made, when considered in connection with registration figures, gasoline consumption, and population growth covering a long period of years, will indicate with reasonable accuracy future traffic density for the state as a whole as far ahead as five or ten years. Individual sections of certain roads will be affected by the construction of new highways, diversion routes near the large cities, the development of large industrial projects or resort areas, etc.; and such factors will have to be taken into consideration in the design of improvements in such locations. It is obvious, however, that reasonably accurate estimates of future traffic should be utilized in planning all future development of our transportation system.

IMPROVED METHODS OF BITUMINOUS SURFACE TREATMENTS

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Surface treatments have come to mean far more than they once did. The early method was merely the spreading of a film consisting of a coat of some bituminous material, followed sometimes, but not always, with covering metal. This covering applied to the early treatments usually consisted of sand, with little attention being paid to its grading. The whole idea was to mop up the excess bituminous material. When that was done, the work was considered finished. It was observed, however, that a succession of such treatments built up a mushy mixture of considerable thickness, which under traffic developed into wrinkles and corrugations. This, together with the slippery nature of the driving surface, raised serious objections to roads and streets of this type. Regardless of any corrugations which developed, the riding qualities of such surfaces were not much improved by these treatments. With the great increase in quantity and speed of traffic during recent years, these objections had to be overcome.

Solutions of these problems were so obviously simple it is strange they did not appear sooner. It finally occurred to those in charge of this kind of work that coarser covering material and dragging of the treated surface, two simple remedies, would eliminate in large part these objections. However, in order to permit dragging, suitable bituminous materials had to be developed. Such progress has been made along this line that no difficulty is experienced in buying what is needed from any reliable tar or asphalt producing company. This is a tribute to the honest sales ethics now almost universally practiced by these companies. This is a wonderful help

to those road officials who do not have access to a testing laboratory and are not experienced in this class of work. The quick-drying bituminous materials so developed have eliminated a great deal of the traveling public's objections to surface treatments, which were due to the splashing of passing vehicles. All objections to surface treatments while the work is in progress and for a few days after cannot be entirely eliminated, but by proper management they can be reduced to the point where the traveling public will be more in sympathy with the road officials' efforts to conserve and improve existing road surfaces. The question of surface treating is more or less prosaic and not very spectacular; but in order to get results, minor details must not be overlooked, and the right thing must be done at the right time.

SKIN TREATMENTS

The methods of light treatments have been developed during recent years to such a point that it is rather difficult to say much about it that is new. Perhaps the newest ideas concern the way the covering aggregate is now handled to secure maximum smoothing effect. It goes without saying that traffic preferably should be detoured while the work is going on. This is better for the work and also for the traffic; but if this is not possible, prompt covering of the bituminous material will greatly reduce the amount of material otherwise picked up by traffic. Certain fundamentals apply always to this class of work. One of these is the accepted fact that surface treating is a warm weather job if best results are to be obtained. As set out in every good specification, the surface should be dry and clean; and no treatment should be started until the surface is in this condition.

With proper conditions prevailing, the first step involves the application of the bituminous material. This may consist of cut-back asphalt, emulsified asphalt, or tar. The different grades of each have been well developed and standardized, so that it is assumed that those having this class of work in charge are at least familiar enough with such materials to choose the correct grade. The amount to be applied varies with the texture and openness of the surface, but care should always be taken not to apply too much. If the surface is very dry and open, it is usually best to put on two small treatments rather than one heavy one, with considerable time elapsing between treatments.

The covering consists of crushed limestone, slag, or gravel. The size should be chosen to fit the texture of the surface if choice of sizes is available. One inch should be the upper limit and one-quarter inch the lower limit of size. The covering should be clean and well graded from coarse to fine. The first application of covering should be just enough to fill the

drag or maintainer as it is pulled over the surface. Whatever the leveling device used, it should have a long base for best results. Covering should start immediately after the bituminous application and can be applied either with mechanical spreaders or direct from the tail gate of a truck (Fig. 1).

Fig. 1. Covering stone being applied from dump truck backing over fresh application of bituminous material.

The dragging should continue until all particles of covering are coated and all depressions filled. After sufficient time has elapsed for the bituminous material to become partially set up, the remaining covering should be applied. If the material is allowed partially to set up, this added covering will stick much tighter to the surface. The dragging may or may not be continued on this last application. If a light roller is available, the surface should be rolled once over after the last dragging. If, after these processes, the surface shows any signs of bleeding, sufficient additional covering should be added to remedy it.

The subject of this paper implies improved methods of surface treatments. If this discussion has anything to offer along that line, I would say in summing up skin treatment that it is, first, the method of applying the covering in two different applications; second, the intensive dragging with a long-base leveling device (Fig. 2), and, third, possibly, rolling.

HEAVY TREATMENTS

Heavy treatments are being used primarily to smooth existing rough surfaces rather than merely to preserve surface. In extreme cases, hand patching may be necessary before treatments start. By the proper number and kind of bituminous applications and the right kind and amount of covering

Fig. 2. Home-made wooden drag pulled by a distributor on county road surface treatment.

and dragging, very extreme cases of roughness may be corrected, and a splendid riding surface developed. Any number of successive treatments may follow one on the other until the desired results are obtained. Care should especially be taken on these heavy treatments to avoid rich mixtures. Rich mixtures will shove and wrinkle under traffic and produce a surface more objectionable than the original. In this class of work, do not be tempted by aggregate that is too fine, even though it is easier to manipulate. A much sturdier and more nearly non-skid surface will result if the aggregate is kept as coarse as reasonable for manipulation. In this class of work, I consider a light roller of about 5-ton weight essential if the aggregate is soft. With harder aggregate, the roller weight should be increased. Rolling should follow each application. This method of heavy treatments does not require elaborate equipment, is rapid, cheap, and, to my mind, very satisfactory. I predict that this simple and cheap method of sealing and smoothing the many miles of old and rough surfaces existing today will come into quite general use.

RESURFACING TREATMENTS

The difference between surface treatments and resurfacing treatments carries over into more extensive operations. Here the idea of added strength may enter in along with that of improving and preserving riding surfaces. Many methods and mixtures have recently been developed to accomplish these results. Each claims merits and advantages over competitors; but, as with all new products, fair and unbiased trial will

have to confirm the claims. All of these products fall into two general classes; namely, road mixes and plant mixes. Both have merit, and here again engineering judgment and the public purse will have to prevail if economical and lasting results are to be obtained. In most of these resurfacing methods, a binder course and a wearing course are usually specified. Because of the great number of mixes being promulgated, which makes it impossible to touch on all of them, I will confine myself to a method recently used by the state.

The two types of surface to be treated consisted of an old bituminous macadam and a section of old cement concrete which were laid several years ago when little attention was paid to the improving of the riding profile, and, as is true of most old roads, were built with an excess crown. Traffic was so slow at that time that the surface was considered comfortable in riding qualities. Now, when the speed of traffic is almost double, these wavy surfaces are most uncomfortable. Considerable weakness also developed under the heavy trucking to which our roads are now subjected, and had to be recognized and corrected.

It was decided on this resurfacing to use a bituminous-coated-aggregate binder course and a rock-asphalt wearing course. This binder course was composed of crushed stone aggregate graded in size from 1½" to ¾". It was coated with emulsified asphalt by the immersion process. The emulsion was timed to break about five hours after coating, which allowed ample time for manipulation.

Two methods were used in leveling this mixture. A finishing machine which has incorporated many of the ideas of a concrete surface finisher was used on several miles. The material was dumped into a hopper on the front of the machine. From there the finisher distributed the material along the surface, and by means of a screen and tamping arrangement laid the coated aggregate true to grade and crown. The finisher is self-propelled and depends on crawler-type treads running along the shoulders for propulsion. The device has much merit in that it is fast, economical with material, and comparatively easy to operate. One disadvantage is that the shoulders must be fairly true to grade and very compact, qualities which sometimes entail added cost.

In the second method, the coated aggregate was dumped into spreader boxes and allowed to flow out in the required amount while the trucks pulled the boxes forward. After the material was so applied, for some considerable distance, it was shaped to crown and grade by an attachment on a 12-foot grader. This attachment consists of a 24-foot shoe made of an I-beam which runs along the center of the road. This is rigidly attached to two special mold boards which replace the regular mold board of the grader. The two edges are kept

at the same elevation by the regular grader operating devices, the operator being guided by a level placed at right angles to the centerline of the road and attached to the mold boards. The mold boards are set for the proper crown. A steel apron runs along the outside edge of the pavement to insure constant and correct width. This method proved very satisfactory but has some disadvantages. The heavy tractor necessary to pull the grader as well as the grader itself has to run on loose aggregate. In order to avoid much turning, a considerable distance has to be covered before the leveler can be started. If unfavorable weather conditions suddenly develop, unmanipulated material may set up so much that it is difficult to shape afterwards.

After this course was laid by either of the two methods, it was rolled almost to resistance. About 100 cubic yards per mile of coated stone ranging from 1″ to ¼″ was then applied to the surface and dragged with a long-base maintainer. The purpose of this covering was to fill any remaining voids and to take out any depressions left by the roller which resulted from unequal compaction of the previous course due to the different depths necessary in smoothing up the original surface. We also found it necessary to apply a light treatment to some of the last rolled surface because of the chipping of the stone under the intensive rolling. When the surface is at this stage, it can be treated somewhat more heavily and left as an excellent and serviceable driving surface if the wearing course is not to follow. The binder course has an average thickness of two inches loose, varying from almost nothing in the center to four or five inches along the edges in many places. It is surprising how irregularly and unevenly some of these old surfaces were built.

The wearing course chosen consisted of ¾″ compacted rock asphalt. This was laid by hand, using 1¼″ metal guide strips for laying the loose material. One unusual thing developed in this course. We found the amount of rock asphalt required dropped off ten or eleven pounds per square yard from that required to lay the same thickness on the usual penetration macadam built as a base in previous practice. During warm weather, the rock asphalt was steamed. Later, after cooler weather set in, it was ground. The planing and rolling were done in the same established way so long used in handling this surfacing material.

The cost of any work is always of interest. In this work, the binder course was laid 18½ feet wide and ran about $2,810 per mile. The rock asphalt was laid 18 feet wide at a cost of $4,000 per mile. With ten-foot finished shoulders and 24-inch stone strip 4 inches deep on each side, the total cost will be about $8,500 per mile.

By this method, an old pavement has high salvage value and the resulting surface is excellent. With the great mileage

of all surfaces now existing and the insistent demand for economy, we as road builders would be betraying our trust if we did not give our most serious consideration to protecting and preserving the enormous original investment.

RESURFACING ROUGH PAVEMENTS WITH THIN LAYERS OF BITUMINOUS MIXTURES

By A. O. Hastings, District Engineer, Indiana State Highway Commission, Greenfield, Indiana

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Because of the great increase in weight and volume of traffic over our highways within the past few years, some of our older, poorly designed pavements have become worn or broken down to such an extent that they demand the immediate attention of highway engineers.

Many of these pavements are in such condition that light maintenance repairs fail to keep up with the destructive forces of traffic and weather. Many still possess sufficient strength and value to render it uneconomical to tear them up and construct new ones. The problem of insuring such surfaces the proper smoothness and stability requires an entire resurfacing.

Initial investments in these pavements are so large as to make the conservation imperative. Many roads are in such condition that they no longer meet the needs of modern traffic. It would be a distinct economic waste to destroy or abandon them. Enormous savings can be effected by resurfacing. By this salvaging method, which I maintain is sound, many advantages are derived. First, the original investment in the old pavement is conserved. Secondly, resurfacing materials may be obtained at very nominal cost, particularly at present prices. Thirdly, the operation may be completed with little or no interruption to traffic. The above economical undertaking results in a pavement good for many years of satisfactory service at a reasonable cost.

Bituminous mixtures lend themselves readily to the patching and resurfacing, or modernizing, of old pavement. The bituminous mixtures adhere readily to the old pavement, waterproof it, add a certain value as a shock absorber between the load and the base, and furnish also a durable non-skid surface. Such resurfacing can usually be done at a cost far below that of complete new construction.

Where such pavements exist, with conditions as described above, the maintenance engineer should carefully study the problem before deciding on the exact amount and type of such resurfacing. He should ascertain the amount and kind of