RESEARCH ON MIXING OF CONCRETE IN BATCH MIXERS

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While in recent years attention has been given to the properties of cement, to the proportioning of the ingredients, and to such matters as water-cement ratio, comparatively little attention has been given to another important element in the making of concrete, its mixing in the mixer itself and the influence of this process upon the quality of the concrete. Little has been written on the elements entering into the process of mixing. Specifications generally give a minimum time limit and require that the mixing water shall be uniformly distributed throughout the mass. In some respects practice seems to be ahead of definite knowledge, in some other ways dearth of definite information has been an impediment to advances in the art of making concrete. Any contributions to definite knowledge of the mixing action in a batch mixer and of the influence of variations in the process upon the quality of the concrete may be expected to be helpful in determining requirements and in improving the resulting product.

What I shall have to say relates largely to information obtained in a comprehensive series of tests extending over more than four weeks in the summer and fall of 1927 made for a manufacturer of concrete mixers, supplemented, of course, by observations and tests made through a number of years. The initiation of the investigation was a sincere effort on the part of the manufacturer to learn more of the process of mixing and to find the characteristics of mixers and the effect of this and that feature of design and operation upon the quality of the product. The research, however, gave by-product information which would seem to be of value to engineers making concrete, and particularly concrete for highway construction.

Mr. Roy W. Crum rendered valuable help and advice in the conduct of the investigation in settling upon limits of variables, approach to conditions desirable for road building, and judgment of observations on the operations and the quality of the concrete.

Mr. Rex L. Brown, experienced in tests of concrete and other materials of construction, gave valuable expert assistance throughout the tests and in the preparation of a report of the investigation.

Many items entered into the tests, as may be judged from the following. Two sizes of mixers—21 and 27 cu. ft. Regular size batch, over-batch and under-batch Concrete rich and lean, wet and dry Fine sand and coarse sand Gravel and stone Cement distributed over the aggregate in the skip or bunched in one place Water put in first or last or distributed throughout the charging Water sprinkled or discharged in full stream Water applied at charging end of drum or at discharging end, or both Various modifications of interior arrangement of drum to learn the characteristics of the mixers and the effect of modifications in designs of blades, buckets and chutes, or whatever names be applied to the interior devices Speed of rotation, fast, medium, and slow Various conditions of cleanness and adhesions of concrete in the drum itself All materials weighed Water tank calibrated Weight of concrete per cu ft taken Slump and flow-table tests Samples of concrete taken from different parts of the drum at several times in a run Concrete samples screened into fine and coarse particles to determine the degree of uniformity Test cylinders Observations of the operation of the mixer and the mixing action throughout the mixing period were made—flowover, stream flow, transverse movement, fullness of space at bottom of drum and evenness from front to rear, wetness of mix and evenness of water content, uniformity of the mass Other observations were made for determining the quality and uniformity of the concrete, the mixing action under particular conditions of the mixer, and the effect of position and internal arrangement of vanes and of modifications in the operation of the machine The remarks I shall make apply principally to the drier mixes, such as are used on the highways of Illinois and Iowa, but most of them are also applicable to construction mixes

Work was done under cover, in a large warehouse, without a floor, and the concrete was utilized in building a floor over a considerable part of this big building No restrictions were made on time of turning out bathes, no interference or delay to the job as might affect the conduct of an investigation carried on in connection with an important piece of construction—the whole object was a test Good portable electric lights at front and rear openings of the drum, and platforms conveniently placed to facilitate observations Experienced observers and helpers in determining the action of the mixer and the meaning of the information

The purpose of this presentation today is (1) to bring out the need of further research and to try to encourage interest in this field, (2) to stimulate engineers to learn more about mixing, and (3) to look forward to better specifications for making concrete Necessarily, the limitations of time will not permit the inclusion of data and observations upon which statements and conclusions are based

What is mixing? The following elements may be included in the process: (a) Intermingling, (b) Intimate mixing, (c) Charging, (d) Discharging. These elements will be taken up in order

My own old ideas of the mixing process (and perhaps others have shared them) involved turbulence, commotion, and with wet concrete churning These now seem to me not only unnecessary, but undesirable

General Intermingling Action 40 cu ft or more of dry materials are placed in the skip or hopper to make 27 cu ft of concrete, 50 per cent more than the final volume, or even greater The intermingling process involves mingling of the fine and the coarse particles, shrinkage of the mass, and its wetting throughout. This intermingling requires more than the mixing of each cu ft of the batch by itself The devices in the interior must bring together portions of the batch from two or more parts of the drum and keep this transverse movement up throughout the mixing time. This process involves transverse movement over the drum of part of the materials all of the time and of all of the materials from time to time The greater part of this intermingling of ingredients should be done in a very short time, say 10 or 15 sec Devices for giving transverse mixing in the drum differ in different batch mixers, as do their effectiveness. Vigorous transverse mixing is an important factor in insuring the distribution of the mixing water uniformly throughout the batch early in the mixing time

The object of intermingling is to increase the density of the mass, to give even distribution of the mixing water, and to mix the batch into a mass having the particles of cement and aggregates well and uniformly distributed

Intimate Mixing Action This second phase of mixing involves a more intimate movement of the materials around and by each other and should include a rubbing, scrubbing, or kneading action among the fine and coarse aggregates and the cement and the water. By some mechanical action the water should be made to freely and effectively surround every particle of cement, free from air bubbles and spaces, ready to give every opportunity for the fullest chemical action over as great a portion of the particle of cement as possible

And this cement paste should come into intimate contact with every particle of aggregate over and over again, being rubbed over and scrubbed over until every portion of the surface is well and evenly coated with the paste and in such a manner that the paste will continue to adhere when the mass is separated into many parts

One principal means of effecting or producing this intimate mixing is what I have termed the *flowover action* of the materials in the mixer operation. This operation is somewhat similar to the so-called "cut" or "roll" of the old hand-mixing—if any one here is old enough to have seen hand mixing of concrete In discharging his shovel, the workman by a twist of the wrist and arm "cut" the shovelful of material; that is, distributed it along the length of the pile and flung it so that it rolled in a thin layer down the inclined pile of concrete. Skill in doing this counted much in getting good mixing by "turning" the batch four times.

In the drum of a good mixer the materials receive this treatment many times. As the drum rotates and the blade or vane rises—I am talking of the drier concretes—the surface of the mass of materials held above by the vane assumes an inclined position, getting steeper as the rotation proceeds, and the upper layer clear back to the shell of the drum rolls or slides inward of the drum and downward over the layer just below until it moves over the edge of the vane and falls freely, another layer following it in continuous action, until finally the space above and back of the vane becomes empty. In the mixing operation, this movement of the materials is principally inward and downward, and not transversely of the drum, except as the slope of the vanes and their "clip" or variation in height from the shell of the drum may give some transverse movement.

This flowover action should not be confused with sliding in mass along the inclined vanes, of which action there is generally relatively little during the mixing operation. Other parts of the interior arrangement of the drum may contribute to flowover action, as buckets and chute in a mixing position.

Adequate and efficient flowover action is an essential feature of the satisfactory mixing of concrete. It gives intimate mixing and the desired rubbing and scrubbing action.

It is well to remark here that flowover flow should be distinguished from stream flow. A mass of concrete moving forward together in a stream does not have the particles moving on or past one another, which is the essential of intimate mixing. Also, showering or impact action has little of the nature of flowover action. Both stream flow and showering have little real mixing action. It takes a movement of particle over particle to effect intimate mixing.

Adequate intimate mixing is essential for producing high quality—for both strength and durability. The effectiveness of intimate mixing has been shown by numerous laboratory tests.

Method of Applying Water. Time. (1) Ahead of dry materials. (2) With dry materials. (3) After dry materials. (4) Before, during and after the entrance of the dry materials.

Purposes to be kept in mind. (1) To facilitate the distribution of the water uniformly throughout the mass. (2) To lubricate and cleanse the drum and act to minimize or prevent adhesions, clogging, and roughnesses in the interior of the drum.

Place of application. front of drum, back of drum, both, in sand

Better on the vacant shell of the drum and blades than on the batch itself

Results (1) Need of lubrication in the drum is apparent The amount of water necessary or desirable for this purpose, to be applied in the drum, may be half or more of the total amount of mixing water used for the drier or medium mixes For many or most mixes used in highway work, especially when the finer sands, over-sanded mixtures, and the finer coarse aggregates are used, the method of applying most or all the mixing water in the sand in advance of the charging operation is likely to lead to unsatisfactory conditions in the mixing operation (2) The best time to apply the water is to start it a few seconds before the dry materials begin entering and continue it until 4 or 6 sec after these materials are all in the drum The time after the materials are in need not be included in the requirement for length of time of mixing (3) The time required to obtain even distribution of water is dependent upon the mixer action Under optimum conditions water was found to be well distributed throughout the batch in 15 sec , and under unfavorable conditions it was poorly distributed after 1 or 2 minutes The effectiveness of the transverse intermingling action in the drum, already referred to, is an important factor in securing quickness and evenness of water distribution Wetted bunches of cement and sand give troublesome results—such masses weigh only 125 lb per cu ft instead of 150

Time of Mixing The time of mixing regularly used in the tests was 60 sec after the batch was in the drum, but the mixer was stopped at intervals of say 15, 30, 45 and 60 sec , and an examination and inspection was made of the condition of the batch, samples were taken and notes made With the great range in variables used in the tests (equipment, nature and proportions of materials, and conditions in the mixer itself), the time at which good mixing was accomplished varied from short to long For optimum conditions, batches would appear well mixed and the water well distributed at the end of 30 sec , and under unfavorable circumstances and poorly designed drum 2 or even 3 min would be necessary for putting the batch into mediocre condition For some circumstances, at a minute's time the batch at one end of the drum would be wet and at the other end dry In some cases the cement and sand would predominate at one end and the coarse material at the other The time needed for mixing is evidently a function of the effectiveness of the mixing machine

Speed of Rotation Changes in speed affected the nature of the mixing action (12 to 18 r p m were used) For the dry concrete, the slower speeds gave a stronger, freer flowover mixing action and the space at the bottom of the drum was more evenly filled from front to back of drum, and the operation of mixing was more rapid for the same length of time Medium and dry concretes require time for moving over the distances the materials have to travel

The transverse movement was also more favorable at the slower speeds With the higher speeds, the movement changed from flowover action to stream flow (giving little intermingling and intimate mixing) and even on to showering and catapulting movements This would not be so true for the wetter mixes and perhaps not at all for sloppy batches

The optimum speed may be expected to vary with the interior design of the mixer and with the nature of the batch It appears that the larger the batch in a given size of drum the slower the speed should be for the best results

Charging the Batch It was found that the skip used for charging the batch into the drum was a useful adjunct in the mixing operation The one on the 27-E mixer was especially effective in producing intermingling of the fine and coarse aggregates and cement as the materials passed into and down the throat of the skip and into the mixer, so that much of the shrinkage of materials was effected during the charging

It should be noted that preliminary mixing of this kind is important, especially in preventing the cement remaining in bunches when the water strikes it On the other hand, in one skip dumping of cement at a certain spot in the skip resulted in very unfavorable conditions for mixing in the drum and even increased the time of discharging the batch from the drum

The use of compartment boxes and hoppers has been found to help in pre-mingling the materials and distributing the cement throughout the aggregate

Discharging the Batch Both quality of discharge and shortness of time are important requirements for a concrete mixer Quality of discharge involves uniformity of concrete, lack of segregation of coarse and fine materials, regularity of discharge, quick ending or freedom from dribbling The time requirement of the discharging operation is an important element from an economic standpoint, since it affects the output of concrete for a single mixer, but this consideration should not be allowed to influence the design of the mixer to the detriment of quality of the mixing operation It is possible that designing the interior to reduce the discharging time may so injure the quality of the mixing operation that the specified time for mixing would have to be increased

Quality of discharge is found to be dependent upon interior design of drum and also upon speed of rotation Too great a speed results in segregation during discharge, particularly near the end of the discharge With a good mixer and for favorable mixing conditions samples of concrete taken at intervals throughout the discharge, as determined by the flow test and by ordinary observation, generally showed uniform quality, except at the end of the discharge under certain of the conditions used Of course, for some of the unfavorable arrangements tried out there was considerable variation in quality during the discharge

The time of discharge of full batch varied from 8 sec to 30 sec or more for very unfavorable conditions in the mixer—all this for dry and medium concrete. For the machines used, a wetter mix would be more favorable for quick discharge The longer times of discharge were due to imperfectly mixed batches, adhesions and roughnesses in the drum, and other unfavorable conditions in some of the combinations tried out in the tests, as well as to the design of the vanes in the interior of the drum Strangely, slowing down the speed of rotation generally shortened the time of discharge

As is to be expected, for free passage down the discharge chute the rate of discharges is generally more rapid during the first part of the discharge, more time being taken to get the later portion of the batch to a point in the drum where it will fall on the chute

Dimensions and Volume of Drum and Batch Capacity. For any given size of drum (diameter and length of drum) and given interior design there will be a limit to the size of batch which may be satisfactorily mixed When a mixer is given an overload, the operation of mixing the batch is slower. The materials are carried farther up the drum As shown in the tests, there is more stream action and less flowover action and also less transverse motion The time required for satisfactory intermingling is greater and the distribution of water throughout the batch is delayed. The conditions become more favorable for deposits and sticking in the interior, which will interfere with mixing and discharging operations. The speed of rotation should be slower for the over-batch

Some A G C batches allowed for 1 yd mixers make as much as 30 cu ft of concrete, an excess of 10 per cent over the rated capacity of a mixer Some concrete mixers examined on work, instead of discharging completely, will retain in the drum 15 per cent of a batch or more, this residual material not being easily discharged. Again, it is not uncommon practice in highway work to start charging the mixer with a new batch as soon as a large part of batch just mixed has been discharged, leaving in the drum the last and much more slowly discharging portion, say 10 per cent or sometimes as much as 20 per cent of the whole batch. This practice in effect assumes that the mixer has a capacity large enough to handle the overload thus put into the drum in succeeding runs It is seen that, for a combination of 10 per cent excess for some of the even bag batches just referred to and the incomplete discharge of the mixer, practiced with a view of shortening the time of discharging, the mixer should be able to regularly handle satisfactorily and without any difficulty a batch of concrete 25 per cent greater than its rated or nominal capacity, or the concrete will not be mixed acceptably This may require an increase in size of drum Evidently there is danger of ineffective mixing in practices that encroach on the limit of allowable overload

Here is another item: A dry mix will need a larger drum than a wet mix. The ratio of volume of batch to volume of drum in a given type of mixer is something that demands careful consideration

Effect of Condition of Interior of Drum A striking result seen in the tests was the influence of the condition of the surfaces of the interior of the drum (including its appurtenances) upon the quality of concrete and the quickness of mixing and even upon the time of discharge Adhesions, slight roughnesses on vanes and shell delayed the intermingling of the materials and the proper distribution of the water With an increase of roughness the quality of the mixing became mediocre A clean mixer is essential to good mixing This, of course, applies to all makes of mixers The best highway mixes have little scouring effects as compared with those having excessive amounts of large coarse aggregate

Standard Method of Testing Concrete All the foregoing relates to quality of concrete in the mixer and as it leaves the mixer Making test specimens of the concrete by the standard method of laboratory work does not produce specimens that are representative of that concrete The further mixing involved in making the cylinder by the standard laboratory method gets away from the conditions of the product to be tested. The standard method is right for its purpose, but when applied to determining the quality at an earlier time it may be very misleading

Comment on Time Requirement The specification for time of mixing should not be based on optimum conditions of mixing The added time for a margin of safety to cover contingencies frequently occurring that affect quality should be sufficiently large to insure high-grade quality under any ordinary circumstances, unless the scrutiny and supervision is to be more active and severe and farseeing than is to be expected even on the best regulated work

Need of Further Research Work I hope I have opened up the subject sufficiently to bring out the need of research in this field and also to cause you to believe with me that the engineers who have charge of highway construction should give greater thought to the mixing operations and help to disseminate knowledge in this field so that a higher and more uniform quality of concrete will result.

DISCUSSION

ON

RESEARCHES ON THE MIXING OF CONCRETE IN BATCH MIXERS

MR BERT MYERS, *Engineer of Materials and Tests, Iowa Highway Commission* In the excellent paper just delivered, Doctor Talbot has probably presented all the information now available on the particular problem which he has studied However, it may not be entirely out of place to mention another function ordinarily performed by a concrete mixer The function referred to is the measuring of mixing water

The importance of the accurate control of mixing water is so well recognized as to require no comment The measurement of that part of the mixing water not contained in the aggregates is ordinarily done by means of equipment furnished by the mixer manufacturer and mounted on the mixing machine

The water measuring equipment furnished with the common type of paving mixer consists of a closed tank connected to a water supply pipe and to a pipe which discharges into the mixer drum Inside the tank is an adjustable syphon, trough, pipe or displacement cylinder designed to allow a controlled quantity of water to be drawn from the tank The mechanism which controls the position of these adjustable devices is marked to indicate the quantity of water which may be expected to be delivered per batch for any given setting

The tank is provided with one or more air relief valves which allow air to enter the tank as water is withdrawn, and to allow air to escape as the tank is filled These air valves are designed to allow all the air to escape from the tank and to prevent the escape of water

One control valve is placed in the supply pipe and another in the discharge pipe These two valves are ordinarily linked together so that when one valve is in the closed position the other is open This arrangement allows the valves to be operated by a single lever and is designed to prevent the possibility of both valves being open at the same time In the case of some equipment, this desirable condition is not attained. There is a period of time in each operation of the valves during which both valves are partly open This allows a quantity of water, which was not included in the quantity measured out in the tank, to enter the mixer drum The magnitude of this error in measurement will vary with the pressure in the water supply line, and with the speed with which the valves are operated

Most of the water measuring equipment of the type described above will measure water quite accurately when connected to a water supply which has a uniform pressure and which contains little entrained air Unfortunately these conditions are not frequently encountered on a highway paving job The pressure in the contractor's water supply line may vary from 0 to 300 pounds per square inch Variations in pipe line pressure of 150 pounds per square inch within a few minutes are not uncommon

The water supply lines are not tight and offer considerable opportunity for the entrance of air Each time the hose which connects the mixer to the pipe line is moved, a large quantity of air is entrapped in the line Thus it will be seen that the problem of measuring in a closed tank, water which is delivered under such conditions, presents some difficulties The inaccuracies in measurement which have resulted have caused highway engineers real concern

In an attempt to determine the magnitude of such errors, to account for some of them, and to discover, if possible, some means to avoid them, the Iowa State Highway Commission conducted a brief study of water measurement on concrete paving mixers in the fall of 1928 Mr A E Stoddard planned and conducted this work

A two inch water meter of the oscillating disc type was connected in the water supply line near the measuring tank This meter was protected by strainers In the water line near the meter and between the meter and the pump were placed an air relief valve and a pressure gage The air relief valve was designed much like the ordinary steam trap This valve removed the air which was present in the form of large bubbles but it probably did not remove all the small air bubbles

Observations were made on seven different mixers of three different makes in actual operation in the field The period of observation for each mixer was one-half of a working day

The amount of water recorded by the meter was observed constantly A record was made of the pipe line pressure at various times during the cycle of operation for each batch of concrete

Starting with the measuring tank full, the discharge valve closed and the intake valve open, it was observed that when the position of the valves was reversed, the meter recorded a flow of water varying in quantity from 0 1 gallon to 3 0 gallons This indicates that water was flowing from the supply line into the mixer drum during the time both valves were partly open For the sake of brevity, this will be referred to as leakage in this discussion The total quantity that flowed through the valves during their operation varied for the make of mixer and for different mixers of the same make The minimum average for this quantity was 0 3 gallon For the mixer which gave this minimum average, the amount of this leakage varied from 0 1 gallon to 0 65 gallons During the observation upon this mixer, the pipe line pressure varied from 85 to 160 pounds per square inch The greatest average for this leakage quantity observed was 1 35 gallons The leakage for individual batches on the mixer which gave this average varied from 0 3 gallon to 3 0 gallons The pipe line pressure varied from 25 to 150 pounds per square inch during the observation on this mixer A new mixer of the same make as the one last mentioned showed an average leakage of 315 gallon with a variation of from 0 1 gallon to 1 7 gallons, with pipe line pressures varying from 15 to 80 pounds per square inch On a third mixer of this same make, but one on which the valves were operated mechanically, the average leakage per batch was 0 811 gallon with a variation of from 0 1 gallon to 2 8 gallons The pipe line pressure varied from 30 to 150 pounds per square inch during the study of this mixer

It should be noted that while the passage of water through the valves during their operation has been referred to as leakage, it is not due to poor condition of the valves but to a feature inherent in the valve arrangement. This leakage will not be apparent to a person observing the ordinary operation of the mixer since it occurs at the time water is flowing from the measuring tank into the mixer drum

The discussion given above refers to the leakage which occurs when the position of the valves is changed from that in which the discharge valve is closed and the intake valve open, to that in which the discharge valve is open and the intake valve closed It is reasonable to suppose that some leakage also occurs when the opposite change in the position of the valves is made Such leakage could not be detected with the equipment used in this study since it would occur at the time water was flowing through the meter into the measuring tank The quantity of this leakage will probably not be great since the pressure on the valves is not great

Before this study was made, the water measuring equipment on each mixer was calibrated to determine what quantity of water would be delivered for any given setting of the measuring control mechanism

A comparison between the quantity of water to be expected from this calibration and the quantity delivered as determined by the water meter proves quite interesting For the mixer which would be con-considered most accurate on this basis the maximum difference was 2 50 gallons

For a 27 cubic foot batch of concrete containing 1 6 barrels or 6 4 bags of cement, this would mean a difference in the water cement ratio of .39 gallon per bag This might be expected to cause a change of ten per cent in the strength of the concrete

For the mixer that would be considered least accurate according to this basis of comparison, the maximum error for any one batch was 7 28 gallons of water This would cause an error in the water cement ratio of 1 14 gallons per bag in a batch containing 1 6 barrels of cement.

Perhaps such errors in water measurement may account for the fact that concrete test specimens taken in the field sometimes have strengths 25 or 30 per cent greater or less than that for which the mixture was designed

To the engineer who is interested in an accurate estimate of the quantities of materials required per unit volume of concrete, these figures are also of interest

A change of 7 28 gallons in the amount of water in a cubic yard batch of concrete will, if there are no air voids in the concrete, cause a change of 3 6 per cent in the volume of the batch.

It appears from these observations that the present method of water measurement employed on paving mixers is entirely too inaccurate to give the control of the quality of concrete that is desired.

It also appears that the difficulties encountered in the field are such that accurate measurement of water by volume in a closed tank is scarcely to be hoped for.

Therefore, some new method of water measurement seems to be desirable. Measurement in a tank open to the air would reduce the errors due to the presence of entrained air in the pipe line and would reduce the leakage through the valves since the pressure on the valves would be greatly reduced By the use of an open tank, some of the simplicity in arrangement and operation possible when a closed tank is used would be sacrificed.

One method which does not seem to have been used for measuring water at a paving mixer is weight measurement While the mechanical difficulties presented are considerable, they would not seem insurmountable and the advantages to be gained in accuracy and ease of positive calibration commend it The weight measurement of water on a concrete paving mixer should certainly not be dismissed without serious consideration Improvements in the control of quality of concrete in pavement construction will surely depend in a very great degree upon improvements in the measurement of mixing water

MR A A LEVISON, *Blaw-Knox Co , Pittsburgh, Pa :* There has been a succession of new ideas introduced into concrete making methods and processes from the standpoint of design, proportioning, mixing, transporting, placing, curing, etc Many advantageous ideas and schemes have been adopted to improve the quality and uniformity of concrete without increasing the cost of this important construction material. In fact, in a number of instances, betterment of the product has been obtained, attended by a reduction of cost

To illustrate the rapidity with which progress is being made in this field, we find that during the past year there has been a considerable advent of radically different mixing appliances than those included under the head of the orthodox concrete mixer Truck mixers have been developed which mix the concrete in transit or after the arrival of the truck loaded with the raw ingredients at the job These devices must also be accorded the same careful research and attention that is given to other types of apparatus for the mixing of concrete Mention is made of this phase of the industry to call attention to the transitory stage that we are now passing through in the development of methods and equipment for the mixing of concrete

We respectfully call attention to that part of the report in which statement is made that under certain conditions, "the method of applying most or all of the mixing water in the sand in advance of the charging operation is likely to lead to unsatisfactory conditions in the mixing operation " We have no knowledge of how these experiments were conducted, whether the experimental work referred to was accomplished with the use of an inundator or simply by pouring water on the sand This would have a considerable effect upon the results attained because the experience has been that good and efficient work can only be done when the sand is properly inundated in an Inundator Attempts have been made to reproduce these results without the use of the equipment intended for this purpose, and the results have not been nearly so satisfactory as they might be otherwise

This suggestion of using proper equipment to carry on tests of the effect of inundated sand on mixer efficiency is offered as a result of experience It is not the purpose of this discussion to question in any way the authenticity of the tests performed

It has been our observation that when inundated sand is discharged into the drum of the mixer, the wet sand performs a real scouring action on the interior of the drum, even better than dry sand or water alone could accomplish The sequence of the operation is to discharge the inundated sand into the drum of the mixer first, and then follow it up with the cement, coarse aggregate and excess water in the order named With this method of proportioning and this sequence of loading the materials into the drum of the mixer, no clogging of the mixer skip or charging hopper has been experienced, and furthermore the interior of the drum has been kept in good clean condition

Under the State Highway Department of North Carolina, where Inundation was used as a proportioning method in the construction of concrete pavements, the time of mix was reduced from one minute and thirty seconds to one minute and fifteen seconds Under these conditions a comparison of cores drilled from one job, part of which was built without Inundation, and part with it, gave the average strength of the non-inundated concrete at an average age of five months as 4942 lbs per square inch, whereas the average strength of the inundated concrete at an average age of two and one-third months was 5423 lbs per square inch

The reason for this reduction in mixing time is that by measuring the sand saturated, a diffusion of a large part of the mixing water through the fine aggregate is obtained prior to mixing, which represents part of the work performed and time consumed in mixing a batch of materials introduced into the mixer in the so-called "dry state" with most of the mixing water added as free water

Professor Talbot's investigation covers only one make of concrete mixing apparatus and it would seem highly desirable to investigate all of the factors brought out in his paper in connection with other makes and designs of concrete mixers.