RECENT DEVELOPMENTS IN CONSTRUCTION METHODS AND APPLIANCES

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Although the past three or four years have witnessed very few fundamental changes either in our methods of building highways or in the general character of the mechanical equipment employed, the constant trend toward higher standards of quality as well as a new appreciation on the part of both engineers and contractors of the economic importance of maximum efficiency in construction operations has brought about many changes and refinements in detail construction practices It is the purpose of this report to discuss the more important of these developments from the standpoint primarily of their effect upon the design and use of the various mechanical appliances which have become so vital a part in the modern construction operation as well as to show by specific examples how improvements in equipment have made it possible to build to higher standards and at the same time effect substantial economies by increased efficiency of operation

Changes in either the design or use of equipment may be brought about by any one, or a combination of the following causes

(1) Changes which are made necessary by modifications in construction practices, as, for instance, the general adoption of weight batching for concrete aggregates which resulted in the development of weighing devices designed to accomplish the purpose quickly and accurately

(2) The adaptation of existing devices, either as is or slightly modified, to new uses, as, for instance, the utilization of the concrete finishing machine for finishing asphalt surfaces and the use of the blade grader for preparing mixed-in-place bituminous surfaces

(3) Refinements and improvements made primarily for the purpose of increasing operating efficiency, as, for instance, the development of the full automatic concrete paving mixer

Every year standards of performance in road construction are being raised and requirements made more rigid At the same time increased efficiency in operation made possible by the thorough coordination of construction operations and the increased use of mechanical equipment has actually resulted in lower unit costs of construction The management studies carried out by the Bureau of Public Roads have pointed the way to new opportunities in this field,—opportunities which have been seized by the Contractor and Equipment Manufacturer alike, with resultant benefits in the shape of better and cheaper highways

In so far as this report is concerned, consideration of the subject will be confined to a discussion of developments in methods and equipment as applied to the construction of road surfaces, including the various low

cost bituminous surfaces, bituminous concrete, sheet asphalt, portland cement concrete and block pavements It is felt that the outstanding developments in the way of equipment design and use will be covered by reference to these types

LOW COST BITUMINOUS ROADS

Several types of bituminous road surfaces known as "mixed-in-place" "re-tread," "blotter type," etc, have been developed in an effort to meet the need for a dustless all-year surface of relatively low cost, for use on the many thousands of miles of secondary roads in this country which do not carry a sufficiently heavy traffic to warrant the construction of high type pavements Although the methods employed in the construction of these surfaces differ in many details, they have at least one point in common,—they must be constructed at reasonable cost The part played by mechanical equipment in making this possible is of course recognized Without the blade grader, for instance, the development of the mixed-in-place type would have been impossible With it, the construction and maintenance of a very large mileage of secondary roads of a sufficiently high type to give all of the service demanded at reasonable cost has been possible

Recent developments in this type of equipment have had to do principally with refinements and improvements Road machines have been constructed which are heavier and more rigid than those formerly used with consequent improvement in the quality of work performed A tendency towards the use of motorized equipment is noted The self-propelled blade grader known as the motor grader is now extensively used in place of the tractor drawn machine In at least one case, a dual drive grader has been developed which, it is claimed, will operate more efficiency under difficult conditions than the conventional type, due to increased traction offered by the four wheels and consequent freedom from skidding This is of course primarily of interest in connection with grading operations in general rather than mixed-in-place oil surfacing operations It should be noted, however, as a significant development in construction equipment of this type

For manipulating mixed-in-place surfacing, spreading and leveling, various types of drags, maintainers, etc, are in use The principle of the ordinary road drag has been developed in the maintainer and 4-way drag by the use of multiple blades so set as to work the material back and forth across the path of the machine before blading it to one side (Figure 1) This adaptation of the old split log drag principle to modern construction methods has been found very efficient not only for leveling up broken stone courses and for general maintenance work but also for mixing bituminous material with the stone Maintainers of this type are of both self-propelled and draw-bar types

The importance of securing smooth level surfaces in this type of construction has resulted also in the use of very long base drags. Mr. A. H. Hinkle reports the use of multiple drags 32 feet in length for smoothing out the surface of the original road bed before placing the retread top.

Another interesting development has been the introduction of the broom drag for leveling and brushing in keystone and cover materials. This is an ordinary road drag in which the blades are replaced by brooms.

The point which is of greatest interest and which should be stressed in a review of this kind is that by the use of equipment such as the blade, drag and maintainer, not only is the cost of the work reduced but the work is better done than it could be by hand labor because of the increased smoothness which it is possible to obtain.

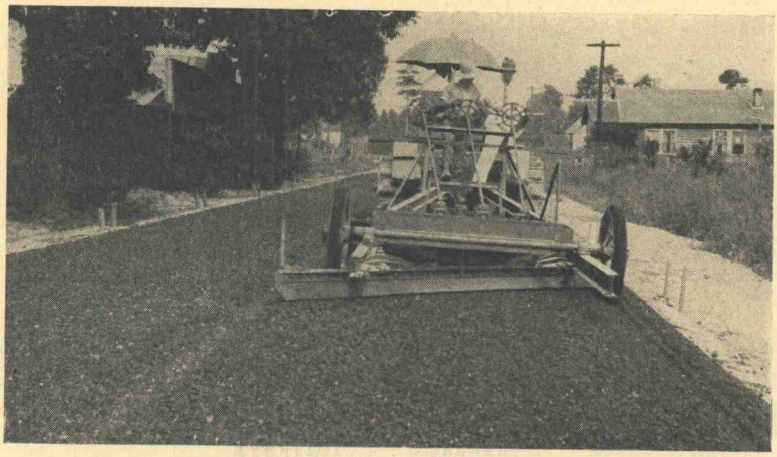

Figure 1. Four-Way Drag for Manipulating Mixed-in-Place Surfaces

Mention should also be made of the fact that the practice of using an asphalt plant for the preparation of gravel or crushed-stone fuel oil mixtures instead of the method of processing on the road is being continued in California. The chief advantage of this method lies in the fact that closer control of the mixture is possible. At the same time, it is claimed, the cost of construction is not increased beyond the point which would take this type of construction out of the low cost classification. A possible disadvantage is the fact that the increased smoothness due to continued processing on the road may not be attained.

In connection with the general subject of crushed stone and gravel surfaces, both plain and treated, mention should be made of improvements in portable crushing and screening plants. Complete self contained portable units are manufactured in which the various operations in connection with the production of surfacing material are carried out as

efficiently as in the larger permanent plants and at the same time the element of portability is retained. A recent development has been the introduction of shaker screens instead of the conventional revolving screens for taking out oversize particles. Plants of this character are of interest not only from the standpoint of efficiency in production, but also because they can be transported quickly from place to place as necessity arises, thereby utilizing local materials to the maximum extent.

Probably the most significant recent development in equipment for low cost bituminous road construction during the current construction season has been the use in at least two states of a self-propelled bituminous road mixer (Figure 2). This equipment, which is mounted on a truck, picks up the aggregate from a windrow down the center of the

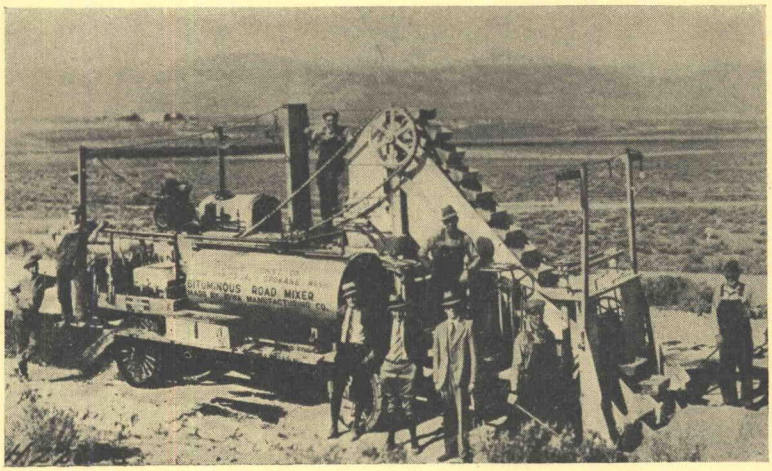

Figure 2. Self-propelled Bituminous Road Mixer

road by means of an elevator, delivers the material through a suitable weighing device to a pug mixer, into which the proper amount of bituminous material is introduced and, discharges the mixed material in a similar windrow behind the machine. The speed of the machine is regulated by the mixing time and averages about 8 feet per minute. The windrow of mixed material is spread by the blade in the usual manner. The extent to which the use of machines of this type will supplant the usual method of processing on the road is uncertain at the present time. It would appear, however, to present distinct possibilities, not only as a time saver, but also because it would make possible a closer control of the mix than is attained by the road mix process. From this point of view a machine of this type seems to possess some of the advantages of both the road mix and the plant mix methods; the former from the standpoint of cost and the latter from the standpoint of control.

BITUMINOUS CONCRETE AND SHEET ASPHALT

During the past three years a considerable advance has been made toward a substantial cost reduction in the spreading and finishing of various types of bituminous roads, through the application of slightly modified concrete finishing machines to this process The adaptation of the well known stone spreader box to the spreading of bituminous materials, has added further to these economies, when used in conjunction with mechanical finishing machines, and in general, there has resulted a material increase in the daily production, with larger plant capacity, and an improved uniformity in the materials so placed, with vastly improved riding qualities

There have been several articles written recently by well known State Engineers indicating the progress made, and results obtained through the use of such equipment, and in this report there will be summarized generally some points of interest

The following types of asphaltic concrete roads have been constructed with mechanical finishing machines

1 Two-course sand asphalt roads
2 Two-inch asphaltic concrete laid on concrete base
3 Two-course asphaltic concrete roads
4 Two-inch rock asphalt surface on concrete
5 Asphaltic concrete (laid cold) on concrete base, two-course construction

The foregoing list indicates, in a general way, the class of work which has been handled by mechanical finishing machines Among the states which have tried this innovation are Alabama, California, Georgia, Michigan, North Carolina, New York, South Carolina and Tennessee

There is some variation in the methods used in the different States, in that the California specification calls for longitudinal raking of the material, whereas in the other States the specification covering the raking has not as yet been deemed necessary, and the action of the standard concrete screed board has spread and re-fluffed the material satisfactorily, so that uniformity of texture and smooth surface is obtained One type of finishing machine is used which gives an initial compression to the material, thus reducing the amount of rolling required, and allowing the rollers to work much closer to the machine

By this method of construction the usual rakers are eliminated, with the exception of one back raker to touch up occasional spots, not properly finished by the machine, and thus some skilled labor is eliminated, with appreciable saving to the Contractor, and with improved results

The economy with the machine comes when the daily tonnage is in excess of 250 to 300 tons, and the capacity of the machines on, for

example, 18-foot roads with 2 inch top, approximates 800 to 1,000 tons a day.

In California it has been possible through improvements in plant arrangement, including a timing device on the mixers and the use of mixers up to 4,400 pounds capacity, to increase the output of plants up to 1,200 tons per day, or about 9,600 square yards of pavement on a 2 inch basis. The use of mechanical raking and spreading machines up to 30 feet in width has made it possible to handle these large tonnages without difficulty and has resulted in a very marked decrease in cost, as well as an increase in quality of the pavement surface (Figure 3).

Where a modified stone spreader box suitable for handling asphalt is used, the spreaders are eliminated entirely, with the exception of three men to hook the boxes onto the trucks, and do a slight amount of

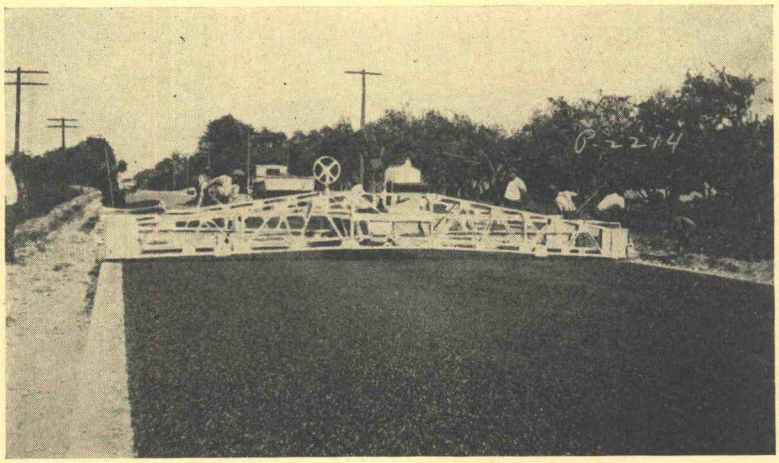

Figure 3. Finishing Machine on 30-foot Asphalt Surface

spreading. The greatest economy comes with the increased daily tonnage, and the use of the spreader box and mechanical finishers in combination, although even on smaller capacities there is a slight saving to be effected, and a decided improvement in surface conditions gained.

Such capacities are not met as yet in the East, although there is every evidence of interest in providing larger plant capacities for this type of operation.

Asphaltic concrete mixtures laid cold have been used successfully by New York State when the time elapsed between the plant and the job does not exceed 24 to 48 hours. However, at the present time material of this nature which is shipped in cars, with an elapsed time of a week or more, is too stiff to be properly handled with a finishing machine, particularly in the thinner top course.

Without question, the use of mechanical finishers and spreader boxes for bituminous surfaces, will grow and extend rapidly, and to obtain the greatest economies no doubt efforts will be made to enlarge the plant capacities, so as to utilize the machine capacity to a greater extent than has been done heretofore.

PORTLAND CEMENT CONCRETE PAVEMENTS

BATCHING BY WEIGHT

Undoubtedly the outstanding recent development in concrete paving practice has been the adoption of the principle of measuring aggregates by weight instead of by loose volume. First used by the State of Iowa in 1923, the practice has spread rapidly until now practically all of the State Highway Departments specify weighing. Moreover the principle

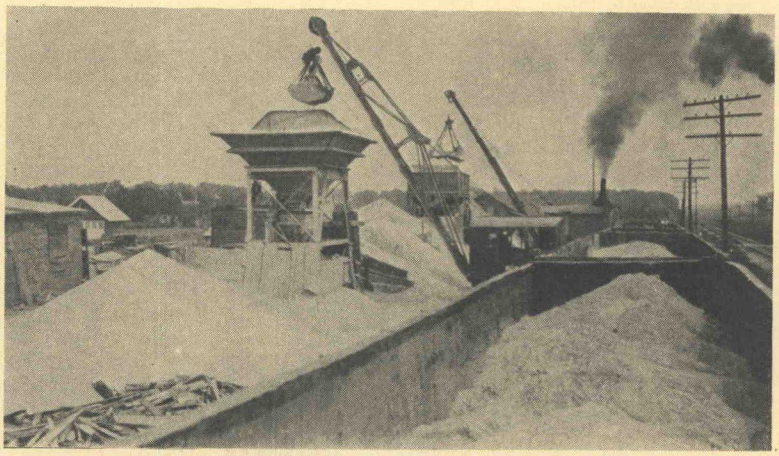

Figure 4. A Paving Job Using 3 Sizes of Coarse Aggregates

has met with such universal favor on the part of Engineers that many states are considering extending the practice to highway structures as well as pavements. In 1929, the Bureau of Public Roads, recognizing the inherent advantage of weight measurement, made the practice a mandatory requirement for Federal Aid insofar as concrete pavement construction was concerned.

Although, on the first jobs constructed, ordinary platform scales were utilized as the essential feature of a homemade outfit, the practical advantages of well built, accurate and self contained equipment soon became apparent, with the result that we now have available a number of commercial bin batcher type weighing plants, including those equipped with full load multiple beam scales, fractional beam scales with removable weights and full load springless dial scales.

The advantages of weight batching as well as the results secured in the State of Iowa were presented in a paper before the Highway Research Board last year[1] and will not be repeated here, except to call attention again to the fact that this method has now found practically universal favor with both engineers and contractors and that a complete reversal or practice in this regard has occurred during the past six years

In connection with the matter of weight measurement in general, it will be of interest to call attention to the fact that in anticipation of the general acceptance of the principle for bridge and culvert construction, there has been developed weighing equipment which can be attached to a small mixer in such a manner as to weigh the aggregates directly in the skip (Figure 4) The further development and improvement of this type of equipment so as to eliminate some of the practical difficulties should facilitate the general adoption of weight batching on small structures with consequent improvement in uniformity of concrete

DESIGNED MIXES AND SEPARATED SIZES OF COARSE AGGREGATES

Within the past few years there has been an increasing tendency on the part of the State Highway Departments to abandon the use of arbitrary proportions as a basis for designating paving mixes and to substitute therefor, either a specification fixing definitely the quantity of cement per unit of volume of concrete, or a specification requiring that the mixture be designed on the basis of strength

Obviously the thought underlying the adoption of either one of these innovations is to secure closer control of the quality of the concrete insofar as it may be effected by the proportions specified The design of the modern concrete pavement slab is based on an assumed strength of concrete It is obvious that the closer the strength of the concrete can be controlled, both as regards magnitude and uniformity, the closer can the design be figured In other words, the more rigid the control, the lower the factor of safety necessary

A trend in construction practice closely associated with the question of designed mixes, is the growing tendency to specify that coarse aggregate be delivered and handled in two or more separate sizes The theoretical advantages of handling aggregates in this manner from the standpoint of uniformity of the resulting concrete are obvious Inspection of aggregates for size at source is enormously simplified due to increased accuracy possible when sampling one size products Segregation in stockpiles is practically eliminated so that by designating the proper proportion of each size by weight the Engineer is able to insure almost exact uniformity as to the grading of aggregates in successive

[1] Control of Materials and Mixtures for Concrete for Pavements R W Crum, Proc Highway Research Board, 9th Annual Meeting, p 276

batches, thus greatly promoting uniformity in both the workability and the quality of the concrete

Although recognizing the theoretical advantages of separated sizes, many Engineers have felt that the ground room required for additional stockpiles, additional time required for batching, etc , would render the practical application of this principle somewhat difficult However, it would appear that there have now been a sufficiently large number of demonstrations under actual working conditions in such states as Louisiana, North Carolina, New Jersey, Wisconsin and California to indicate that this innovation is not only entirely feasible from a practical standpoint but the results which have been secured amply justify the very slight additional cost

Equipment has kept pace with the requirements of designed mixtures and multiple aggregates Previously a single bin containing two compartments, one for sand and one for coarse aggregate, was in general use The use of multiple aggregates usually requires two bins, although in cases where only two sizes of coarse aggregate are specified, single bins having three compartments have been used (Figure 4)

In cases where three or more sizes of coarse aggregate are specified, stockpiling is a problem that makes desirable the use of two bins placed sufficiently far apart so that stockpiles may be formed, between them These bins should have sufficient capacity to allow the crane time to move back and forth, at the same time keeping both bins filled In some instances this has been accomplished by carrying one hour's supply of aggregate in each bin However, in cases where stockpiling and trackage facilities are not of the best, it has been found necessary to use two cranes, one for each bin In planning a layout for a central proportioning plant, using multiple sizes of coarse aggregate, great care should be exercised in placing the various units so as to facilitate rapid loading Experience in both North Carolina and Wisconsin, where three sizes of coarse aggregate have been used, has demonstrated that the efficient operation of a loading plant under these conditions is readily accomplished There can be no question but that the use of two sizes of coarse aggregate is thoroughly practical

BULK CEMENT AND WATER MEASUREMENT

There have been two other developments in connection with the measurement of materials which should be mentioned, first, the growing tendency to use bulk cement, and second, the great improvement in water measuring devices on paving mixers

Aside from the increased accuracy due to actually weighing the cement rather than assuming that a bag will always weigh exactly 94 pounds, the chief advantage of using bulk cement lies in the fact that the full capacity of the mixer can be utilized continuously In other words,

through the weighing of all materials, including the cement, and the accurate measurement of the water, it is possible to control the yield of each batch to within very narrow limits This is not only a further aid to uniformity but makes possible a more efficient operation of the paver from the standpoint of production This latter point will be discussed in some detail later

Equipment for handling cement in bulk, consisting of unloaders, scrapers, elevators (both mechanical and pneumatic), storage bins, weighing hoppers, and discharge boot for handling cement from bin to trucks, has come into general use in certain localities The method of handling bulk cement from car to truck in hand carts and weighing on platform scales, continues to be used Even though manual labor is involved, the latter method is preferred by many to sack cement because of its greater flexibility and the ability to take full advantage of the capacity of the mixer irrespective of the actual proportions designated

Improvement in the design of water measuring devices on paving mixers has likewise been marked The most significant change has been brought about by the requirement that paving mixers be equipped with an auxiliary tank placed above the measuring tank in order to relieve the latter of variations in pipe line pressure In a paper before the Highway Research Board last year the results of a series of investigations into the factors affecting accuracy of water measurement were discussed [2] The use of the supplementary tank was found to add materially to the accuracy of measurement

The correct determination of the amount of water used in mixing is, however, dependent not only on the accuracy of the tank measurement but also on the ability to make the proper correction for water in the aggregates It is becoming the practice in certain states to require that sand be stockpiled at least 24 hours before being used This requirement is of special importance in those cases where sand is being transported by truck from a nearby washing plant Under such conditions the use of the sand without stockpiling has been found to give very unsatisfactory results because of wide variations in water content during the day

SUBGRADE AND FORMS

Increased requirements as to accuracy in pavement thickness has resulted in far more attention being paid by Contractors to the subgrade than formerly was the case The power subgrader and form grader are coming into general use There is a growing tendency to require that forms be set on excavated material only, thus insuring stability under the

[2] Accuracy of Water Measurement on Paving Mixers F C Lang and Bert Myers, Proc 9th Annual Meeting Highway Research Board, page 332

finishing machine There seems also to be sentiment in favor of an 8-inch base form instead of the present 6-inch base One state has also called attention to the fact that if a longer form could be developed it would be more satisfactory than the present 10-foot form The same state believes that further improvement should be effected in the power subgrader so as to cut closer to final grade than is now possible At the present time Contractors are often required to place from 8 to 10 per cent excess concrete in order to insure the specified thickness at all times This condition has been partially remedied by the use of the subgrade planer behind the mixer During the past season a sprinkler system has been installed on the planer for sprinkling the subgrade, the water flowing only as the planer moves forward In this way water reaches the grade only after it has been brought to the final cross section

JOINTS

The pendulum swings! After ten years of building concrete roads without transverse joints and after a number of years of experience in the use of longitudinal joints formed by a corrugated metal strip, the last two years has seen a tendency to return to expansion joints and the adoption of the dummy longitudinal joint Both the transverse and longitudinal joints are being cut into the pavement by mechanical or manual means after the concrete is in place

Two types of machine have been develpoed for this work, one being a cutting roller carried behind the finishing machine which cuts the longitudinal joint as the finishing machine proceeds and the other being a special machine for cutting both longitudinal and transverse joint This machine is also designed so as to install a preformed joint filler in the groove thus formed In some instances the space left by the cutter is filled with a poured bituminous filler, and in others, the joint is finished over the top by the finishing machine, it being the belief of the proponent of this last method that there has been developed a sufficient plane of weakness so that cracks will be concentrated at this point In nearly all instances, transverse dowels are placed sufficiently low that the cutter of the machine will pass over them without disturbing them

FINISHING

There have been no radical changes in equipment for finishing The double screed type of finishing machine is now used almost exclusively, although finishing machines have been developed in which the second screed can be interchanged for a tamping element and this machine made suitable in circumstances where tamping is required

A new development may be looked for from the vibration of concrete at very high frequency while finishing Although the use of a vibrator has been somewhat general for mass and reinforced concrete, and the

vibration of concrete road surfaces at relatively low frequency has been common, the application of high frequency vibrators to finishing machine screeds is new

A standard finishing machine equipped with three vibrators, two on the front screed and one on the rear, has recently been tried out on a concrete paving job with apparently satisfactory results The progress of this new development will be watched with great interest

A power operated longitudinal roller has also been developed which does mechanically what is now accomplished by means of the longitudinal wood float, with the advantage, however that the roller being set to theoretically perfect crown, assures not only smoothness but also full thickness of pavement The insistence of Engineers upon smoother riding qualities in the road, and upon the removal of scum and laitance to make the surface more "healthy," are two demands which may eventually require the use of mechanical equipment for truing and cleaning the surface of the concrete

REINFORCING

There appears to be a real need for a satisfactory way for handling reinforcement in concrete road construction Reinforcement, where used, has been carried on chairs, suspended on hangers, supported on the forms, and laid on sleds of pipe of T beam construction, which sleds are pulled forward as the paver moves forward Studies of cracks in pavements where sleds have been used and cores taken at such points have lead to the opinion that this type of construction should not be continued It appears that no matter how carefully the concrete is puddled, after the sled is pulled forward a plane of weakness results which is a cause of a crack In Pennsylvania a template so designed that it can be pulled ahead by an auxiliary winding drum mounted on the paver, has been used to strike off the first course of the concrete Following this, the reinforcement is placed and the top course spread by the boom bucket The availability of 25-foot booms on paving mixers has resulted in additional space for the preparation of the subgrade and handling reinforcement

EARTH COVERING, SHOULDERING, ETC

A power machine for covering newly laid concrete with earth has been developed (Figure 5) which has been working particularly in the Southern States where earth covering is specified, and is overcoming the objection that earth covering can not be uniformly distributed over the slab A sprinkler attachment provides for sprinkling the earth the first time over The machine has a capacity of approximately 1,200 feet in from 3 to 4 hours

The mechanical finishing of shoulders and the preparation of backslopes and ditches have found their places in concrete road construction. Among mechanical developments might be mentioned the use of the pull shovel for trimming backslopes and forming the shoulder and berm. This machine stands on the pavement, reaches out to the top of the cut or, in the case of deep cuts, to the end of its reach and brings the backslope to approximate finished line and grade. The ditch is cleaned out. Any excess required for building the shoulder is dropped as the shovel dipper comes in. Excess dirt not required at the point where the machine is at work is loaded into a truck to be hauled to points ahead where needed. An experienced operator with such a machine can

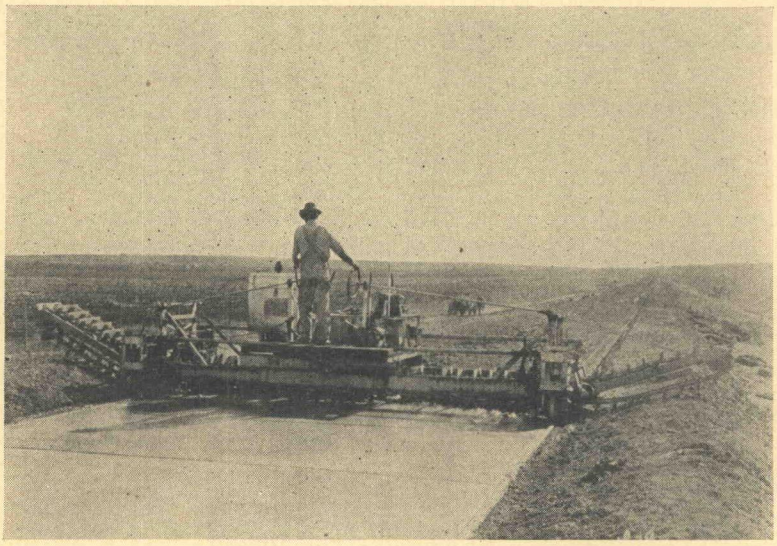

Figure 5. Earth Covering Machine for Curing Concrete Pavements

practically eliminate hand work. Final finishing of the ditch and shoulder may be done by hand or by machine. Two types of finishing machines for the completion of the shouldering have been developed; one, a blade with the cutting edge built to conform to the cross section shown on the plans and second, a machine in which the surface is finished by a line of digging buckets held to line and grade and operated at high speed. In the operation of both of these machines, the edge of the concrete is used to establish line and grade. Some difficulty may be expected with both types on rocky ground but where the pull shovel is adopted for preparing the shoulders, it will be found convenient to use it for burying boulders that would otherwise be very hard to handle. The rapid development of mechanical shouldering equipment is assured.

THE AUTOMATIC PAVER

An outstanding development in paving equipment from the standpoint of production efficiency is the full automatic paver

In this machine, the timing of the control is transferred from the operator to the batchmeter The elapse of the specified mixing time is designated by the ringing of the batchmeter bell The meter releases a mechanism that opens the discharge chute, engages the skip clutch for raising the skip, and at a predetermined time opens the water valve, and locks the skip hoist brake at the end of the skip travel Great uniformity of concrete has resulted The control of time of entry of water, the control of the amount of water, and the control of the speed of the entry of water have materially helped

TANDEM PAVER

Contractors, believing that only through mass production can large plants and expensive organizations be justified, have developed the use of the tandem paver One 27E paver receives cement, sand, coarse aggregate and water, mixing it for approximately one-half of the specified mixing time and then discharging the batch into the skip of the second mixer The skip of the second mixer is then raised and the partially mixed concrete is charged, to be mixed for the remainder of the specified time When the mixing has been completed, the concrete is discharged into the boom bucket to be delivered onto the grade

Averages over days, weeks and months have shown an increase of from 50 to 75 per cent over averages where a single paver has been used on similar work This justifies the additional expense for equipment as, although the investment in pavers is double, the total investment for plant is not double because of the availability of the same railroad set-up, the same bins and the same method of handling material from cars to bins Thorough planning of the plant is essential as otherwise the handling and unloading of materials become the bottle-neck of the operation

There are differences of opinion as to the relative advantage of this type of operation over the method of splitting the organization and handling two pavers from a single or two central proportioning plants However, the control of operations under a single superintendent and a single staff of foremen, together with the control of hauling units, apparently has marked advantages Where industrial railroad has been used, the advantage of the tandem mixer over the two single pavers is apparent, eliminating the maintenance of two lines of track and the difficulty of balancing two operations at some distance from each other One Contractor using trucks reports 21,100 linear feet of 20-foot pavement (43 75 cubic yards per 100 linear feet) in 151 8 hours, or an average of 140 feet per hour His best day's work was 1,882 feet in 13

hours, 10 minutes,—an average of 142 93 feet per hour During this time, 807 batches were placed at an average speed of 61 5 batches per hour, the above under a specification calling for a minimum of one minute mixing time after all materials were in the drum Another Contractor using industrial railroad reports 946 feet of 18-foot road in 5 hours as his best half-day's work, using a batch of 29 7 cubic feet This is equivalent to a rate of 74 batches per hour In 10 5 hours, he placed 1,937 feet, or an average of 64 batches per hour, and in five days, or 55 total hours, he placed 8,979 feet, or 163 feet per hour, equivalent to 57 batches per hour, including all delays

READY MIXED CONCRETE AND QUICK MIXED CONCRETE

Permanent well equipped central mixing plants for the manufacture of concrete have been well established for a number of years, especially in the vicinity of the large cities In the past, however, the theoretical and practical advantages of such installations have been neutralized somewhat by the difficulty of transporting the concrete to the job without segregation The agitator type of truck body seems to be an answer to this problem Any means which will keep the concrete in the truck agitated mechanically during hauling should remove a serious obstacle to the utilization of central plant mixed concrete, provided of course the workability of the concrete is maintained up to the point of placing

In so far as road construction is concerned, the central mixing plant has been utilized principally in city street work, for bridge structures and in the construction of concrete shoulders in road widening programs No great amount of paving work has been done up to this time One possible reason for this has been the problem of efficiently spreading the concrete from trucks in the regulation widths The use of truck mixers of both the drum and paddle type in which the mixing is done in the truck itself as distinct from the agitator type in which the concrete is mixed completely before being charged into the truck body, has increased greatly within the last few years Here again, the utilization of such equipment, in so far as highway construction is concerned, has been confined largely to road widening and to bridge construction There appears to be a distinct field for both the central mixing plant and the truck mixer in supplying concrete on locations where the quantity involved is too small to warrant the installation of an expensive plant and yet where it is desired to maintain quality to a high degree

BRICK PAVEMENTS

There have been two recent developments in connection with the construction of brick pavements which are of considerable significance, the first a tendency towards the use of a tar or asphalt mastic cushion course in place of sand bedding and the second the introduction and use

of a combined wheeled pouring kettle and squeegee (Figure 6) for applying the filler. The advantages claimed for the mastic cushion are increased stability without sacrifice of flexibility. The wheeled squeegee makes possible a much more uniform application of the filler than when hand squeegees are used, because the pouring and the squeegeeing operation are both controlled by one man. It is possible by this method to squeegee more of the filler into the joints and thus leave a much smaller excess upon the surface of the brick, with consequent reduction in danger from skidding.

Mention should also be made of the experimental metal base brick pavement laid this year in Illinois. In this experiment, the usual con-

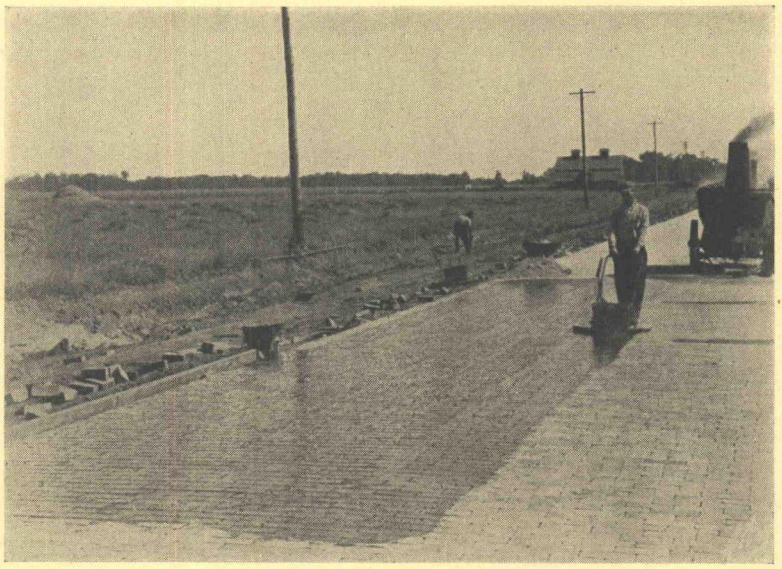

Figure 6. A Combined Pouring Kettle and Squegee Used in Construction of Brick Pavement

crete base was replaced by No. 10 gage corrugated metal sheets laid upon the subgrade direct. In all other respects standard construction methods were followed. The behavior of this test section under traffic will be watched with interest.

CONCLUSION

The subcommittee has endeavored to give in the above discussion a general view of the present trends in design and use of road construction equipment, with reference primarily to changes which have been made necessary by reason of the growing demand for higher standards of quality combined with greater efficiency in operation. In order to

obtain an accurate cross-section of the prevailing thought on the subject, the Committee communicated with the heads of the construction divisions of the various state highway departments, and requested from each a statement as to the most significant developments along this line during the past three years The report embodies the ideas of the construction engineers as reflected in the large number of replies to this letter which have been received The Committee wishes to express its appreciation of the cooperation extended by the representatives of the state highway departments, without which the preparation of a complete report would have been impossible

DISCUSSION

ON

RECENT DEVELOPMENTS IN CONSTRUCTION METHODS AND APPLIANCES

MR H HERSHEY MILLER, *Pennsylvania Department of Highways* The presentation of such an important subject as "Recent Developments in Construction Methods and Appliances" is not only timely but should prove of inestimable value to the Highway Engineer and the Constructor

It is not my purpose to try to add to the complete report covering new appliances or the adaption of existing devices to new uses, but rather to present some data covering efficiency records on paving projects in Pennsylvania

These studies were conducted in order to determine, if possible the causes for different rates of progress on concrete paving projects by different contractors having essentially the same equipment

The method of rating the contractors was based on percentage of possible working time utilized and number of batches mixed per actual working hour For instance, if the possible working time was 60 hours and 12 hours were lost due to breakdowns in equipment, inadequate loading or hauling facilities, lack of materials, delays in grading or setting forms, the contractor was rated as 80 per cent efficient in time utilized

The mixing operation was based on a possible 40 batches per hour of actual working time or $1\frac{1}{2}$ minutes per batch (Pennsylvania specifications require $1\frac{1}{4}$ minute mix) If the actual number of batches mixed per hour were 30 due to delays in placing steel, discharging batches, placing and finishing concrete or preparation of grade in the pit, the contractor was rated as 75 per cent efficient in batches mixed

The true efficiency rating was based on percentage of working time

utilized, times percentage of batches mixed, divided by 100 or 80 × 75 − 100 = 60 per cent

A comparison of the efficiency ratings covering the year 1929 and the year 1930 including the week ending October 2 follows

EFFICIENCY RECORD ON PAVING PROJECTS

Year	Time utilized	Batches mixed	True efficiency
	per cent	*per cent*	
State average, 1930	82 63	79 68	65 84
State average, 1929	76 40	60 00	45 84

From these data it can be seen that the efficiency has been increased nearly 50 per cent by bringing to the attention of the contractor his lack of coordination In conducting these studies time lost due to conditions beyond the control of the contractor were not used in the computations

Some Engineers might deem these studies as not related to his job, but I am sure that our Department has benefited in decreased costs as reflected in bid prices, the contractors have benefited in increased profits, the public has benefited in earlier use of the roads and in addition the quality of the work has improved, as indicated by a comparison of roughometer determinations, drilled cores and beam tests

In conclusion it seems that the Contractors' Associations would do well to study job operations and construction methods, with the thought of presenting to their members a simple workable outline that could be used for analyzing and correcting conditions on the individual projects After all the contractor is the one person who should be vitally interested in efficient construction methods and efficient operations, and appliances become of secondary importance as an aid in securing these results

MR C N CONNER, *American Road Builders Association* I have recently learned from manufacturers of construction and maintenance equipment that many of them are interested in developing equipment for low cost roads One in particular has devised a machine which he claims will thoroughly mix the mixed-in-place type in one pass of his machine Another method with which engineers from Indiana and Missouri are familiar is known as precoating the aggregates This is done by dipping the aggregates in a vat of bitumen The manufacture of new types of equipment for constructing and maintaining low cost roads should be thoroughly investigated as a field for profit to the manufacturer and a means of reducing costs to the owner

Chip spreaders for use in the application of aggregates for the con-

struction of surface treatments are not mentioned in the report They are more economical than the customary hand methods because

(a) There may be a quick application of cover materials with a minimum delay and inconvenience to traffic
(b) There is a reduction of waste of material as compared with hand spreading from piles along the roadside
(c) A more uniform distribution of cover material results than by hand methods
(d) When projects are of appreciable size there is a reduction in cost

There is need for improvement in equipment which will give early compaction to low cost roads, particularly the untreated types such as sand-clay This fact was brought out in a report made by Dr Strahan to the Bureau of Public Roads in the State of Georgia, but in so far as I know, but little attention has been paid by manufacturers to his recommendations