Concrete Mix Design by Packing Density Method

Prashant P Chauhan[1], Madhav P Kadam [2]
[1]*Student, NDMVP's KBT College of Engineering, Nashik*
[2]*Professor, NDMVP's KBT College of Engineering, Nashik*

***Abstract*— Packing density is a new mix design method used to design different types of concrete. To optimize the particle packing density of concrete, the particles should be selected to fill up the voids between large particles with smaller particles and so on, to obtain a dense and stiff particle structure. A higher degree of particle packing leads to minimum voids, and the maximum density and requirement of cement and water will be less. In this work, the correlation curves are developed for the packing density method between compression strength and water-cement ratio, paste content to reduce the time involved in the trial to decide the water-cement ratio, and paste content for a particular grade of concrete. Results obtained by the packing density method are compared with IS code method. A large number of trial casting will be carried out for the M25 grade of concrete. The finalized mix proportion for the M25 grade of concrete will be used to cast the cube specimens for 7 days, 14 days, and 28 days curing age. The co-relation curves will be plotted for packing density results. The curve can be used to decide the water-cement ratio and paste content for the specified grade of concrete in the case of the packing density method thus reducing the material and time involved in trial testing.**

***Index Terms*— Bulk density, voids ratio, packing density, mix design, plotting**

I. INTRODUCTION

There are various methods of proportioning for various types of concrete such as Fineness Modulus method, Minimum Void method, Maximum Density Method, Water Cement Ratio method, Arbitary method.

The subject of optimizing the concrete composition by selecting the right amounts of various particles has already aroused interest for more than a century. Concrete is a multiphase material consisting of coarse aggregate, fine aggregate, binding material and water. Thus, the properties of concrete depends upon the characteristics of the aggregates, performance of cement paste and interfacial transition zone. Approximately 75% of the concrete volume is occupied by the aggregates in which around 45% are coarse aggregate, it is assumed that the aggregate properties greatly affect the durability and the structural performance of concrete material. In concrete, cement is very expensive item than aggregates and is responsible for huge amount of carbon dioxide generation.

To decide water cement ratio in mix design, curves are used as per IS code method. Here an attempt has made to develop co-relation curves between compressive strength of concrete versus water cement ratio and paste content versus Compressive strength. These co-relation curves help to reduce the trials and decide the water cement ratio and paste content for the given grade of concrete.

Packing Density Method of mix design is the only mix design method used for proportioning normal concrete, high strength concrete, no-fines concrete and self compacting concrete. No adequate literature is available on this method. To develop a dense and stiff particle structure, optimization technique should be used in which particle packing density of concrete is optimized by filling the voids between larger particles with smaller ones. Geometrically based particle packing models can help to predict the water demand of concrete, and thus the material properties.

The mix design is basic essential tool for concrete technology and basic principal of the mix design is to obtain required properties of material at minimum cost. For sustainable concrete production the basic tool is concrete mix design. The performance of concrete is governed by two states namely fresh and hardened state. In the fresh state if concrete not workable then it cannot be placed and competed. In hardened state the compressive strength is the main factor which governs its property and it seems to be sign for good concrete.

There are various existing methods developed by the various countries and these methods are used for design of concrete mixes such as BIS code method,

British code method, ACI code method, etc. In general practice the concrete mixes are designed by using given standards. The aggregates and cement are tested in labs and with the help of data available in the codes for the design of mixes.

II. PROBLEM STATEMENT

The different geographical basis which has variation in quality of material and which affect the level of variation in achievement of concrete grading, this method is helpful to select same type of grading of material, minimize voids to increase particle packing and to reduce the binder content & achieve economy.

III. OBJECTIVES

The objectives of this paper are as below.

1. Cement reduction: Striving to decrease cement content in concrete, aiming for environmental sustainability and resource optimization.
2. Cost optimization: Exploring strategies to achieve an economically efficient concrete solution without compromising quality or performance.
3. IS specification alignment: Employing the same materials as per Indian Standards (IS) for the packing density method to ensure superior outcomes in line with established specifications

IV. LITERATURE REVIEW

(Aswathi, et al., 2019) studied that packing density is new mix design method used to design various types of concrete. To optimize the particle packing density of concrete, the particles should be selected to fill up the voids between larger particles with smaller particles and so on, in order to get a dense and stiff particle structure. Higher degree of particle packing leads to minimum voids, maximum density and cement and water requirement will be less. In his project, durable concrete is produced by packing density method with dolomite powder as partial replacement to cement. The reduction in the consumption of cement will not only reduce the cost of concrete but also the emission of carbon dioxide into atmosphere. Dolomite powder is obtained by powderising the sedimentary rock Dolostone. Dolomite powder has some similar characteristics of cement. Using dolomite powder in concrete we can reduce the cost of concrete and increase the strength. The replacement percentages tried were 0%, 5%, 10% and 15% by weight of cement. The compressive strength, flexural strength and split tensile strength of concrete with dolomite powder was compared with those of the reference specimens. The results indicates that replacement of cement with dolomite powder will increase the compressive strength, split tensile strength and flexural strength of concrete. The cement content reduced by using packing density method and also by replacing cement with dolomite powder.

(Walhekar, et al., 2018) they found out that packing density method of mix design of concrete is a new method to design different types of concrete. The mix design obtained from the packing density method has suitable workability, maximum packing density, and minimum voids ratio. The geometrical characteristics like shape, size, and proportion of fine aggregate and coarse aggregate affect packing density. The objective of this research is to study the mix design of concrete using a packing density method. In this work large number of trail to decide the proportion of aggregate for that optimum bulk density and packing density calculated for different varying proportion of 20 mm: 12.5 mm coarse aggregate (i.e. 90:10, 80:20, 70:30, 65:35, 60:40 and 50:50) and for varying proportion coarse aggregate : fine aggregate (i.e. 90:10, 80:20, 70:30, 60:40, 55:45 and 50:50). To finalize the mix design using packing density method also varies the percentage of excess cement paste (i.e. 5%, 7%, 9%, 10%, 11% and 12%). Tests were performed for the properties of fresh concrete like Workability test (Slump cone) and hard concrete like Compressive strength, split-tensile strength, Pull-out test and rebound hammer tests were determined at 7, 14 and 28 days. The obtained results for the above-mentioned test using packing density method are satisfying the standard results. The percentage of excess cement paste increases the workability of concrete increases.

(Huang, et al., 2017) investigated that packing density method is new kind of mix design method, generally used for design normal, high strength and self-compacting concrete. This method considers the volume and density variation between different types and sizes of aggregate. The adoption of packing density method optimises the particle packing density of concrete by selecting the right amount of various aggregates to fill up the voids between large and small aggregates, which allows a more dense and stiff structure. His work devoted to the studies of material

and mechanical properties of recycled aggregate concrete using packing density method. This paper considers mix of two different aggregate sizes of 10 and 20mm ratios and water-cement ratio of 0.35, 0.45 and0.55. In total of fifteen concrete mix designs are considered. Their work presents the material properties of aggregates which were obtained from the material testing. The mix design method and results of mechanical testing will be discussed. The results show that the packing densities of natural and recycled aggregates are different, and should not be treated in the same way. By using packing density mix design method, recycled aggregated concrete strengths fluctuation can be resolved, and the concretes can have similar strengths consistency, regardless the recycled concrete aggregate replacement ratios. His method minimise the influence of recycled concrete aggregates obtain from various sources with variable quality. From the material test results found that the natural and recycled concrete aggregates have different density, volume and absorption, hence it should not be considered the same.

(Patil, et al., 2017) said that The Experimental investigations are carried out for determining the effect of packing density (PD) of aggregate on characteristics of Self-compacting concrete (SCC).For this purpose several mix designs of SCC for the proportion of C.A:F.A (45:55) was carried out. The SCC was prepared as per the said mix proportion of CA: FA and test were carried out on L box, J-ring test, V funnel and slump cone to find fresh property, cubes and cylinders were casted for testing the hardened properties of SCC. The obtained results of fresh and hardened properties of SCC for proportions of CA: FA was compared with the standard values as per EFNARC guidelines, ASTM. Higher packing densities leave less space for voids to be filled with water, which reduces the water demand and increases the strength of concrete mixtures.

(Kore, et al., 2017) invented that the details of optimized mix design for normal strength concrete using particle packing density method. Also the concrete mixes were designed as per BIS: 10262-2009. Different water-cement ratios were used and kept same in both design methods. An attempt has been made to obtain sustainable and cost effective concrete product by use of particle packing density method. The parameters such as workability, compressive strength, cost analysis and carbon di oxide emission were discussed. He said that, the compressive strength of the concrete produced by packing density method are closer to that of design compressive strength of BIS code method. By adopting the packing density method for design of concrete mixes, resulted in 11% cost saving with 12% reduction in carbon dioxide emission. Cement content in decreased in this method hence the cost is also decreased.

(Teja, et al., 2015) found out that the usage of plastic has become in evitable in present world. The consumption of plastic in packaging, automotive and industrial applications has been increased extensively. Out of various types of plastics used, polystyrene a light weight classified plastic type which has high heat retaining tendency is been used for the present study. The use of Self Compacting Concrete (SCC) which is capable of flowing in form work and congested reinforcement without any mechanical vibrator fills the concrete voids with its high paste content is highly durable and economical. A comparative experimental studies on the arrived M30 grade SCC is carried out with replacement of coarse aggregate with polystyrene plastic wastes varying from 0% to 50% to determine optimum replacement. Fresh properties of SCC reveal the enhancement of workability satisfying permissible limits. An optimum replacement upto 30% coarse aggregate with plastics aggregates is suggested without any significant variation in compressive strength. Durability properties such as water absorption, sulphate resistance are improved under plastic replaced concrete at all levels. This type of plastic aggregate can be used successfully as a partial replacement of coarse aggregate in Self Compacting Concrete especially in precast industry as precast elements. It ensures the reduction in dead load hence it is economical.

(Fennis, et al., 2008) invented that Geometrically based particle packing models can help to predict the water demand of concrete and thus the material properties. In his work it is described how centrifugal consolidation can be used to determine the packing density of powders. The method is assessed based on experimental data, calculations and polarization and fluorescence microscopy of the samples. Results show

that an average maximum packing density can be measured, which depends on the initial water powder ratio, the use of super plasticizer, the mixing procedure of the paste and the applied compaction energy. Viscosity measurements show the influence of the particle packing density on water demand and how concrete mixtures can be designed to lower the cement content in concrete. Mixtures with a smaller particle size distribution are less likely to segregate, since the mass difference between the particles is smaller.

(Glavind, et al., May, 1999) found out that when selecting a concrete mix design, it is always desirable to compose the aggregates as densely as possible, i.e. with maximum packing. That minimises the necessary amount of binder which has to fill the cavities between the aggregates for a constant concrete workability. Apart from an obvious economic benefit, a minimum of binder in concrete results in less shrinkage and creep and a more dense and therefore probably a more durable and strong concrete type. Their work presents a packing model which can be used to optimise the aggregate, both the theory behind, the available computer program and the necessary experimental measurements. The application of packing calculations for concrete mix design to select the types and amounts of materials, to select the amount of binder, and to design the air void system will be described. His work is described for selecting aggregate types and corresponding amount, for selecting the amount of binder, and for designing the air void system.

V. METHODOLOGY

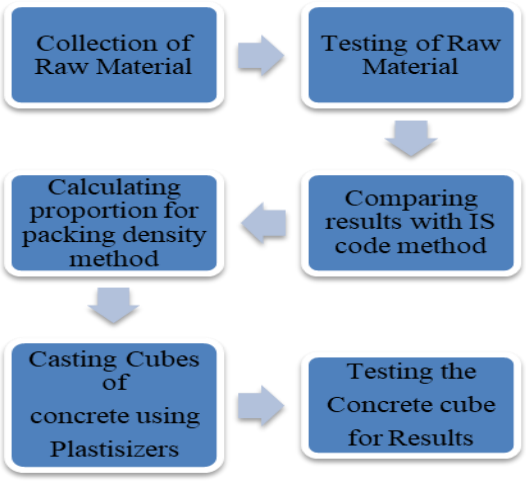


Figure 1 Methodology of Paper

VI. RESULTS

Final results of all tested materials:

Sr. No.	Description	Unit	Result
1	Average Specific gravity for 20 mm coarse aggregate.	-	2.63
2	Average Specific gravity for 10 mm coarse aggregate.	-	2.64
3	Average Specific gravity for fine aggregate.	-	2.64
4	Fineness modulus for fine aggregate.	-	3.88
5	FI & EI Combined for 20 mm aggregate.	%	21.66
6	FI & EI Combined for 10 mm aggregate.	%	16.85
7	Moisture Content of artificial washed sand.	%	20.8
8	Mean of Aggregate Impact Value. (In %)	%	13.78
9	Mean of Aggregate Crushing Value. (In %)	%	23.17

Aggregate proportions of packing density method:

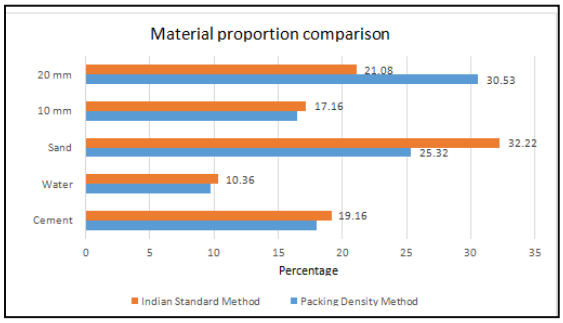
Materials	Proportions at Maximum Packing Density		
	20 MM	10 MM	FA
Coarse Aggregates	65 %	35 %	--
All-In-Aggregates	65 %		35 %
Final Proportions	42.25 %	22.75 %	35 %

Finalized mix proportions designed by packing density method:

Sr. No.	Material	Unit	Quantity
1	Cement content	Kg/cum	419.33
2	Water content	litre	226.44
3	Wt. of Fine aggregate	Kg/cum	591.48
4	Wt. of 10 mm aggregate	Kg/cum	384.46
5	Wt. of 20 mm aggregate	Kg/cum	714.00
6	W/C ratio	-	0.54
7	Total	Kg/cum	2335.70

Finalized mix proportions designed by IS code method:

Sr. No.	Material	Unit	Quantity
1	Cement content	Kg/cum	440
2	Water content	litre	238
3	Wt. of Fine aggregate	Kg/cum	739.13
4	Wt. of 10 mm aggregate	Kg/cum	393.96
5	Wt. of 20 mm aggregate	Kg/cum	483.20
6	W/C ratio	-	0.54
7	Total	Kg/cum	2294.29



Graph 1 Graph of Material Proportion comparison

Compressive strength of cube cast using packing density method:

Sr. No.	Days	Unit	Packing Density Strength	IS Code Strength
1	3	Mpa	17.24	16.09
2	7	Mpa	22.61	21.65
3	28	Mpa	32.26	31.46

Cost comparison of Packing Density Method and IS code method:

Material	Unit	Unit	Packing Density	IS Method
Cement	Rs.300	Bag	2520	2640
Crushed Sand	Rs.4000	Brass	2368	2960
10 MM	Rs.2000	Brass	770	790
20 MM	Rs.2000	Brass	1430	970
Total Amount	-	Rs.	7088	7360
Cost Saving		Rs.	272	-

Discussion:

From the above values it is clear that fine aggregate particles are required more in case of packing density method compared to IS code method. Therefore, water and cement required in case of packing density method is more. In case of IS method coarse aggregate 20 mm and 10 mm down sizes are graded based on sieve analysis results but in case of packing density method aggregates quantity are decided based on actual packing of particles. Coarse aggregate particle 20 mm downsize required will be more in case of packing density method compared to IS method. But both the methods have resulted in nearly same compressive strength at 28 days curing. Coarse aggregate particle may also contribute towards the strength along with bond. In case of packing density, finer aggregate particles required are more and paste required is also more. In this case contribution to the strength due to bond area may be more.

VI. CONCLUSION

- Reduced cost of concrete.
- Decreased porosity.
- Increased compressive strength of concrete.
- Reduced cement consumption.
- In case of packing density method water cement ratio decreases with increase in grade of concrete.
- The water and cement content for packing density and IS code method is nearly same for any particular grade of concrete.
- The workability of concrete achieved is more in packing density method compared to IS code method for the same grade of concrete.
- The fine aggregate particles required are more in case of packing density method compared to IS code method. Therefore, water and cement required in case of packing density is more.
- The fine aggregate and coarse aggregate 20 mm down size required is more in packing density method and coarse aggregate 10 mm down size required is more in IS method.

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