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Experimental Study of M20 Grade Concrete Using Packing Density Method

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Abstract— Packing density method of mix design of concrete is 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 packing density method and develop the correlation between bulk density, packing density and voids ratio. 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 and50:50). 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 hardened concrete like compressive strength, split- tensile strength, pull-out test, rebound hammer and flexural Test etc. tests were determined at 7, 14 and 28 days. The obtained results for above mentioned test using packing density method at 9% of excess cement paste are satisfying the standard results.

I. INTRODUCTION

In Pressing thickness technique for blend configuration is the main blend structure utilized for proportioning typical solid, high quality cement, no-fines concrete and self-Compacting concrete. However, no satisfactory writings are accessible on this strategy. Envision a solid blend made out of a solitary measured total and concrete glue in particular. So as to top off all the holes between the total particles in order to drive away the air voids in the solid blend, the volume of concrete glue must be bigger than the volume of holes inside the total skeleton, Figure 1.1(a). On the off chance that, rather than a solitary mea strategy urged total, a multi estimated total is utilized, the littler size total particles would top off the holes between the bigger size total particles, prompting a littler volume of holes inside the total skeleton, Figure 1.1(b). This has two ramifications. Right off the bat, with a multi-sized aggregate used, the volume of cement paste needed to fill up the gaps within the aggregate skeleton would be reduced. Secondly, if the volume of cement paste is kept the same, the use of a multi-sized aggregate would increase the volume of the excess paste (the portion of paste in excess of 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 renders workability to the concrete mix, Figure 1.1(c). Figure 1 illustrates how the concept of packing density can be applied to concrete mix design. In Figure 1.1(a), the single-sized aggregate can be packed together to occupy only limited space, i.e. can achieve only a relatively low packing density. In Figures 1.1(b) and 1.1(c), the multi-sized aggregate can be packed together much more effectively to achieve a much higher packing density.

Envision that particles of diminishing sizes are combined with the end goal that the holes between the particles are topped off progressively by littler size particles. On the off chance that the topping off procedure is expanded limitlessly by consolidating particles of incredibly fine size, all the voids can be topped off by strong particles, prompting a pressing thickness extremely near 1. Be that as it may, truly, this can never be accomplished because of a few reasons. Right off the bat, since the best size particles can't be excessively fine and the biggest size particles can't be excessively enormous, there is a functional cutoff to the size scope of the particles and subsequently there is in every case a few voids staying unfilled. Secondly, the shape of the aggregate particles has a limiting effect on the packing of the aggregate. It has been found that the major shape parameters affecting the packing density are the shape factor and convexity ratio of the aggregates particles (Kwan and Mora 2001). The shape factor is defined as the mean value of the (thickness×length)/ (breadth^2) ratios of the particles, while the convexity ratio is defined as the mean value of the ((solid area)/convex area) ratios of the particles, as illustrated in Figure 1.2. A low shape factor and/or a low convexity ratio would adversely affect the packing density, due to the relatively large interlocking action of the particles.

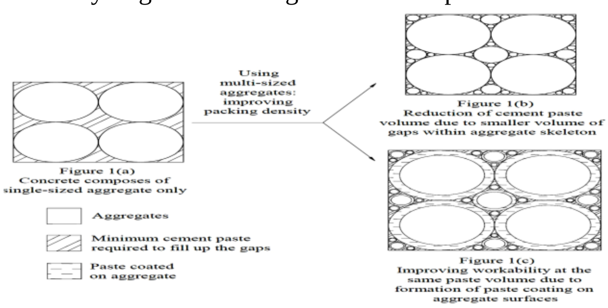

Figure 1. Packing of aggregate (Kwan and Mora et al)

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II. MATERIALS AND METHODOLOGY

Materials used in this context of investigation are cement, water, fine aggregate and coarse aggregate and the same are tested in the laboratory. Fresh concrete and Hardened concrete is tested for different tests.

Cement consists of four major compounds Tri-calcium silicate (C_3S), Di-calcium silicate (C_2S), Tri-calcium Aluminates (C_3A) and Tetra-Calcium Aluminium ferrite (C_4AF). Tri-calcium Silicate (C_3S) and Di-calcium silicate (C_2S) is the most important compound responsible for strength. Together they constitute 70-80 percent of cement. The average C_3S content in modern cement is about 45 percent and that of C_2S is about 25 percent. During the course of reaction of C_3S and C_2S with water, calcium silicate hydrate (C-S-H) and calcium hydroxide ($Ca(OH)_2$) are formed. Calcium silicate hydrates are the most important products and determines the good properties of concrete. C_3S readily reacts with water and produces more heat of hydration. It is responsible for early strength of concrete. C_2S hydrates rather slowly produces less heat of hydration. It is responsible for later strength of concrete. The C_3A portion of cement hydrates more rapidly, thereby reducing the workability of fresh concrete. Regarding particle size distribution, it may be noted that finer particles hydrate faster than coarser particles and hence contribute more to early age strength; however, at the same time, the faster the rate of hydration may lead to quicker loss of workability due to rapid and large release of heat of hydration. After reviewing all above requirements Ordinary Portland Cement (OPC) grade 53 cement is used throughout the experimentalwork.

Cement is tested in laboratory and is as follows:

- Finenesstest.
- Standard Consistencytest.
- Initial and final Setting Time test.

Sr. No.	Mass of cement (g)	Mass of water added in cement (ml)	Penetration measured from the bottom (mm)
1	400	25 x 4 = 100	29
2	400	30 x 4 = 120	15
3	400	31 x 4 = 124	9
4	400	32 x 4 = 128	7
5	400	35 x 4 = 140	2

Table 1. Observation for standard consistency of the cement paste

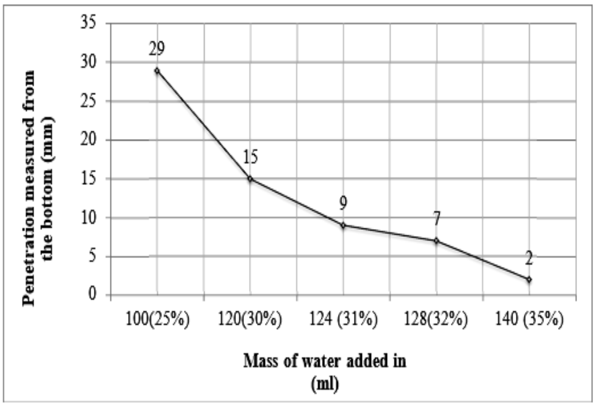


Figure 2. Standard consistency cement paste

TESTING OF FINEAGGREGATE

Aggregate is tested in laboratory and is as follows;

A. Specific gravity
B. Moisture content
C. Finenesstest

A. Determination of specific gravity of fineaggregate

Specific gravity= D/ (D-(A-B))
= 493/ (493-(1823-1414))
= 2.684

B. Determination of moisture content of fineaggregate

Moisture content = [(C-D)/C]*100
= [(500-491.5)/500]*100
= 1.70%

Sr. No.	Property	Result
1	Particle shape and size	below 4.75mm
2	Specific gravity	2.693
3	Moisture content (%)	1.73
4	Fineness Modulus	2.692
5	Silt content	Nil
6	Surface moisture	Nil

Table 2. Observation table for specific gravity of fine aggregate

Sr. No.	Particulars	Sample-1	Sample-2
1	Wt. of Sample Under test (C)	500	500
2	Wt. of Oven dry sample (D)	493	490
3	Wt. of Pycnometer + Aggregate + water (A)	1823	1822
4	Wt. of Pycnometer +water (B)	1514	1514
5	Specific Gravity	2.684	2.698
6	Moisture content	1.4%	2.0%

Table 3. Observation table for fineness modulus of fine aggregate

Average Specific gravity of fine aggregate will be taken as 2.693.

C. Determination of Fineness modulus of FineAggregate

Fineness modulus = sum of cumulative % of mass retained on the sieve /100

= 269.2 / 100

= 2.69

Sieve Size	Mass retained (g)	Cumulative mass Retained (g)	Cumulative mass retained (%)	Mass passing(%)
4.75 mm	00	00	00	100
2.36 mm	74	74	7.4	92.4
1.18 mm	268	342	34.2	65.8
600 µ	194	536	53.6	46.4
300 µ	266	802	80.2	19.8
150 µ	140	942	94.2	5.8
			Σ =269.2	

Table 4. Physical properties of fine aggregate

TESTING OF FINEAGGREGATE

Aggregate is tested in laboratory and is as follows;

A. Specific gravity
B. Moisture content
C. Aggregate impact value
D. Aggregate crushing value
E. Elongation index
F. Flakiness index

A. Determination of specific gravity of coarse aggregate

Specific gravity= D/ (D-(A-B))

= 745/ (745-(3236-2750))

= 2.822

Average Specific gravity will be taken as 2.822 for 12.5 mm & 2.912 for 20 mm aggregate.

B. Determination of water absorption of coarse aggregate

Moisture content = [(C-D)/C]*100

= [(750-743.5)/750]*100

= 0.86%

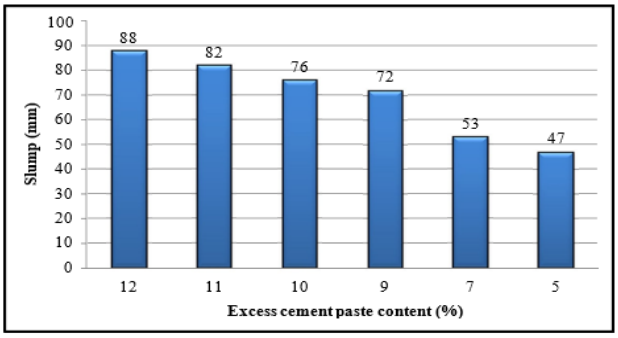
The free moisture content in coarse aggregate is 0.86%

III. RESULTS AND DISCUSSION

For checking workability of concrete slump cone method is used. Table shows the results of workability of concrete with Excess cement paste content (%).

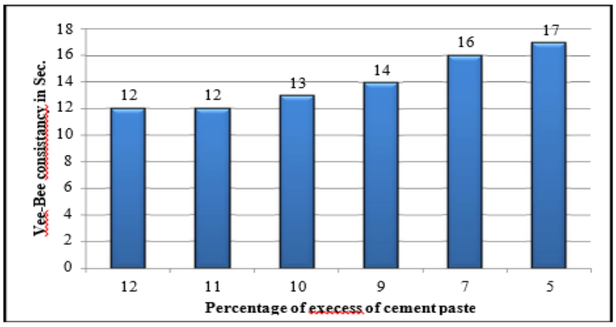
Sr. No.	Excess cement paste Content (%)	Slump (mm)
1	12	88
2	11	82
3	10	76
4	9	72
5	7	53
6	5	47

Table 5. Experimental test results for workability of concrete (Slump-cone)



Graph 1. Workability of concrete (Slump-cone)

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.



Graph 2. Workability of concrete (Vee-bee consistency)

Figure 3. Vee-bee consistometer test

The compression strength test and split tensile strength was performed on standard compression testing machine of 1000 kNcapacity, 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, 24.57N/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 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 1.67 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.

IV. CONCLUSIONS

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

- In packing density method the fine aggregate particle required 5.47% more as compared to the IS code method i.e. in packing density method 773.07 kg/m^3 and in IS code method 733 kg/m^3 . In packing density method the 12.5 mm size aggregate required 42.97% less as compared to IS code method and in packing density method the 20 mm size aggregate required 33.07% more as compared to IS code method.
- As the bulk density increases the packing density also increases and voids ratio deceases. For 60:40 coarse aggregate to fine aggregate proportion the maximum bulk density of aggregate is 1.987 g/cm^3 for same proportion the packing density is 0.715 g/cm^3 and voids ratio 28.57%. Therefore, instead of single size aggregate if we used different size aggregate results in more workability, strength, and overall performance of concrete and reduce the permeability, porosity.
- As the percentage of excess cement paste was increase the compressive strength also increases, for 9% excess of cement paste gives the 29.95 N/mm^2 and split tensile strength 4.03 N/mm^2. 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.

- 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 MPastrength was observed for 5%, 7%, 9%, 10%, 11% and 12% respectively.

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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 satisfactoryresults.
- The flexural strength of various percentage of excess of cement paste of concrete 3.52 3.82, 4.19, 4.23, 4.52 and 4.69 MPa at 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 satisfactoryresults.
- Use of phenolphthalein indicator changed the colour of harden concrete to pink which indicate that concrete was not affected by atmospheric carbondioxide.
- Velocity of an ultrasonic pulse passing through the concrete is more than 3.5 km/second which suggest that concrete quality is good. Due to good filling effect voids from the concrete reduces which increases velocity of ultrasonic pulse through concrete.

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