses being adjacent the bottom of the pavement, so that the resulting pavement becomes definitely softer in going from top to bottom, is to be regarded as coming within this invention. There are, of course, more particular aspects of this invention.

In the examples of road construction shown in Figs. 1 and 2, specific penetrations of bituminous binders are given for the purpose of affording concrete illustrations of this invention. More generally for the number of courses shown in Fig. 1, for example, the bituminous binder in course 11 may preferably have a penetration ranging from about 125 to about 175, although satisfactory results are also afforded using a bituminous binder having a penetration of about 100 to about 300. In course 12, the bituminous binder preferably has

a penetration of about 85 to about 125 or more broadly about 85 to about 150. For course 13, the bituminous binder may have a penetration preferably of about 70 to about 100. For the top course 14, the penetration of the binder is suited to the climatic conditions prevailing where the road is laid and may range from about 30 to about 70 as above described.

In the example shown in Fig. 2, the penetration of the bituminous binders in courses 17 and 20 and 21 may correspond to the penetration of the binders above described in connection with courses 11 and 14 respectively of Fig. 1. Course 18 of Fig. 2 may contain binder corresponding in penetration to the penetration of the binder in either of courses 12 or 13 of Fig. 1 or may be intermediate. For course 18, a bituminous binder having a penetration of about 85 to about 125 is preferably used, although satisfactory results may be afforded by the use of binder having a penetration of about 70 to about 150.

While there is considerable latitude in the selection of binders for the various courses, it is preferable to control the gradations in penetration between different courses within certain limits. Thus superior results are achieved by limiting the difference in penetration of binders for adjacent courses to less than about 80 and by employing a difference in penetration between binders of at least some adjacent layers which is greater than about 15. Preferably the difference in penetration between binders for at least some adjacent courses is between about 25 and about 70. Moreover, the total variation in penetration of bituminous binder from the top to the bottom of the road should be sufficient to afford self-healing properties according to this invention which are adapted to the requirements of the sub-grade on which the road is laid. Thus, for a weak sub-grade such as dirt or thin gravel, the total variation in penetration of binder from a surface course to a bottom course should be from about 150 to about 300. For better sub-grades and foundations, the total variation should be from about 25 to 150.

It is not essential that the roads embodying this invention have the number of courses hereinabove described in connection with Figs. 1 and 2. The roads shown in Figs. 1 and 2 are primarily designed to be laid over weak foundations. If a pavement is to be laid on a sub-grade which is believed to be of fair stability or on an old road in fairly good condition as a sub-base, a lesser number of layers of materials having different penetrations may be employed. For example, referring to the road shown in Fig. 1, it would be possible to leave out the layer 11 altogether under such conditions. In such case, the new road overlying the sub-base would be somewhat thinner due to the lesser number of courses employed. If a thicker road is desired, the thickness of the courses could be increased so as to give the road the desired thickness. Further in this connection, on sub-grades or old roads of relatively high stability, two courses only may suffice. In such case, layers 11 and 12 may be omitted. Even in such case, however, there is an advantage in using in combination a surface layer having a hard bituminous binder and having, for example, a penetration of about 30 to 70 in combination with a subjacent layer of definitely softer binder and having, for example, a penetration of about 85 to 100. If the old road when reopened is to be used for light traffic only, a course of material containing a soft binder hav-

ing a penetration of about 85 to 100, for example, could be employed for a period of time prior to adding a superposed course containing a harder binder. Thus the courses omitted from those described in connection with Figs. 1 and 2 will vary with the sub-grade to be covered and the traffic conditions to be withstood.

While it is preferable in the practice of this invention to employ a plurality of layers or courses having bituminous binders, the hardness of which progressively decreases from top to bottom, it is not without the scope of this invention to include a layer containing relatively hard binder between two layers of softer binder. Thus, for example, the layer 20 shown in Fig. 2 could be made of somewhat softer asphalt than the layer 19 without departing from the scope of this invention. It is preferable, however, that the reinforcing intermediate layer of hard asphalt shall not exceed 25% of the total thickness of the completed road. Moreover, the "blinding in" of any of the intermediate courses or layers employed according to this invention, as by application thereto of a sealing coating of bitumen or bitumen mixed with fine aggregate, is within the scope of this invention.

The control of the aggregate in the various courses and the proportions of bituminous binder used therewith is not to be regarded as essential although certain aspects of this invention relate to these more specific features. Thus when a relatively soft bituminous binder having a penetration of about 100 to about 300 is used as a bottom layer, it has been found that superior results are afforded by mixing the binder with the aggregate so as to very thoroughly coat the aggregate, for example by means of a mixer or other mechanical agitation. Moreover, it has been found desirable to use relatively fine aggregate on the average such as about $\frac{3}{4}$ " down to sand and powder, the major proportion passing a 10 mesh screen and to control the grading so that there is less than about 12% of voids. If the void content cannot be controlled so as to be less than about 12%, somewhat greater void content is permissible in the practice of this invention, although effort should be made to keep the void content down as much as possible. Such a course is very flexible and has high healing power and at the same time is resistant to penetration of moisture into the pavement from below.

In courses wherein a binder is used having a penetration of about 70 to about 150, it has been found to afford improved results when a graded aggregate is used which is coarser on the average than the aggregate in the layer above described. Aggregate containing stones the diameter of which are about one-half the thickness of the course and graded smaller sizes and some fines may be used in these courses. Combined flexibility and stability are thus afforded. In this layer also it is preferable to keep the void content below about 5%.

The top course containing the hardest binder and designed to resist heavy traffic for prolonged periods preferably contains finer aggregate than the aggregate used in subjacent layers just described and a substantially greater proportion of binder. The proportion of voids is preferably not more than about 5%.

The making of courses of low void content is preferably accomplished by grading the aggregate from particles of largest size down through intermediate sizes and to an impalpable dust.

However, such careful grading is not essential and a low void content can be achieved by other means if necessary as by using sufficient quantities of fine filler.

5 The thickness of the various layers can of course be determined as desired. Ordinarily, in laying a road on virgin or primed sub-grade, a road of about 6 to 8 inches in thickness, when made up in successive courses according to this invention, gives desirable results. The separate courses are preferably about one inch to about three inches in thickness. With more stable foundations, the number of courses and the total thickness of the road may be reduced depending on the relative stability of the foundation and the degree of permanence desired.

10 The manufacture of pavements having the features and advantages hereinabove described may be practiced according to this invention in connection with a method of road making wherein a bitumen of low penetration and brittle enough to be ground to a powder at ordinary temperatures, is amalgamated with a flux oil to form a binder coating for aggregate material, the penetration of the composite binder being that which is desired in the finished road. In one such method of road making, aggregate material is coated with the powdered asphalt and substantially non-volatile flux oil by suitable mechanical means and the aggregate coated with the binder parts is spread in place and rolled. After pressure has been applied to the pavement by rolling and subsequent traffic, the binder parts amalgamate with each other without application of heat to produce a composite binder for the aggregate.

According to this invention, a road may be manufactured having a plurality of courses or layers wherein the aggregate is bonded together by bituminous binders of different penetrations, using but a single high melting point bitumen and a single flux oil. By way of example, a flux oil of about 700 seconds Furol viscosity at 122° F. and a hard asphalt having a penetration of about 1 to 5 at 77° F. may be selected which will flux with one another at ordinary temperatures under applied pressure. By using about 63 parts of flux with 37 parts of the hard asphalt, a composite binder having a penetration of about 150 is afforded. This binder may be used as a bottom layer for the road. Using the same powdered asphalt and flux oil, the same may be mixed together using 42 parts of powdered asphalt to 58 parts of flux oil to produce a composite binder having a penetration of about 100. This binder may be used as a second course in the manufacture of a road.

By mixing about 53 parts of the flux with about 47 parts of the hard asphalt, a composite binder having a penetration of about 73 is produced which may be used in a third course. If the flux oil and hard asphalt are used in about equal proportions, a composite binder having a penetration of about 57 is produced. Such a composite binder would be satisfactory as a top course for a road laid in cold climates. For warmer climates, about 47 parts of flux to 51 parts of asphalt produces a composite binder having a penetration of about 41. Such a binder could be used as a top course for roads in warm climates.

It is to be understood that the foregoing percentages of flux oil, hard asphalt and the characteristics of these two binder-parts have been

given for purposes of illustration and that the percentages and the characteristics of the two binder parts may be modified without departing from the scope of this invention. In this connection, the characteristics of different powdered 5 asphalts and flux oils differ to considerable degree depending upon the source or sources from which they are derived and the methods of their refinement.

According to this invention, it is possible to lay a road having any number of courses containing aggregates coated with binders of different penetrations using but a single supply of the hard asphalt and flux oil binders.

This invention may also be practiced by laying any one or more of the plurality of courses by conventional hot mix methods, or cut back or emulsion methods of road construction and the like.

We claim:

1. A pavement comprising a plurality of courses containing aggregate and bituminous binder for the aggregate, the binders for the aggregates in different courses having substantially different penetrations and a sub-course of said pavement containing a binder which has a substantially greater penetration than the binder for the surface course.

2. A pavement comprising a top course containing aggregate and a bituminous binder, and an underlying layer of greater thickness than said top course containing aggregate thoroughly coated by mechanical mixing with a bituminous binder which is materially softer than the binder in said top course.

3. A pavement comprising a top course containing aggregate and a bituminous binder for the aggregate, and an underlying layer coated with a bituminous binder which is materially softer than the binder for said top layer, there being not more than about 8% of voids in the said top course and not more than about 12% of voids in said underlying course.

4. A pavement comprising an intermediate course containing aggregate and a bituminous binder for the aggregate, an overlying course containing aggregate and a bituminous binder coating which binder coating is materially harder than the binder in said intermediate course, and an underlying course containing aggregate and a bituminous binder which binder is materially softer than the binder for said intermediate course.

5. A pavement comprising an intermediate course containing aggregate and a bituminous binder for the aggregate, an underlying course containing aggregate finer on the average than the aggregate in said intermediate course and a binder which binder is softer than the binder in said intermediate course, and an overlying course containing aggregate which is substantially finer on the average than the aggregate in said intermediate course and a bituminous binder which binder is substantially harder than the binder in said intermediate course.

6. A pavement comprising an intermediate course containing aggregate and a bituminous binder for the aggregate, an underlying course containing aggregate finer on the average than the aggregate in said intermediate course and a binder which binder is softer than the binder in said intermediate course, and an overlying course containing aggregate which is substantially finer on the average than the aggregate in said inter-

mediate course and a bituminous binder which binder is substantially harder and is employed in substantially greater proportions than the binder in said intermediate course.

5 7. A pavement comprising a top course containing aggregate and a bituminous binder having a penetration of about 30 to about 70, and an underlying course containing aggregate and a bituminous binder having a penetration of about 85 to about 150.

10 8. A pavement comprising a top course containing aggregate and a bituminous binder having a penetration of about 30 to about 70, and a substantially immediately underlying course containing aggregate and a bituminous binder having a penetration of about 85 to about 150, the aggregate in said underlying layer being substantially coarser than the aggregate in said top course.

20 9. A pavement comprising a top course containing aggregate and a bituminous binder having a penetration of about 30 to about 70, an underlying course containing aggregate and a bituminous binder having a penetration of about 150 to about 300, and an intermediate course containing aggregate and a bituminous binder having a penetration substantially greater than the penetration of the binder in the top layer and substantially less than the penetration of the binder in the underlying layer.

30 10. A pavement comprising a first course containing aggregate coated with a bituminous binder having a penetration of about 30 to 150, and a substantially immediately underlying course containing aggregate coated with binder the penetration of which is about 15 to about 80 greater than the penetration of the binder for the first course.

40 11. A pavement comprising a plurality of courses containing aggregate material coated with bituminous binders of different hardness the hardest course being adjacent the top and the softest course being adjacent the bottom, the difference in penetration between adjacent courses not being greater than about 15 to about 80 and the total difference in penetration between different layers being greater than about 80.

50 12. A pavement comprising a base course containing aggregate nearly all the particles of which are less than $\frac{5}{8}$ inch and are coated with a bituminous binder having a penetration of about 100 to about 300, the void content of said base course being less than about 12%, and an overlying course containing aggregate the particles of which are on the average substantially coarser than the particles of aggregate in said base course and are coated with bituminous binder having a penetration of about 85 to about 150, the void content of said overlying course being less than about 8%.

60 13. A pavement comprising a top course containing aggregate nearly all the particles of which are less than about $\frac{5}{8}$ inch and are coated

with a bituminous binder having a penetration of about 40 to about 70; and an underlying course containing aggregate the particles of which are substantially coarser on the average than the particles of aggregate in said top course and are coated with a bituminous binder having a penetration of about 85 to 150.

14. A method of making a pavement which comprises laying a first course of aggregate coated with a soft bitumen of relatively high penetration on a graded surface, subjecting the course to traffic for an interval of time, laying over said first course a second course of aggregate coated with a bitumen which is harder and of lower penetration than the bitumen in the first course, subjecting the second course to traffic for an interval of time, and subsequently laying an additional course of aggregate coated with bitumen which is harder and of lower penetration than the bitumen in said second course.

15. A method of making roads which comprises laying a permanent course containing aggregate coated with a bituminous binder susceptible of the penetration test, subjecting the course to traffic and then superposing upon said course a second course comprising aggregate material coated with a binder which is harder than the binder for the first course and which is between about 30 and about 70 penetration, the difference in penetration between the binder for the first and second courses being more than about 15.

16. In a method of road making wherein aggregate material is coated with a powdered bitumen and with a flux oil which is adapted to amalgamate substantially without the application of heat with said powdered bitumen to form a composite binder for the aggregate, the steps comprising coating a first portion of aggregate with a powdered bitumen and with a flux oil in proportion adapted to produce a composite binder having a certain penetration and then coating a second portion of aggregate with a flux oil which is substantially similar to the flux oil used for coating said first portion of aggregate and with a powdered bitumen which is substantially similar to the powdered bitumen used in coating said first portion of aggregate, the flux oil and powdered bitumen used for coating said second portion of aggregate being used in substantially different proportion from the proportion employed in coating said first portion and being adapted to produce a composite binder for said second portion of aggregate, the penetration of which differs substantially from the penetration of the composite binder for said first portion of aggregate, and consolidating said first and second portions of coated aggregate in place to produce substantially without the application of heat composite binders of the character aforesaid for said different portions of aggregate.

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