Nilesh Chande, et. al. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 13, Issue 7, July 2023, pp 109-114

RESEARCH ARTICLE OPEN ACCESS

Comparative Experimental Study of Various Grade Mixed Design Concrete As Per Is Code Method and Packing Density Method

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ABSTRACT
A novel technique for designing various types of concrete is the packing density approach of concrete mix design. The mix design obtained using the packing density approach has an acceptable level of workability, the highest possible packing density, and the lowest possible voids ratio. Packing density is influenced by the geometrical traits of fine aggregate and coarse aggregate, such as shape, size, and proportion. The goal of this work is to investigate concrete mix design utilising the packing density approach and establish a relationship between bulk density, packing density, and void ratio. Numerous trials were conducted in this study to determine the aggregate percentage for the best bulk density and packing density estimated for several variable proportions of 20 mm: 12.5 mm coarse aggregate (i.e. 90:10, 80:20, 70:30, 65:35, 60:40, and 50:50), as well as for other factors. For different ratios of coarse to fine aggregate, such as 90:10, 80:20, 70:30, 60:40, 55:45, and 50:50, see table below. The amount of surplus cement paste is varied when finalising the mix design using the packing density method (i.e., 5%, 7%, 9%, 10%, 11%, and 12%). At 7, 14, and 28 days, tests were conducted to assess the qualities of fresh concrete, such as workability test (Slump cone), and hardened concrete, such as compressive strength, split-tensile strength, pull-out test, rebound hammer, and flexural test, etc. The findings obtained for the aforementioned test employing the packing density method at 9% extra cement paste are satisfactory.

Keywords - Compressive strength, Flexural strength, split tensile strength, workability, bulk density, packing density

Date of Submission: 03-07-2023 Date of acceptance: 14-07-2023

I. INTRODUCTION

The only mix design approach utilised for proportioning regular concrete, high strength concrete, no-fines concrete, and self Compacting concrete is the packing density method. However, there is a lack of relevant literature on this approach. Imagine a blend of cement paste and a single-sized aggregate for concrete. The volume of cement paste must be greater than the volume of gaps within the aggregate skeleton in order to completely fill all gaps between the aggregate particles and eliminate air spaces in the concrete mix. The smaller size aggregate particles would fill in the spaces between the bigger size aggregate particles if a multi-sized aggregate were employed in place of a single-sized aggregate, resulting in a reduced volume of Gaps can be seen in the collective skeleton. There are two effects of this. First off, using multiple-sized aggregate would lower the amount of cement paste required to fill in the gaps in the aggregate skeleton. The use of a multi-sized aggregate, if the volume of cement paste is kept constant, would also increase the volume of the excess paste (the portion of paste over that needed to fill up the gaps within the aggregate skeleton), which disperses the aggregate particles, provides a coating of paste for each aggregate particle, and makes the concrete mix workable. As a result, the paste demand and the workability of a concrete mix are significantly influenced by the size distribution or grading of the aggregate.

It has long been understood that the grading of the aggregate can significantly affect how effectively the concrete mix performs (Powers 1968). Simply put, numerous factors (the different size fractions of the aggregate) are required to define grading, and the interactions between these many parameters frequently cause the effects of the various parameters to be unclear. It is now abundantly obvious that the packing density of the aggregate is the single factor that has the greatest impact on the performance of concrete. The proportion of the volume of solids to the bulk volume of the solid particles is known as the packing density of a certain aggregate or lump of solid particles.A higher packing density results in a lesser volume of voids to be filled and vice versa since the bulk volume is equal to the volume of solids plus the volume of voids. The application of packing density to concrete mix design.

According to , the single-sized aggregate can only be packed densely enough to occupy a small amount of space. The multi-sized aggregate can be packed considerably more efficiently to attain a substantially higher packing density. With the paste volume maintained, the increase in aggregate packing density might be used to either increase the workability of the concrete while keeping the water cementations ratio the same or raise the strength of the concrete by lowering the water cementations ratio while retaining the workability. The increase in packing density of the aggregate might be used to improve the dimensional stability of the concrete in addition to increasing the excess paste at a given paste volume to improve the workability and/or strength of the concrete. In a concrete mixture, the cement paste is what produces the heat of hydration that results in thermal expansion or contraction in the early stages and shrinks over time when exposed to drying. As a result, early thermal expansion or contraction and long-term drying shrinkage would cause changes in dimension of the hardened concrete to be greater the larger the paste volume. The water cementations ratio also affects the heat of hydration and drying shrinkage of the concrete, both of which are greater at higher water cementitious ratios. The use of a smaller paste volume at a fixed water cementitious ratio or a lower water cementitious ratio at the same paste volume would both significantly increase the dimensional stability of the concrete due to the reduction in paste demand caused by a higher packing density of the aggregate for the same workability.

Imagine combining particles of varying sizes so that smaller-sized particles fill in the gaps between the larger particles one by one. All the spaces can be filled with solid particles if the filling process is extended indefinitely by adding particles of incredibly small size, resulting in a packing density very close to 1. In practise, however, this is impossible for a number of reasons. There is a practical limit to the size range of the particles, therefore there are always some gaps that remain unfilled since the smallest size particles cannot be too small and the largest size particles cannot be too huge. Secondly, The packing of the aggregate is constrained by the form of the aggregate particles. The form factor and convexity ratio of the aggregates particles have been shown to be the two main shape characteristics influencing packing density (Kwan and Mora 2001). As the convexity ratio is defined as the mean value of the particle's ((solid area)/convex area) ratios, while the shape factor is defined as the mean value of the particle's ((thickness×length)/(breadth2) ratios. Due to the relatively strong interlocking effect of the particles, which prevents the particles from arranging themselves at the ideal locations or orientations, a low form factor and/or a low convexity ratio would negatively affect the packing density, as indicated.

1.1 Scope

The scope of project work is to study the optimum materials and cost effectiveness of designing the M40 grade of concrete using packing density method. The effect of proportion of fine and coarse aggregate and the percentage of excess cement paste on the properties of fresh and hardened concrete.

When selecting a concrete mix design, it is always desirable to compose the aggregates as densely as possible, i.e. with maximum packing. That minimizes 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, creep and denser therefore probably a more durable and strong concrete type. The scope of present work is to use the optimum materials which will enhance the different parameter of the concrete.

1.2 Research objective

1. To study the mix design of M40 grade concrete using packing density method.
2. To determine the various test results to shows the relation between bulk density, packing density and voids ratio.
3. To determine material variation in packing density method and Indian standard code of practice.
4. To determine the proportion of fine and coarse aggregate and percentage of excess cement paste which gives maximum strength as per IS code standard.
5. To establish the relationship between various test of concrete incorporating with excess of cement paste and aggregate proportion.
6. To evaluate the mechanical properties of concrete containing Nano metakaolin, Nano

ISSN: 2248-9622, Vol. 13, Issue 7, July 2023, pp 109-114

zirconium oxide and Nano ferric oxide as cement replacement in concrete.

7. To study the physical properties of concrete material.
8. To arrive a mix design summary for concrete using IS code methods.
9. To compare the strength for different percentage of partial replacement of Nano metakaolin, Nano zirconium oxide and Nano ferric oxide with ordinary concrete.

II. MATERIALS & METHODOLOGY

2.1 The materials used in this present work are Ordinary Portland Cement (OPC-53 grade), coarse aggregates and fine aggregates and water.

2.2 Cement

On the other hand, faster hydration rates may result in a quicker loss of workability due to a large and rapid release of heat during hydration. Following an evaluation of the aforementioned specifications, OPC grade 53 cement is utilised throughout the experimental work.

2.3 Aggregates

Aggregates are larger than 4.75mm or that has been retrained using a 4.75 mm IS sieve is referred to as coarse aggregate. Tests will be performed in accordance with IS 383 – 1970 to identify the various physical properties of a coarse aggregate with a nominal size of 20mm. This experiment makes use of 20mm coarse aggregate.

2.4 Water

Portable water was used throughout the experiment in compliance with IS 456: 2000 criteria.

2.5 Mix Design

Grade designation = M40
Type of cement = OPC
Maximum nominal size of aggregate = 20 mm
Minimum cement content = 360 kg/m3
Maximum water cement ratio = 0.4
Workability = 75-100 mm
Expose condition = Extreme (RC)
Degree of supervision = good
Type of aggregate = crushed angular aggregate
Maximum cement content = 450-500 kg/m3

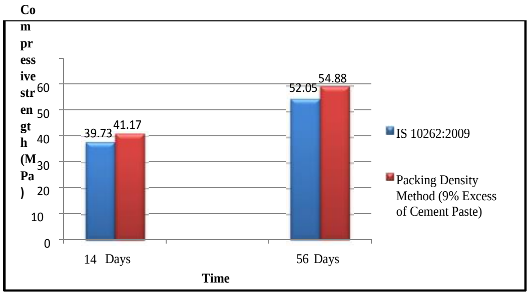
III. RESULTS

Results of fresh and hardened concrete with partial replacement of Nano Ferric Oxide, Nano Metakaolin and Zirconium Oxide in combination are discussed in comparison with those of normal concrete.

For the combinations of concrete mixes three cubes were being casted each for varying curing days 21, 56 days & three cylinders and three beams were being casted for curing period of 28 days and 56 days. Test for the same being conducted under compressive testing machine of capacity 2000KN.

3.1EXPERIMENTALCOMPRESSIVE STRENGTH VARIATION RESULTS

Sr. No.	Description	Compressive Strength (MPa)		Remark
		28 Days	56 Days	
1	IS10262-2009	39.73	52.05	As per Clause No. 3.2,Page No.1 of IS 10262-2009 Target mean compressive strength at 28 days for M40 concrete is 26.6MPa
2	Packing density method (9% excess of cement paste)	41.17	54.88	
3	Increased in strength in packing density method (MPa)	1.44	2.83	



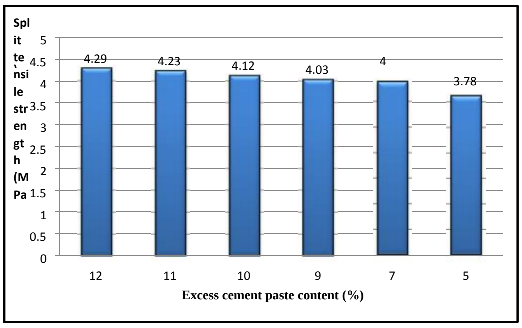
Graph 1. Compressive strength variations in packing density method and IS 10262-2009

3.2 Split tensile strength

Sr. No.	Excess cement paste content (%)	Split Tensile Strength (MPa)	Strength Increase 28 days (MPa)
1	12	4.29	0.13

 DOI: 10.9790/9622-1307109114

2	11	4.23	0.19
3	10	4.12	0.30
4	9	4.03	0.38
5	7	4	0.41
6	5	3.78	0.63

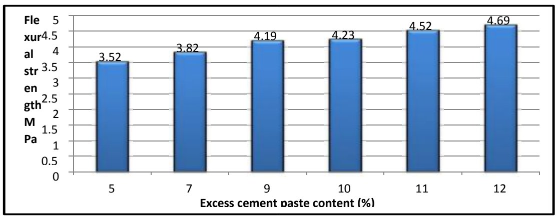


Graph 2. Split tensile strength (Packing density method)

3.3 FLEXURAL STRENGTH TEST

Table III
Experimental test results for flexural strength

Sr. No.	Excess cement paste content (%)	Mean Flexural Strength (MPa)	Strength Increase 28 days (MPa)
1	12	3.52	0.00
2	11	4.23	0.19
3	10	4.12	0.30
4	9	3.82	0.30
5	7	4	0.41
6	5	3.78	0.63



Graph 3. Flexural strength using packing density method

IV. SUMMARY

As the percentage of coarse aggregate and fine aggregate is 60:40 respectively it gives the maximum bulk density and packing density of mix that will help to reduce the volume of cement paste. In that again coarse aggregate of size 20 mm and 12.5 mm is divided into 70:30 respectively it gives the maximum bulk density and packing density which can also help to reduce the volume of cement paste.

In packing density method the fine aggregate required more as compare to IS code method, that significantly increases the packing density of concrete and bond area for coarse aggregate that contribute the more strength. The filling would be better if particles with more size are used, the medium size particles fill into the larger size particles whereas the smaller size particles fill into the voids between medium size particles and successive fillings continue.

As the percentage of excess cement paste increases the workability of concrete increases. During this the excess cement paste increases the volume of cement gel which can help to improve the workability, packing density and decreases the voids ratio.

The compression strength test and split tensile strength was performed on standard compression testing machine of 1000 kN capacity, as per IS 516-1959. As the percentage of excess cement paste increases the strength also increases. When the excess cement paste was 9% it gives compressive strength about 41.17 N/mm^2, 54.88 N/mm^2 for 28, 56 days respectively and split tensile strength was about 4.03N/mm^2 after 28 days. Thus it can be concluded that 9% was the optimum level for excess cement paste.

The Pull-out test and flexural strength test was performed on standard Universal testing machine of 1000 kN capacity. As the percentage of excess cement paste increases the strength also increases. When the excess cement paste was 9% it gives bond strength was about 2.25 N/mm^2 after 28 days and the flexural strength was about 4.19 N/mm^2 after 28 days. Thus it can be concluded that 9% was the optimum level for excess cement paste.

The mechanical properties of concrete depend on cement paste composition, paste volume, the physical characteristics of aggregate such as texture, shape and nature. The rough textured aggregate develops higher bond of aggregate.

Well establish correlations are not available for bulk density, packing density, voids ratio and excess of cement paste, so an attempt was made to develop these values. For that various trial calculations are involves to check the workability of concrete and overall performance of concrete for various percentage of excess cement paste.

V. CONCLUSION

The influence of mix design of concrete using packing density method has been studied based on experimental work conducted, the following conclusion are drawn.

1) The fine aggregate particle needed in the packing density technique was 5.47% more than needed in the IS code method (733 kg/m3 vs. 773 kg/m3 in the packing density method). The 12.5 mm size aggregate needed 42.97% less packing density than the IS code approach, and the 20 mm size aggregate needed 33.07% higher packing density than the IS code method.

2) As bulk density rises, packing density rises as well, and the voids ratio falls. Maximum bulk density of aggregate is 1.987 g/cm3, packing density is 0.715 g/cm3, and voids ratio is 28.57% for a 60:40 ratio of coarse to fine aggregate. Therefore, using diverse size aggregate instead of just one size increases the workability, strength, and overall effectiveness of concrete while lowering its permeability and porosity.

3) The compressive strength increases together with the proportion of surplus cement paste; for example, 9% excess cement paste results in 41.17 N/mm2 and 4.03 N/mm2 for split tensile strength. Therefore, we infer that 9% of surplus cement paste is needed for M40 grade concrete in order to get satisfactory results while still being economical.

4) The bond strength improves as the amount of excess cement paste in the concrete rises, but it then decreases again, reaching strengths of 0.13, 0.19, 0.30, 0.38, 0.41, and 0.63 MPa for concrete with excess cement paste percentages of 5%, 7%, 9%, 10%, 11%, and 12%, respectively. Therefore, we infer that 9% of surplus cement paste is needed for M40 grade concrete in order to get satisfactory results while still being economical.

5) At 5%, 7%, 9%, 10%, 11%, and 12%, respectively, the flexural strength of concrete with varying percentages of extra cement paste was 3.52 3.82, 4.19, 4.23, 4.52, and 4.69 MPa. Therefore, we infer that 9% of surplus cement paste is needed for M40 grade concrete in order to get satisfactory results while still being economical.

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