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Batching and Mixing of Mortar and Concrete Ingredients for Superior Strength

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ABSTRACT:
A concrete plant, also known as batch plant is device that combines various ingredients to form concrete. In general, it is a process of combining all ingredients of concrete as per the mix design. Batching and mixing are extremely important parts of mortar and concrete manufactures they influence properties of concrete both in plastic as well as in hardened stages. Also, it is one of the important processes, which is to be done to obtain a quality concrete. Many processes are carried out in various parts of the world with many changes and different equipment. There are various types of batching and mixing equipment and methods that is to say from manual to most sophisticated computerized batching and mixing. Mechanization improves quality of batching and mixing, its speed and thereby can most often result in economy. There are number of factors which are to be considered while doing the process which are discussed in this paper. Moreover, the machinery, which is to be required while making concrete or for batching process and discharging and unloading of the mixture, are also discussed in brief.

I. INTRODUCTION

Concrete is the most widely used construction material in the world. This material is not going to be easily replaced by any other material on account of its economical as well as the technical advantage. This material is generally produced at the site in our country and therefore needs to be carefully supervised and controlled in order that it performs the way it is technically expected to perform [1].

Concrete is made from raw materials such as cement, natural and manufactured aggregates, water and at times concrete additives (chemicals). It is worth noting that cement and aggregates are manufactured or obtained from natural solid stone, which is quarried, crushed, screened and processed to give the required physical and chemical properties [2].

This paper covers the batching and mixing process of concrete manufacture [3]. The processes of batching and mixing of concrete or mortar materials are very similar to preparations of a dish in cookery as per a recipe wherein various ingredients depending on their individual properties have to be mixed in correct proportions to give the required flavour and taste.

II. Influence of batching and mixing processed on fresh concrete

The factors, which influence the quality of fresh concrete, are as follows [4]:

A. Consistent quality of raw materials

Consistent quality of raw materials is very essential. Batching and mixing are more consistent if the raw materials with consistent specific gravity, fineness, grain size, strength and other properties are used. Variation in grading

and fineness can create variations in concrete quality as the water demand or workability for the same proportions may increase or decrease.

B. Accuracy of batching (volumetric/ weighment)

Batching accuracy is also important. It is preferred to do weigh batching and not volumetric batching of cement and aggregates. However, if accurate weigh batchers are not available it is preferable to do proper volumetric batching. Bulkage correction for natural moist sand is necessary in the case of volumetric batching.

C. Adequacy of mixing (manual/ mechanical)

Mixing is generally practised manually in case of mortar and at times even for concrete. Manual mixing is not recommended until and unless trained skilled worker carries out the work in a systematic manner. Machine mixing is faster and more efficient than manual mixing. It is often observed that mixers used in our country are not properly designed to cater adequate mixing of concrete materials. Care should be taken that mixers available on site are capable of mixing the concrete ingredients.

D. Mixing time

It is necessary to ensure that adequate time is given for proper mixing of concrete ingredients. However, mixing time may greatly depend on the workability of concrete mix, type of mixer and it's size or capacity.

E. Batching and mixing, equipment and methods

There are various types of batching and mixing equipment and methods that are to say from manual to most sophisticated computerised batching and mixing. Mechanisation improves the quality of batching and mixing, its speed and thereby can most often result in the economy. Manual batching and mixing is more prone to errors and slowers in speed than mechanical arrangement. Volumetric batching if done with proper boxes (farmas) and filled up to the brim and levelled is quite accurate for batching aggregates.

III. Properties of fresh concrete

Workability of concrete can vary if aggregate and cement are not properly batched and mixed or if mixing water is not added in correct proportion [5-6].

A. Cohesiveness of concrete

Cohesiveness of mix also vary if cement and fine aggregates are not properly batched or bulkage correction, while batching volumetrically, are not made. Excessive water addition can cause loss of cohesiveness in the mix, which can, in turn, create segregation problems. Loss of cohesiveness can also result in bleeding of concrete and shrinkage.

B. Homogeneity of concrete

It is quite obvious that concrete ingredients if batched and mixed properly give a homogeneous mix which is essential so that the properties of concrete are uniform. A non-homogeneously mixed concrete can result in large strength variations, shrinkage, bleeding, segregation and various other defects, which will result in poor quality of concrete or mortar.

- STRENGTH: Strength of concrete is mainly dependent on the strength of cement used and the quantum of water added to the mix. The increase in water cement ratio of the mix will result in lower strength. The strength of concrete structures will also vary, depending on the non-uniformity of the concrete, which may have resulted due to inadequate mixing, segregation and/or bleeding.

- DURABILITY: Improper proportioning of water in the mix or increase in water content due to erroneous proportioning of fine aggregates and cement can seriously cause durability problems. The increase in water cement ratio of the mix due to any reason can cause a serious reduction in durability of the concrete. Variation in cement quantity added to the mix from batch to batch can also cause durability problems if the cement quantity is added less than the desired mix proportions
- SURFACE FINISH AND TEXTURE: If due to batching error there is a deficiency of the fine aggregates and cement, the surface finish will be poor. If mixing is not adequate it will also lead to poor surface finish and variation of texture. If the mix is lean there is a likelihood of segregation, which will lead to poor finish due to honeycombing and ultimately durability problems.

IV. BATCHING OF MATERIALS:

There are three modes of batching generally adopted for cement and aggregates. They are as follows [7]:

1. Random volumetric batching with absolute no control on the size and shape of containers used resulting in large errors and variations. Cement is batched assuming each bag contains 50 kg.
2. Proper volumetric batching of all ingredients, using measured boxes (farmas) and with control of filling them to brim and levelling. Sometimes cement is batched by volumetric measure or weighed.
3. Proper weighing is done of all ingredients either using a weigh batcher or utilising the weighing system on the batching mixing plant.

Batching of water should be generally carried out by using the measured container or by using water measuring meters or gauges. Random adding of water can cause great harm to concrete by way of strength variations and loss of durability.

Accuracies required for measuring various materials of concrete are recommended as follows:

MaterialsAccuracy of measurements % of batch quantity

Aggregates	+ 2 to 3
Cement	+1 to 3
Water	+1 to 3
Admixtures	+3 to 5

It is always preferable to weigh batch cement and aggregates separately. This is necessary because the weight of cement in a batch is small and critical in comparison to that of the weight of combined fine and coarse aggregates. There is always some amount of moisture present in the aggregates, particularly in sand. Therefore, if cement and aggregates are batched in the same container some particles of cement and wet sand will stick to the sharp corners of the hoppers and eventually set thereby reducing the capacity of the hopper and also resulting in innocent weighment.

A. Volumetric batching

For volumetric batching, it is convenient to make steel or wooden boxes of various sizes/ volumes. It is generally preferred to have boxes of various sizes readily available at the site so that any adjustment, which is required to be made by way of change in mix design or due to bulkage of sand, can be done easily.

B. Weigh batching

Weigh batching of aggregates is generally preferred. However, the locally available weight

batchers do not function properly because of the poor metallurgy of their components like levers, knife-edges and springs. Besides, maintenance and regular calibration are most often neglected at the site. Generally, the workers dump the head load of material into the weighing pans. This dumping causes an impact at regular intervals on the weighing mechanism and damages the mechanism.

Care is also required to be taken to ensure that the workers dump one type of aggregates in the weighing pan at a time. It is often observed that due to poor control at site head loads of different types of aggregates are put simultaneously resulting in chaotic batching. It is also necessary to control the loading of the aggregates so that exact weight of particular size of aggregates is added till the pointer shows the correct indication. The workers generally dump full head loads without reading the indicator scale as a result of which correct weight is not generally batched causing variations.

Weigh batching is also done in modern concrete batching and mixing plants, which have very sophisticated automatic microprocessor controlled batching arrangements. Not only the aggregates are batched in correct proportion but also their moisture content is automatically determined and necessary corrective action taken so that mix has correct consistency as desired. The system operates to an accuracy of as much as 0.2% relative moisture and it enables every desired consistency range to be maintained and further checks on consistency (slump) are superfluous. Therefore, without a doubt, this equipment, which is now in use at few sites in India, have the best possible control to give excellent quality and speed of batching of all ingredients of concrete.

V. Loading the skip or hopper of the mixer

The following sequence of loading the skip or hopper with dry materials is advantageous

a) Coarse aggregates
b) Fine aggregates
c) Cement

If there is a chance of cement being flown away due to strong wind, cement is loaded before the sand. The following sequence of loading the skip or hopper, when

a) One-half quantity of coarse aggregates
b) Cement
c) Moist sand
d) Balance half quantity of coarse aggregates

This is to prevent choking of the skip mouth due to dampness in sand. Smaller size mixers have no skip. Materials are therefore directly added into a drum in the following sequence:

a) Cement
b) Fine aggregates
c) Coarse aggregates

The coarse aggregates are added last as they help push in any cement or sand that may adhere to the mouth of the mixer.

VI. VARIETIES OF MIXERS:

Mixing Equipment can be generally classified into 4 types.

A. Rotating non-tilting type

In this type of mixer, the drum rotates around the horizontal axis. The drum is loaded by means of loaded skip/ hopper, which is pulled up or lowered by means of a wire rope and a pulley movement. The discharge chute at the other end unloads the mix when it is manually dropped to allow the mixed concrete to slide and drop. The non-tilting type mixers have generally higher capacities than tilting type mixers.

The interior of the drums is fitted with helical blade lifters, which scoop up the concrete material on the way up and drop it on the way down as the drum rotates. This causes intermixing of batch materials. There are

basically two types of non-tilting mixers. One with a chute, which rotates only in one direction, called the non-reversible type and the other reversing type mixer, which has two sets of a blade in the drum. One set is used to mix the concrete when the direction of rotation is reversed.

B. Rotating tilting mixer

In this type of mixer, the drum is conical and revolves around an inclined axis. The mixing is generally carried out at a drum inclination of 20 to 30 degrees to the horizontal. It is either charged by means of a skip, which is lifted up by means of a wire rope, and pulley movement as stated above or by means of manual feeding directly into the mouth. However, manual feeding is generally done for small capacity mixers. The tilting drum mixer is more suitable for every stiff workability as the entire mix can be easily emptied or discharged by tilting the drum.

The interior of the drum is fitted with blades and baffel plates to act as scoops. The appropriate speed of drum rotation and internal alignment of blades/ baffel plates causes disruptive forces between the wall of the drum and its contents resulting in the concrete materials being intensively turned over and agitated. These types of mixers are good if the concrete mix is designed for medium or high workability. Their performance and efficiency reduce if mixes of lesser or stiffer workability are to be mixed.

C. *Pan type*

In this type of mixer, the drum is stationary or free running with blades rotating around the vertical axis. These mixers are very efficient as mixing process is faster and spraying of water on the mix is uniform and assists in efficient mixing. The mixers can have much larger capacities than the types of mixers described above. The loading of these mixers is generally done in a similar manner as for drum mixers. The skip unloads the aggregate material from the top; cement is separately added through another hopper, which is loaded by a screw conveyor or manually.

Water is added through the nozzle inlets on the circumference of the pan. The mixing arms are centrally mounted. However, at times to tackle very stiff and difficult mixes it has one or more eccentrically mounted arms or an agitator, which also rotates as it revolves. The mixed material is unloaded from the sliding gate at the bottom of the mixer.

There are different types of pan available depending on their mechanical design. They are as follows: 1. Stationary pan

2. Free running pan
3. Co-rotating power driven pan
4. Counter rotating pan

Generally, stationary pan with rotating mixing arms is in use at construction sites. In pan mixers, the mixing arms rotate in an anticlockwise direction and positive action of these elements upon the material to be mixed achieve efficient mixing. This action is further improved by scraping blades which force the material back into the mixing area.

The design feature in the counter-rotating pan is that it rotates clockwise, while the mixing elements rotate anticlockwise or perform a transverse motion. The entire volume of the pan in the concrete gets mixed thoroughly achieving high mixing speed.

D. The paddle type

The paddle mixers are yet another type of mixers which are available. The paddle mixers consist of cylindrical non-rotating open through in which materials are mixed by paddle rotating around the horizontal axis on one or two shafts. In a twin shaft paddle mixer, two shafts rotate in opposite directions. The high-intensity mixing takes place in the region of overlap of two sets of paddles. The paddles are mounted helically so as to produce 3dimensional mixing movement of

materials. The electric drive of the mixer shaft is spring mounted to improve trouble free mixing function. As compared to pan mixer the single shaft paddle mixer has compact advantageous inner dimensions. The helical inclination of the paddle gives an optimum mixing effect producing an intensive counter-flow mixing. The paddle mixers are found more suitable where dry mixes are required. However, they are generally suitable for all ranges of workability from stiff to very high.

VII. Batching and mixing plants

The modern batching and mixing plants have revolutionised concrete production using microprocessor controls with the latest state-of-the-art technology. These plants have very high capacity of production, very great accuracy and can be handled by just a single operator. They are fully computerised and automatic, semi-automatic or can be even run in the manual mode of operation. The capacities of these plants range from 30 CuM per hour to 200 CuM per hour. These plants have sometimes two mixers, which can work simultaneously. The weigh batching is extremely accurate and sturdy not requiring repeated calibration. The moisture and water adjustments are automatically controlled depending on the workability required.

These batching plants have different types of aggregate storage such as star pattern open bins; tall cloverleaf silo, pocket silo or inline silo. The aggregate materials are fed into a weighing system automatically and loaded into the mixer. Cement is stored in bulk in a silo and is weighed separately in a different hopper. Cement is generally conveyed by a screw conveyor from the silo to the weighing hopper and unloaded into the mixer separately. The correct quantity of water is added into the mixing drum directly. Water is sprayed uniformly on the concrete materials as they are being mixed.

The batching plant mixers have generally high discharge so that the transit mixers can be loaded conveniently below them for transporting the concrete to the desired location.

VIII. Discharging or unloading a mix

The entire content of the mixer drum should be emptied before recharging the drum with next batch. The drum must be emptied into a single hopper or container from which it can be picked up and transported either manually by gamelas or by wheelbarrows. Discharging the mix directly in gamelas or wheelbarrows may cause segregation.

The mix should not be dropped or discharged through a large height to avoid segregation. Generally, the discharge height is restricted, between 60 to 120 cms for tilting, non-tilting and reversing drum type mixers and about 150 cms for high discharge type mixers. The wet or highly workable mix has a tendency to segregate; hence it is advisable to remix it with a shovel before filling up the wheelbarrow or gamela.

The mix from the batching plant is generally discharged from a greater height into a transit mixer, which agitates the mix and helps the mix to get uniformly remixed in case it has segregated. If the mixer discharges into a long chute the concrete will segregate and lose finer materials. It is, therefore, necessary to prepare a mix, which has adequate cohesiveness and correct workability to slide down the chute with ease but without segregation.

Before the mechanical mixing operation is closed, it is very important to clean the drum and blades free from all adhering concrete materials before it hardens. It is generally advisable to add around three gamelas of coarse aggregate and around 10 to 15 litres of water into the drum and allow it to rotate for a couple of minutes till all adhering material have come off. The contents are then discharged and the mixer drum is once again flushed with water.

There is always a tendency, of the workers, to leave as soon as concreting operations are over. The mixer operator must be made responsible for the closing operation. Leaving uncleaned unwashed mixer will result in loss of time prior to the next mixing operation. Chipping and banging damages the mixer body, destroy its efficiency and results in poor mixing. Uncleaned internal surface also reduces the mixer capacity due to building up of concrete/ mortar on the blades and the internal surface of the drum. It would be even advisable to brush and wash the mixer with soap water and then flush it with clean water.

The performance of the mixer is judged basically from the consistency of the concrete from batch to batch as well as within the batch. While strength can be one of the criteria for judging the mixer performance, it is not considered adequate as strength variations in the sample cubes may be due to several reasons right from filling of the cube to its curing.

The quality of mixing is distinctively affected by following two factors associated with the mixer operations besides blade's configuration and drum's shape and speed.

- Mixing time
- Homogeneity of concrete mix

This is the time required by a mixer to mix different ingredients and transform them into a uniform, intimate mixture, which meets the specific requirements.

The mixing time for the type of mix materials and mix consistency should be optimum. It is always preferable to mix the materials for an optimum time, which may vary from anything between 30 seconds to 120 seconds depending on the type of equipment and mix consistency.

Some mixers available these days are very efficient and can mix a large quantity of concrete even up to 3 CuM in a matter of 30 seconds. Minimum mixing times are meaningful to attain a certain quality of mixing while maximum mixing times are required to safeguard against excessive segregation.

During the mixing operations and within a specific mixing time the individual ingredients must get transformed into a uniform intimate mixture, which meets the specific requirement. Mixing time represents only part of the mixing process the rest of the time in the cycle period is mainly spent in batching time. The mixing time is taken from the time all ingredients are added to the mixer drum till the time the intimately mixed concrete ingredients are unloaded from the mixer.

If the mixing time is less than required, the quality of mixing will be poor and the concrete mix will not be uniform and consistent. If the mixing time is more than required, it can cause segregation; evaporation of water leading to drop in workability and the frictional effect can produce an increase in temperature of the mix, which should be minimised in warm/hot weather.

Rotating drum mixers need 60 to 90 seconds mixing time while the pan mixers because of forced action type mixing need only around 30 to 45 seconds.

Concrete batching and mixing equipment besides being expensive has often to work under rough job conditions, particularly at sites. In order to keep the equipment in good working condition, the preventive maintenance such as systematic cleaning, inspection, lubrications, adjustments and repairs should be undertaken before the actual breakdown occurs disrupting the work at the site.

Regular maintenance as per manufacturer's maintenance manual must be carried out at regular intervals.

Conclusion

Accuracy and precision of batching concrete and mortar materials and the uniformity of mixing are important requirements of good quality concrete production. The bigger the mixer and better the automation the better is the quality of mixing.

The quality of concrete mixes is far superior if prepared by batching and mixing in microprocessor controlled batching plant than in small conventional mixers. The quality and speed of concrete production are much superior if manual controls and workforce are avoided or reduced. Large dependence on labour deployment can cause quality and speed problems and can result in extra costs even though the first costs may appear to be lower.

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