Experimental Study of M20 Grade Concrete using Packing Density Method

Mr. G. P. Walhekar[1] Dr. M. R. Wakchaure[2]
[1]PG Student [2]Associate Professor
[1,2]Department of Civil Engineering
[1,2]AVCOE, Sangamner, India

Abstract— 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 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 were determined at 7, 14 and 28 days. The obtained results for above mentioned test using packing density method are satisfying the standard results.

Key words: Bulk Density, Packing Density, Voids Ratio, Excess of Cement Paste

I. INTRODUCTION

Concrete is the most widely used construction material in the construction industry and offers a number of advantages, including durability properties, low cost, and high performance concrete. Concrete is produced by proper proportioning of cement, water, fine and coarse aggregate proportion, so as to satisfy the overall performance of concrete. Thus the mix proportion of aggregate in concrete gives the required workability, maximum bulk density, maximum packing density, minimum voids ratio. The above mentioned parameter is depends upon the geographical properties of aggregate like size, shape and mix proportion of fine and coarse aggregate. In packing density method also calculate the cement paste required to fill-up the gaps between this aggregate, so as to minimize the voids and maximize the packing. In packing density method the fine aggregate and coarse aggregate provides required workability and minimize the porosity, permeability and segregation. It has been shown that the excess cement paste varies then the workability changes, so it effect on good quality concrete. However, it should be noted that if fine and coarse aggregate proportion varies then the large change in the packing density and voids ratio.

II. MATERIALS & METHODS

A. Materials

1) Cement

For this research, locally available ordinary Portland cement (53 grade) of Specific gravity of cement 3.15 was used throughout the work.

2) Physical Properties of Fine Aggregate

Locally available fine aggregate used was 4.75 mm size confirming to zone II with specific gravity 2.693. The testing of sand was conducted as per IS: 383-1970.

3) Physical Properties of Coarse Aggregate

Crush stone aggregate of size 20 mm and 12.5 mm was used throughout the experimental work. Coarse aggregate used was 20mm with specific gravity 2.912 and coarse aggregate of 12.5 mm with specific gravity 2.822. Testing of coarse aggregate was conducted as per IS: 383-1970.

4) Water

The water used was potable, colour less and odor less that is free from organic impurities of any type.

B. Concrete Mix Design

Mix design is process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible.

1) Determination of Aggregate Fraction

It is calculated using the bulk density method, bulk density it is the ratio of solid mas to the bulk volume of water. The aim of obtaining maximum packing density the proportion of fine and coarse aggregate was calculated by using bulk density of mix proportion.

2) Determination of Packing Density

The packing density is the ratio of solid volume of aggregate particles to the bulk volume occupied by the particle. It has been observed that when the bulk density is maximum the packing density also maximum.

3) Determination of Voids Content

It is the ratio of volume of voids between the aggregate particles to the bulk volume occupied by the aggregate. It has been observed that when the packing density is maximum the voids content minimum and the required amount of binder will be less. The voids content is calculated as one minus the packing density.

Excess cement paste content (%)	Water (lit.)	Cement kg/m^3	Fine Aggregate kg/m^3	Coarse aggregate 12.5 mm kg/m^3	Coarse aggregate 20 mm kg/m^3
5	188.61	342.94	789.34	355.20	827.63
		1	2.30	1.04	2.41
7	193.37	351.58	779.80	350.91	818.79

		1	2.22	1.00	2.33
9	197.17	358.50	773.07	347.88	811.72
		1	2.16	0.97	2.26
10	198.76	361.38	770.26	346.62	808.78
		1	2.13	0.96	2.24
11	200.34	364.24	767.46	345.35	805.83
		1	2.11	0.95	2.21
12	202.24	367.72	764.09	343.84	802.30
		1	2.08	0.94	2.18

Table 1: Mix Design of M20 Grade of Concrete using Packing Density Method

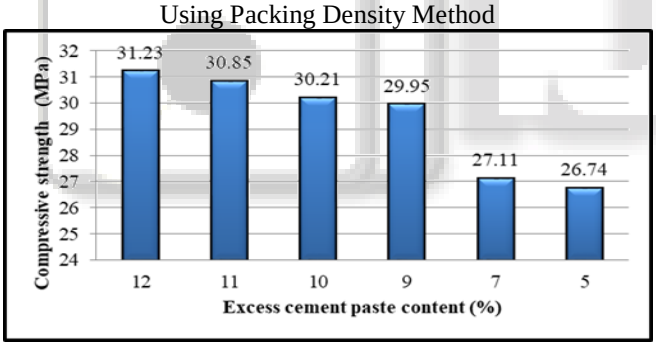
III. RESULTS & DISCUSSION

A. Compressive Strength Test

A cube compression test is performed on standard cubes of size 150 x 150 x 150 mm after 7, 14 and 28 days of immersion in water for curing.

Sr. No.	Excess cement paste content (%)	Compressive Strength (MPa)		
		7 Days	14 Days	28 Days
1	12	21.02	25.78	31.23
2	11	20.82	25.12	30.85
3	10	20.58	24.86	30.21
4	9	20.45	24.57	29.95
5	7	17.55	24	27.11
6	5	17.33	23.62	26.74

Table 2: Experimental Test Result for Compressive Strength Using Packing Density Method



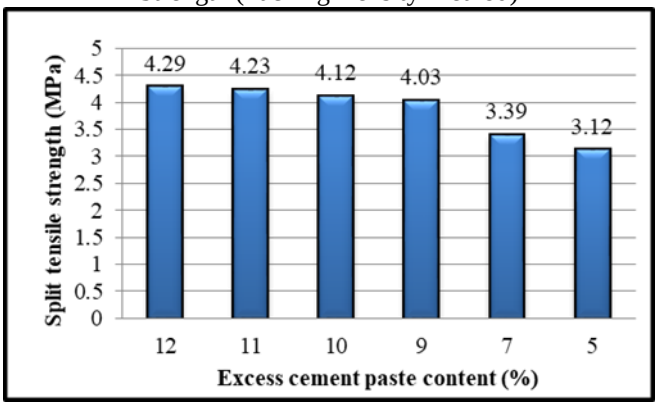
Graph 1 Compressive strength of concrete excess of cement paste for 28 days

B. Split Tensile Test

The split tensile test is well known indirect test used to determine the tensile strength of concrete. Cylinder is tested after 28 days. Split tensile strength of cylinder specimens is determined by placing between the two plates of compression testing machine, iron strips of 3 mm thick, 25 mm wide and 300 mm long, were placed between the plates and surface of the concrete specimens.

Sr. No.	Excess cement paste content (%)	Split Tensile Strength (MPa)
1	12	4.29
2	11	4.23
3	10	4.12
4	9	4.03
5	7	3.39
6	5	3.12

Table 3**:** Experimental Test Results for Split Tensile Strength (Packing Density Method)



Graph 2: Split Tensile Strength of Concrete Excess of Cement Paste for 28 Days

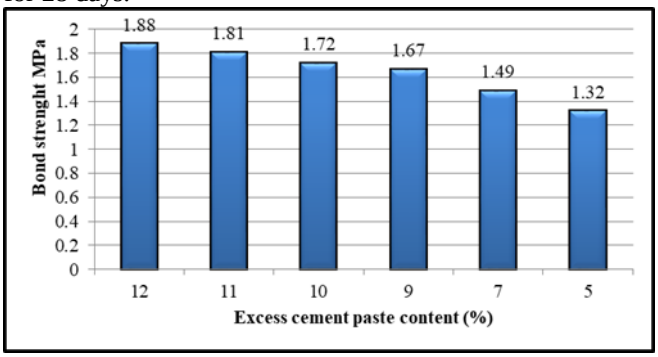
C. Pull Out Test

Specimens are prepared by filling the concrete of M20 grade in mould having internal dimensions 150 mm X 150mm X 150 mm and inserted the mild steel or *TMT* bar at the center of specimen. Specimens are cured for 28 days and tested in *UTM*. 3 cubes of each variation were casted for the conduction of test and cured for 28 days under water. Pull out test results obtained are given as follows:

Sr. No.	Excess cement paste content (%)	Bond Strength (MPa)
1	12	1.88
2	11	1.81
3	10	1.72
4	9	1.67
5	7	1.49
6	5	1.32

Table 4**:** Test Results for Pull out Test

It is clear from table 4, maximum bond Strength obtained for concrete with 9% excess cement paste content is 1.67 MPa for 28 days.



Graph 3: Bond Strength of Concrete Excess of Cement Paste for 28 Days

IV. CONCLUSION

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 20.45 N/mm^2, 24.57 N/mm^2, 29.95 N/mm^2 for 7, 14, 28 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 bond strength increases with the percentage of excess cement paste increases in concrete but again it deceases 1.32, 1.49, 1.67, 1.72, 1.81 and 1.88 MPa strength was observed for 5%, 7%, 9%, 10%, 11% and 12% respectively. So we conclude that the excess cement paste required for M20 grade concrete is 9%, keeping economy in mind 9% excess cement paste gives the satisfactory results.

ACKNOWLEDGMENT

It is not possible to express the things in words what I feel, but here I tried to express my thoughts in the form of acknowledgement. It has been privilege for me to be associated with Dr. M. R. Wakchaure, my project guide. I have been greatly benefited by his valuable suggestions and ideas. It is with great pleasure that I express my deep sense of gratitude to him for his guidance, constant encouragement, for his kindness, moral boosting support more than I could possibly express. I am thankful to Dr. J. B. Gurav, Head, Civil Engineering Department, for providing the required facilities to complete this report. I must say thanks to all the teaching and non-teaching staff of department for their valuable cooperation and support.

REFERENCES

[1] Wong, H. C. H. & Kwan, K. H. A. "Packing density of cementitious materials: part 2 – packing flow of OPC + PFA + CSF". Materials and structures, Vol.41, 2008, p.773-784.
[2] Fennis, S. A. A. M & Walraven, J. C. "Measuring the packing density to lower the cement content in concrete". Tailor made concrete structure London, 2008, p. 419-424.
[3] Glavind, M. & Peterson, E. J. "Packing calculations applied for concrete mix design". University of Dundee, May 1999.
[4] Wong, H. C. H. & Kwan, K. H. A., "Packing density: A key concept for mix design of high performance concrete".
[5] Kantha Rao, V. V. L. And Krishnamoorthy, S., "Aggregate mixtures for least-void content for use in polymer concrete".
[6] Huber, G.A., & Shuler, T.S. "Providing Sufficient Void Space for Asphalt Cement: Relationship of Mineral Aggregate Void and Aggregate Gradation. Effects of Aggregates and Mineral Fillers on Asphalt Mixture Performance". ASTM Special Technical Publication 1147, 1992.
[7] Vavrik, W.R., Huber, G., Pine, W.J., Carpenter, S.H., & Bailey, R. Bailey Method for "Gradation Selection in HMA Mixture Design". Transportation Research Circular number E-C044. Transportation Research Board, 2002.
[8] Vavrik, W.R. "Asphalt Mixture Design Concepts to Develop Aggregate Interlock". Ph.D. thes is. University of Illinois at Urbana–Champaign, 2000.
[9] Andersen, P.J. & Johansen, V. "Particle packing and concrete properties", Material Science of Concrete: II, 1991, Skalny J and Mindess S (Edited), The American Ceramic Society, Inc., Westerville, Ohio. p. 111-147.
[10] Senthil kumar V, Manu Santhanam, "Particle packing theories and their application in concrete mixture proportioning: a review" The Indian Concrete Journal 2003, p.1324–1331.
[11] Golterman, P., Johansen, V., Palbfl, L., "Packing of Aggregates: An Alternative Tool to Determine the Optimal Aggregate Mix," ACI Materials Journal, Vol. 94, No. 5, 1997, p. 435.
[12] Erol Tutumluer, Tongyan Pan, Samuel h. Carpenter, "Investigation of Aggregate Shape Effects on Hot Mix Performance Using an image Analysis Approach", Final Report on the TPF-5 (023) Department of Civil and Environmental Engineering, University of Illinois At Urbana Champaign Urbana, Illinois, 2005, p.1-121.
[13] M. R. Jones, L. Zheng and M. D. Newlands, "Comparison of Particle Packing Models for Proportioning Concrete Constituents for Minimum Voids Ratio", Materials and Structures/ Materiaux et Constructions, Vol. 35, June 2001, p.301-309.

