Portland Cement Concrete Paving with Central-Mixed Concrete

W.P. Yamarick, Chief Engineer, C.F. Replogle Co., Circleville, Ohio

The increased volume of highway construction during the past decade has challenged the ingenuity of designer, contractor and equipment manufacturer. Greater need for intricate interchanges, urban construction and other complicated pavement arrangements promoted the consideration of more efficient construction methods. Central-mixed concrete offered the necessary characteristics of high-capacity automation, versatility and portability. Through the cooperative efforts of owner and contractor this method has now proved its merit by performance and ranks as an outstanding development of the highway industry. This paper represents the experience of a contractor employing central plant procedures on varied highway projects for the State of Ohio.

●FOR THE PAST two decades, "paver on the grade" has been the universally accepted technique for producing high volume, quality concrete for large highway paving projects. With the continuing impetus of progress and competition, standards were established by industry that influenced the consideration of other methods. High production, versatility, and rigid quality control were all met by central-plant installations. Equipment improvement, advent of air-entraining concrete and modification of restrictive specifications made practical the application of this technique to highway construction. In general, central-plant installations include the following basic approaches:

1. Transit mix — the proportioning of material at a central location and mixed in a transit-mix truck either en route or at the work site.
2. Shrink mix — the proportioning and partial mixing at a central plant and delivered to the work site in transit-mix trucks.
3. Central-plant mix — the proportioning and complete mixing of materials at the plant and delivery to the work site in agitator or non-agitator trucks.

This report is devoted to central-plant mixing and hauling with non-agitating trucks. Numerous comparisons to pavers are made throughout because of the almost universal familiarity with this type of operation.

CENTRAL-PLANT INSTALLATION

The components of a central plant are basically similar to a conventional dry batch installation with the addition of a mixing unit. Aggregates are weighed and delivered to a rotating drum, cement is measured conventionally, delivered with the aggregate or fed directly to the mixer where water is added and the resultant mixture discharged into a hauling unit or an accumulating hopper.

The modern plant is usually fully automatic with interlocked batching and mixing controls so as to minimize human errors. The operation of the plant is electric, powered by portable generators or commercial current. A master control panel is normally located at the mixer with auxiliary controls at each operation to permit manual operation should the automatic mechanism fail.

A typical cycle of a central plant is as follows: the cycle can be considered to begin when the drum returns from its discharging tilt. The drum returned to its mixing position actuates a relay that opens the discharge valve of the water weighing hopper and the proportioned water is fed to the drum. A few seconds later the drum is charged with aggregate followed by cement. After the specified mixing time has elapsed the concrete is discharged and hauled to the placement site. During the mixing operation, cement and aggregates are automatically proportioned and stored, either on a conveyor belt that directly charges the mixer or in a holding hopper located above the mixer, and then charged by gravity.

The concrete is hauled to the placement site in trucks equipped with specially designed non-agitating bodies. Capacity of these vehicles varies from 4 to 6 cu yd. The concrete is gravity discharged by raising the beds and spotted accurately by chutes that are hydraulically actuated. At the pouring site the concrete is placed in a self-powered box-type spreader. This spreader is equipped with a hopper which travels across the grade from one form to the other depositing concrete evenly to the correct depth. When depositing bottom course concrete, this spreader has a capacity of approximately 150 to 180 cu yd per hour. For half-width paving, concrete is usually discharged directly on the grade and spread with a conventional screw spreader. However, it is desirable, if not necessary, on full-width paving to place the mix inside the forms by other means. As yet, auger and paddle spreaders are not available to efficiently transfer concrete 18 to 20 ft at the rate necessary to handle the production of a large central plant. In the event only auger spreaders are available when paving full width, hauling units would have to pour from both sides of the pavement or travel inside the forms on the subgrade. After placement of the mesh, the top lift can be placed by a second box spreader or by backing the first spreader that deposited the bottom lift. Because most specifications permit a heavier first lift, many contractors find it possible to use a conventional auger spreader on the top lift without diminishing production. The remaining operations of finishing and curing are identical to the other paving methods and are not discussed herein.

INVESTMENT CONSIDERATIONS

A contractor purchasing a new paving spread will base a major portion of his decision on initial investment and operating costs. It is reasonable to assume that the finishing equipment is comparable in cost regardless of the paving method employed. Therefore hauling units and plant are the two remaining requirements to be considered.

Hauling Units

In general a fewer number of slightly more expensive hauling units is required for central-mix paving operation. The additional initial cost results from the use of specially designed, single-purpose bodies. The fewer number results from reducing the waiting time at the plant for loading and reducing the time at the grade for discharge. For example, the average total time to load and discharge a 6-cu yd hauling unit is between 1½ to 1¾ min. This is about equivalent to the time necessary for a single 1⅓ dry batch to be weighed at the plant and dumped into the skip of a paver. The travel time for either vehicle being equal. Simply stated — improved equipment usage is realized in a wet-batch haul through the reduction of waiting time at the batch plant and grade for an equivalent yardage.

From an investment viewpoint, however, the contractor considering central plant is confronted with the additional expenditure for hauling units, whereas in a paver operation, hauling units are universally available on an hourly rental or a per batch basis. This possibly represents the major difference in basic initial cost in the two techniques. At an average cost of $15,000 each for ten to fifteen hauling units, an investment of this magnitude must be justified on the basis of:

1. Availability of capital.
2. Continuity of work that would permit the distribution of the fixed costs of depreciation and interest.
3. Available projects consisting of hauls sufficiently comparable so that a base number can be acquired to handle the plant production efficiently. Occasionally the

capacity of the plant is not fully used on extreme hauls of a job because it would be too costly to own hauling units for the few days necessary to pour out the long-haul yardage. A dry-batch hauler, however, has the versatility of more readily adding trucks on the long haul to satisfy the demand of pavers.

Plant Facilities

The production available from a paver or a central plant is largely dependent on the required mixing time. Extensive tests conducted during the past few years verify that time required for proper mixing is not a factor of drum size or batch size. Therefore, for comparative purposes, an 8-cu yd mixer operating on a 2-min cycle (total time to produce and discharge one batch) yields the equivalent of 2 and a fraction dual-drum pavers when operating on a 60-sec mixing time. It appears that the initial investment per cu yd for this phase would be ½ to ⅓ less for central mix. This however does not follow in the case where commercial power is not available and portable generators must be employed to operate the electric drives of a central plant. In this type of installation the initial cost would roughly be equal.

The batching equipment, namely the bins and weighing facilities, are of comparable cost. An appreciable saving occurs in a central-plant installation where municipal or suitable stream water is available and can be piped directly to the mixer. This arrangement is rarely feasible in a paver operation and results in the elimination of two or more water trucks per paver.

The equipment investment requirement resolves itself to (1) the individual contractor's operational program and (2) the specific location of paving projects that may or may not have available commercial water and power supply. No convenient formula applies to all situations. The economics of investment must be reviewed, therefore, on an individual basis.

The author's Company made the following comparative analysis for its own requirements in 1958:

Central-Mix Plant

Fully automatic, portable, 8-cu yd plant.
Production: 240 cu yd per hour when operating on a 1-min 30-sec mixing cycle.
Estimated Cost:

1. 8-cu yd mixer drum complete with base and holding hopper	$ 40,000.00
2. 36-in. conveyor complete	20,000.00
3. Automatic batch bins, cement silos, etc.	60,000.00
4. 300 KW generator and accessories — assembled by the company	30,000.00
	$150,000.00

34E Dual-Drum Paver Plant

Production: Maximum production of two 34E pavers when operating at 100 percent efficiency and a 1-min mixing cycle is 240 cu yd per hour. Probably production is less than 200 cu yd per hour.

1. Two 34E dual-drum pavers	$100,000.00
2. Batch plant — 3 stop	55,000.00
3. 2 water trucks	15,000.00
	$170,000.00

The addition of one water truck to the central plant cost would make its investment close to that of the paver plant. It is pertinent to recognize, however, that the production of 240 cu yd per hour or 200 cu yd per hour f6r the pavers may be optimistic where theoretical output of a central plant is not uncommon, and with proper plant design, can be expected. In addition to initial investment, the C. F. Replogle Co. believed that the obsolescence factor as well as maintenance costs were far more favorable to central plant than pavers.

FIELD CONSIDERATIONS

Plant

Approximately four acres are required for aggregate stock piles and plant. A sloping terrain or a side hill arrangement provides drainage and more important, a difference in elevation between the mixer and the batch bins. The mixer drum must be set high enough to discharge into trucks or higher if into a holding hopper (Fig. 1). Conveyors are used to take the aggregate from the weigh batchers to the mixer drum. At an average incline of 18 to 20 deg to prevent aggregate rolling on a belt, the length of the conveyor is proportionate to the difference in elevation between the weigh batcher and drum.

Many installations place both the cement and aggregate on a conveyor belt. This offers the desirable advantage of pre-blending all materials, except water, by ribboning the cement on the belt with the aggregates. The batch enters the drum in a proportioned mixture that greatly improves the uniformity of the concrete. Repeated field tests have verified the desirability of this operation. The loss of cement from the belt is negligible and is considered less than that experienced in a paver operation. This pre-blending operation can also be accomplished by storing the aggregate and cement in a holding hopper prior to charging the mixer. The effectiveness of both techniques has prompted certain authorities to consider this as a factor in reducing the mixing time required by their specifications.

The central-mix plant presents a different maintenance task to a contractor because practically all drives and controls are electrical. Sealed explosion-proof motors, control panels enclosed in dustproof housings, etc., have resulted in availability of 95 percent or better. This degree of performance can be insured only through the training of competent mechanics and electricians. An effective preventive maintenance program is vital. Any breakdown of the plant results in complete stoppage of production, whereas in a multiple-paver spread the failure of one mixer reduces output but doesn't completely terminate operations.

A mobile radio installation is almost mandatory to permit close contact between the plant and pouring site. A breakdown of a key machine on the forms might occur when upwards of 100 cu yd is mixed and must be either placed in the forms or wasted. A 5- or 10-min delay in notifying the plant might add another 25 to 50 cu yd to handle. This surge of mixed concrete, however, offers an advantage in the event of a plant breakdown because there is usually sufficient concrete on the way to the grade to pour to a bulkhead.

Grade

After the concrete is placed in the forms, the finishing of central-mixed concrete is performed by conventional methods. The placing of concrete within the forms by a box-type spreader has proved satisfactory and efficient. The box or hopper has an open discharge gate so the concrete flows directly on the grade and is large enough to receive the full yardage of a hauling unit. Because the combined weight of the machine and concrete is appreciable, the spreader is so designed to transfer its weight to two forms by use of four wheels and two walking beams on each side. Nevertheless it is advisable to use heavy-duty forms to minimize deflection during operation. Particular care must be exhibited in superelevated sections to insure sufficient penetration by form pins into the subgrade to resist the overturning of forms by the spreader. The use of a box-type spreader presents other operational considerations because of its size, 24 ft by 28 ft. Lifting on and off forms must be closely supervised to avoid any racking which would interfere with subsequent mechanical operation. In addition, transferring from one site to another requires the dismantling of this spreader to permit hauling over highways.

When operations approach a bridge that must be crossed, light mine rail are laid and the equipment traveled to the other side under their own power. No time is lost, because mixed concrete can be placed directly on the grade ahead by the hauling units, while the finishing equipment is crossing the structure.

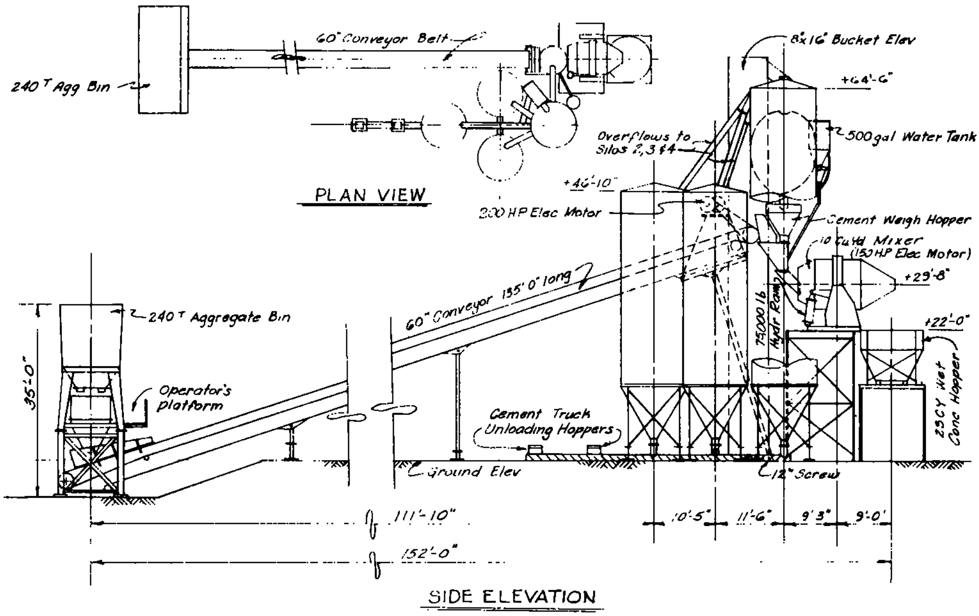

Figure 1. Batch plant arrangement 10 cu yd mixer.

Usually concrete is poured at more than one location at one time. This is accomplished by the organizing of a crew for main line and a crew for approaches and miscellaneous work. Properly scheduled completion of the main line is concurrent with the completion of all other paving. The full plant capacity is therefore used at all times from beginning to end of a paving project.

Hauling

Central-mixed concrete is transported in specially designed bodies of either the agitating or non-agitating variety. The choice largely depends on the specific requirements of the contractor. Agitation is looked on with favor by many commercial consumers of ready-mix concrete who favor concrete being mixed as it is discharged. Certain urban hauls lend themselves to agitated hauls, particularly those of extended travel time. However, these considerations may be academic in choosing the type of hauling units for the majority of highway pavement construction. Extensive tests confirm the acceptability of both methods, each having its own particular characteristics that may be desired to meet a given requirement. Many contractors have gone to non-agitated hauling units because of lesser initial and operating costs.

No detrimental effects have been experienced in transporting concrete in non-agitating units on paving projects in the State of Ohio. Hauls in excess of 5 miles are uncommon; however, 10- and 12-mi distances have been completed acceptably. Factors other than distance should be considered, such as haul road, atmospheric conditions, air content, and slump. It is usually possible to pour away from the central plant and use this pavement to travel on after the curing period, thereby increasing travel speed and reducing time of delivery. Smooth, properly maintained haul roads also reduce the disturbance of the mix that might promote segregation during haul. It is very important that the air content be kept at the upper limits permitted by specifications. A mix of five to seven percent air is desirable, which after hauling extended distances, places and works well. No significant loss of air is realized even on the most extended hauls. Such efforts can insure the delivery of concrete with no detrimental characteristics.

Vibrators are installed on dump bodies to insure rapid and thorough discharge. Bodies require thorough cleaning at the end of each shift. Dirty beds promote further buildup of the following shift and add unnecessary weight to the hauling unit. The trucks must possess a great degree of dependability because of the risk of concrete setting up in the body during a breakdown. Exceptionally well-maintained haul roads are necessary to minimize mechanical failure of trucks. The high center of gravity of rear dump hauling units require that berms be bladed level particularly in superelevated sections to avoid overturning. Pouring operations are usually scheduled to permit discharging the vehicles on the driver's side. This allows faster spotting and more important, a safer operation because the driver can gage his movements personally and, therefore, more accurately.

CHARACTERISTICS THAT WILL PROMOTE MORE EXTENSIVE USE IN FUTURE

Versatility

To properly handle modern traffic, pavements have become increasingly intricate in design. Complicated interchanges and the intersections require extensive variable width lanes, tapered sections, dog legs, approaches, and like work. This is generally low production work involving extensive hand labor to pour and finish. The use of pavers results in the use of only a small portion of its capacity thereby greatly increasing the cost of this operation. Central mix offers the flexibility to perform this work efficiently. The plant production can be fully realized by pouring in multiple locations at one time. It is common practice to pour at ten or fifteen locations in one day in addition to maintaining production on the main line pavement. Further, the delay in production when moving a paver from one location to another is all but eliminated because of the maneuverability of truck hauling units.

Central mix offers particular adaptability when operating in inaccessible or restricted areas. The congestion of pavers, batch trucks and water trucks is eliminated and replaced by a delivery spread. When only narrow berms are available for working area, it is often necessary to operate the paver inside the forms while backing the batch trucks a considerable distance down the subgrade. The rutting of the subgrade, tracking of foreign material by the batch trucks, and placing of joint assemblies close to the placement of concrete may be undesirable. These objections can be minimized or entirely eliminated in a central-mix operation when sufficient berm is available for the travel of trucks.

Paving with central mix is particularly adaptable to areas congested by restricted working room and necessity of maintaining public traffic. Very often this category of work cannot feasibly be performed by pavers because of the amount of equipment necessary at the pour. Under such conditions, a contractor may choose to construct such pavement by purchasing commercial ready-mix concrete. The cost of this pavement is increased and the yardage of pavement poured by the plant is decreased over which the fixed cost of move-in and set up are distributed.

Automation

The construction industry is following the trend of time toward reduction of labor and improvement of product through automation. Locating the facilities of batching and mixing at one site greatly implements the conditions under which automation can be economically applied. Labor reduction may in reality be a secondary benefit. Each variable controlling quality, such as moisture in aggregate, air content and slump, can be reflected accurately and quickly without the delay of manual performance. Additional benefits are realized by the owner because fewer qualified inspectors are required to administer a centrally located, automatized operation.

Many contractors have experienced considerable operational difficulties when automatizing a paver-batch plant. A batch plant serving three pavers on a 1-min mix must produce approximately 240 batches per hour. Measuring cement, water, and 3 aggregates would require 1,200 operations per hour. A 12-cu yd central plant on a 1- to 1½-min mixing cycle can reasonably be assumed to approach the output of three pavers. At 30 batches per hour only 150 measurements are required. The sheer number of additional cycles necessary to produce an equivalent amount of concrete greatly increases the exposure of mechanical failure.

Capacity

The quantity of concrete that can be economically produced by a central plant is virtually unlimited. Additional mixer drums at the plant would yield as much concrete as could be hauled by the available units. Because the congestion at the site of pour is greatly diminished, only the imagination of the contractor in building a plant and the engineer in designing the project would control the ultimate capacity of the installation.

DEVELOPMENTS AND INNOVATIONS

The technique of central-mix concrete paving is of comparatively recent origin. Research and developments will produce improvements that will surpass accepted standards of today. Fully automatic batching from a central station will soon be common. Electrical controls will conduct every phase of a batching operation. The quality and uniformity will be confined within minute tolerance by instruments that will compensate for moisture variations in aggregate for each batch. The effort being directed to not only eliminating human error but also to reflect more quickly the variances in materials that control the quality of concrete.

The importance of water-cement ratio has been recognized as an all important factor to quality concrete. Significant progress has been made in the development of side discharge dump bodies that will handle concrete of minimum slump that would still be workable. They are a non-agitating body design that rotate as a unit about a center shaft parallel to the chassis. The discharge is not restricted by collecting chutes and the full length of the body permits the rapid flow of concrete into a box-type spreader.

The turbin mixer being developed and tested at present offers interesting advantages desired by central plant manufacturers. The compactness of a turbine mixer would lower plant height making construction more economical and improve the over-all portability of the plant. In addition, the reduced mixing time offers high production desired by industry.

Innovations and improvements such as these are unlimited — the challenge of which will be continually met by the contractor and the engineer. The highway industry needs an atmosphere of assistance and cooperation such as prevalent in Ohio. Specifications must permit and stimulate new techniques to be developed and tested. Pavements of higher quality and reduced costs will be the result. Eventual savings will be shared by owner and contractor — the final beneficiary will be the public who will travel on more high-type pavements.