

when taken over that traffic could scarcely get over them, but today, after four years of maintenance they are carrying some of our heaviest traffic without showing any signs of wear or failure, and are becoming more and more like boulevards as time goes on.

BITUMINOUS MACADAM ROAD CONSTRUCTION

By A. O. HASTINGS,
District Engineer, Indiana State Highway Commission.

In selecting the type of pavement to be laid in a certain section of road careful study should be given to the amount and kind of traffic going over this road at present and also to the probable increase within the next few years. Careful study should be made of the condition of sub-soil and the old base.

If the present road has a good gravel or stone base that is holding up very well, a bituminous macadam top course is a very economical pavement to use. If it is a new grade there is a question whether some other types of pavement would not be as economical. One of the greatest economic reasons for laying a bituminous macadam pavement is the salvaging of the old base. A well compacted gravel or stone surface that has been hammered by heavy traffic for a period of years has considerable value and that value may be conserved by laying a bituminous macadam top course.

Grading

Let us consider first the grading. By use of a grader, wheel scoops, drag scoops or wagons, the berms, shoulders and ditches should be brought to the proper cross section and in conformity to the base grade taking care of the drainage as necessary. Unlike many other types, the shoulders on a bituminous macadam road should be built prior to the laying of the pavement. Many bituminous macadam roads have been built with but little berm. Much better results could have been secured had there been a good berm built before the pavement.

The cross section for an 18 foot pavement includes a 2 inch crown in the pavement proper with berms 5 to 6 feet wide sloping $\frac{1}{2}$ inch per foot and with a flat slope of approximately 4 to 1 into the ditch. The old base should be reinforced and levelled up with a water-bound macadam course or at least patched with water-bound patches so that the foundation grade will conform very closely to the finished crown and grade and to sufficient depth to hold up the loads which it will have to carry. Much care should be used in leveling up the old base

as much better results will be secured in the finished surface if the top course is the same thickness at all places. Specifications for laying a water-bound course to level up old base should be about as rigid as if the road was to be left as a water bound surface.

Suggested Specifications for Water-Bound Macadam Course

This course shall consist of a one course water-bound limestone, slag or crushed boulders, of a depth indicated on the plans or the estimate (this depth should be chosen after careful study of the old base), constructed in accordance with these specifications on the base course which shall be trued up where necessary with water-bound macadam patches, to a uniform grade and crown before the top course is placed thereon.

The coarse aggregate for this course shall consist of No. 1 (3½" to 2½") or No. 2 (2½" to 1½") size specified according to thickness of patch or course.

(A) Crushed stone shall consist of angular fragments of tough, durable crushed lime stone, trap rock, or boulders, having a French co-efficient of wear of not less than seven. It shall be free from thin and elongated pieces. If it is produced from crushed boulders, not more than ¼ the surface area shall consist of the original smooth surface of the boulder.

(B) Slag—The screenings used in filling this course shall consist of crushed limestone or slag meeting the above specifications except as to size. No. 7 (½" to 0) size screenings shall be used, if of slag or limestone with a French co-efficient of wear of more than nine. No. 5 (¾" to 0) screenings shall be used if of limestone with a French co-efficient of wear of nine or less.

No coarse aggregate shall be placed until the screenings for filling same have been neatly stored in piles along the side of the highway.

The coarse aggregate shall be spread on the base to such thickness as will produce the complete depth called for. Side forms of the proper size should be used to fix the depth of loose material and assist in spreading the same to a uniform surface. In spreading care must be taken to preserve the grade and crown, also to prevent a wavy irregular surface. After the stone is spread on the base it should be harrowed to aid in producing a uniform and even surface. Any thin, flat, elongated or oversized stone that appear on the surface at any time during the progress of the work should be broken up or removed. Special care should be taken to have a uniform material in the surface in order to secure a smooth and uniform finished base.

All patches or areas of fine or under-sized materials appearing in this course should be removed and replaced with suitable material before final filling and water-binding.

Rolling: The coarse aggregate should be rolled with a self-propelled three wheel roller weighing not less than ten tons. The rolling should begin with the outside drive wheel covering at least equal parts of metal and shoulder, and if the shoulder is sufficiently strong and uniformly built it is well to have even more of the roller wheel out on the shoulder the first trip. The roller should be run forward and backward along the edge of the metal until the shoulder and the metal are firmly bound together. The rolling should then progress gradually towards the center of the road lapping about ⅓ width of the rear roller wheel until the entire course has been thoroughly keyed and the interstices of the metal reduced to a minimum and all settlement in the stone has ceased. Should any low

places develop in the surface during the rolling, the stone shall be loosened and enough coarse aggregate added to make a smooth and uniform finished surface.

After the dry rolling has been completed as described above, screenings should be applied gradually over the surface during the finishing process of dry rolling in such an amount as will completely fill the interstices. The screenings should not be dumped on the surface of the stone but should be cast thinly with spreading motion of the shovel from piles at the road side. The rolling should continue while the screenings are being spread so that the jarring effect of the roller will cause them to settle to the bottom. Care should be exercised not to apply the screenings too fast and choke the stone but the large stone should be kept in sight at all times. Continue to add screenings until all voids are filled, **the direct bearing of the roller still being on the coarse aggregate.**

Immediately after the voids of a section of the macadam have been filled with screenings as above described, the macadam should be sprinkled until saturated, the sprinkler being followed by the roller. More screenings should be added if necessary. The sprinkling, sweeping and rolling should continue until a grout has been formed of the screenings and water that will fill all of the voids and form a wave of grout before the wheels of the roller. The macadam should be kept wet at least twenty-four hours before the final rolling, and it should be puddled as many times as it is necessary to procure satisfactory results. When a section has been thoroughly filled and grouted as described above such section should be allowed to dry out after which it is ready for the application of the bituminous macadam course.

The approximate cost of this course varies according to the amount of reinforcement necessary on the old base, but striking an average from the cost of State jobs coming under my supervision, will average approximately 50 cents per square yard or approximately \$5,200.00 per mile, 18 feet wide. After the base has been properly reinforced and leveled up with the water-bound macadam we shall proceed with the laying of the top course of bituminous macadam. This course should be about three inches in thickness when thoroughly compacted.

The Bituminous Macadam Course

At this time the berms should be carefully graded and any irregularities leveled off so that when rolling is started on the top course with half of the roller wheel running out on the berm, the earth forming the berm will compact to a true grade, just level with the grade of the edge of the stone in the bituminous macadam course. Should there be high and low places in the berms the irregularities will follow the rolling as it progresses towards the center of the road and a wavy irregular surface will be produced.

Berm boards should be used in spreading the coarse aggregate. Very handy berm boards for a three inch compacted course are 2"x4" timbers set on edge, lined and leveled with the proposed line and grade. The coarse aggregate being dumped and spread to crown and grade, and checked up by use

of a crown board resting on the berm boards. The coarse aggregate may be dumped on the surface and spread by hand or a rough spread made by use of spreader boxes. Very careful spreading of the coarse aggregate is necessary to produce a smooth surface.

When the coarse stone has been carefully spread it should be rolled in the same manner as described in water-binding beginning with half the roller wheel on the berm and progressing towards the center of the road until the coarse stone is thoroughly keyed but not rolled enough to crush much of the stone.

The coarse aggregate should consist of crushed stone or slag all passing a $3\frac{1}{2}$ inch opening when the per cent of wear is less than $4\frac{1}{2}$ and a 4 inch circular opening when the per cent of wear is $4\frac{1}{2}$ or more. Not over 25 per cent should pass a two inch opening; 6 per cent a $1\frac{1}{2}$ inch opening, and 2 per cent a 1 inch opening.

When the coarse aggregate has been properly keyed it is ready for the application of the first coat of bituminous material meeting state highway specifications for Tar TP-6 or Asphalt A-2. The bituminous material should be applied to the aggregate when it is dry, when the temperature is above 45 degrees F. and when the lowest temperature within the proceeding eight hours has been above 32 degrees F. The coarse aggregate should be disturbed as little as possible by the application of the bituminous material. The bituminous material should be uniformly applied at the rate of $1\frac{3}{4}$ gallons per square yard and at a pressure of not less than 25 pounds per square inch by means of an approved pressure distributor. The distributor should be a self-propelled distributor with a manifold having a horizontal shift of not less than ten inches and should be equipped with wide tires to disturb the stone as little as possible. Hand pouring pots or nozzles should not be used except where special conditions would make it impracticable to use the distributor. The bituminous material should be heated by suitable appliance so designed as to admit of even heating of the entire mass with an efficient positive control of the heat at all times. Care should be taken so that the bituminous material is not heated beyond the highest permitted temperature specified, either before or during the application.

The coarse covering (key stone) should have been placed in neat piles along the berm prior to the spreading of the coarse stone. It should meet the specifications required for coarse aggregate except as to size. The coarse covering should all pass a $1\frac{1}{2}$ inch circular opening with not over 5 per cent retained on a $1\frac{1}{4}$ inch screen, 70 to 100 per cent should be retained on a $\frac{3}{4}$ inch screen with not over 15 per cent passing a $\frac{1}{2}$ inch opening.

Immediately after the bituminous material is applied there should be evenly spread over the surface just sufficient coarse covering material to prevent the bituminous material from sticking to the wheels of the roller (approximately 1 cubic yard to 125 square yards of surface). The road should then be rolled thoroughly before the bituminous material hardens enough to prevent the covering material from being readily incorporated with it. Should it be cool weather the rolling must progress rapidly. If it is extremely warm, it is sometimes necessary to wait and allow the bituminous material to cool some before rolling. As the rolling progresses additional covering should be added and broomed into the voids, care being taken not to put on an excess of covering at this time. The rolling should continue until a solid compact and smooth surface results conforming to the cross section on the plans. Should any humps or depressions develop during this rolling, the coarse aggregate should be loosened and additional stone and bituminous material added so that when rolled it will produce a smooth surface.

When sufficient rolling has been done and the voids fairly well filled with covering stone the first seal coat of heavy bituminous material should be applied consisting of about $\frac{3}{4}$ gallon per square yard of surface. Then the fine covering is spread evenly over the bituminous material in a thin layer just sufficient to keep the bituminous material from sticking to the roller wheels and the road should be **thoroughly** rolled. At this point in the construction of a bituminous macadam road I do not think it would be possible to roll too much. Fine covering should be broomed into the voids until the voids are well filled. At this time the second seal or surface treatment should be applied consisting of a lighter bituminous material (Indiana state highway specifications for asphalt OH-2 or Tar TM) at the rate of about $\frac{3}{10}$ gallon per square yard of surface. After applying the final seal coat of bituminous material, fine covering should be applied and if asphalt is used it should be rolled. If Tar TM is used the surface should be dragged as explained for surface treatment of Tar TM.

By conserving the old base a good pavement may be laid as described above at a very reasonable cost.

The following are a few points to be watched carefully in the above described method that will materially help in securing better results:

1. See to it that the berm compacts smooth and true to grade as the rolling begins. After the first application of bituminous material do not apply too much coarse covering but apply just enough to pass the roller without the bituminous material sticking to the wheels.

2. Roll until the coarse stone is thoroughly compacted, and feed in coarse covering as needed, do not choke it.

3. After second application of bituminous material apply only enough fine covering to get the roller over it without picking up, and roll thoroughly before additional fine covering is added. Fill the voids, but do not choke it.

4. At all times during the process of construction of both the water-bound and the bituminous macadam top courses, the coarse stone should be visible on the surface of the road.

5. Keep the cover stone spread uniformly. If for any reason it is applied alternately thick and thin, it should be thoroughly broomed before rolling. A bunch of chips will cause a depression in the road for when the roller hits a pile of chips the coarse stone is mashed down and when traffic comes on the road the pad of fine stone is brushed off and a dip in the surface results.

6. Emphasis should be given to the amount of rolling. Too much rolling can not be done after the first seal coat is applied, and also after the surface treatment, where asphalt is used. Some roads have been built without enough rolling at the proper time and costly maintenance follows.

Costs

As to the cost of constructing an 18 foot bituminous macadam pavement, three inches thick when compacted, I will quote from prices paid by the State for pavements laid in my district. Between Chester and Fountain City in Wayne County the cost was 90 cents per square yard. Pavement laid on the National Road east and west of Richmond, using some additional stone to level up the old base which was already a surface treated macadam, cost \$1.07 per square yard. Pavement laid between Muncie and Selma about 85 cents per square yard.

The above will average from \$9,000.00 to \$11,000.00 per mile for an 18 foot surface varying mainly as to cost of the aggregate used. Adding the expense of reinforcing the old base with water bound macadam to the cost of laying a bituminous macadam top course gives a total cost of about \$15,000.00 per mile of completed surface.