

Optimization of Aggregate Gradation and its effects on properties of normal strength concrete(M20)

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Abstract - Aggregate as the main constituent of concrete about 70.0% to 80.0 % occupy the total volume of the concrete. They highly affect the both fresh and hardened concrete properties of the concrete. By using the optimization techniques such as Talbot's grading curve or Power curve, Coarseness factor chart and Fineness modulus. The cement content can be reduced, it gives the dense arrangement and improve the properties of the concrete such as workability, durability, compressive strength, etc., from this experimental investigation by using of this optimization of combined aggregate gradation the concrete is prepared by using the different N values are 0.45,0.55,0.65 and 0.75 based on the fineness modulus. In this experimental investigation the mix design is done for Normal strength concrete of 20MPa based on IS 10262:2009 and optimization techniques and prepared specimen. The tests are conducted on fresh and hardened concrete like Slump test, Bulk density of concrete, Compressive strength, Rebound hammer, Ultrasonic pulse velocity and water absorption test. Based on the test results the N value is 0.45 for maximum compressive strength and high workability. Cement content can be reduced up to 15% is possible for 20Mpa normal strength concrete based on the test results.

Key Words: Coarseness factor, Workability factor, Power Curve, Fineness modulus, Slump, Compressive strength

1. INTRODUCTION

In concrete the main constituents are cement, water, aggregates. In cement concrete the aggregates are occupy nearly 70% to 80% of the volume concrete. Normally aggregates is the important constituents in the concrete. It gives as structure of the concrete. The aggregates effects on the properties of fresh and hardened concrete. The aggregates reduce the shrinkage and economy of the concrete. By use of the aggregates their influence on cement concrete properties like strength, durability workability etc. For the achievement of high economy, the aggregates should be made clean, strong, bond strength, shape and texture, specific gravity, bulk density, voids, moisture content, fineness modulus and porosity. The concrete mix preparation made by using of cement, coarse aggregates of two different sizes such as 20mm, 10mm, fine aggregate and potable water used for mixing. The coarse aggregates give the good structural ability to the concrete and fine aggregates fill the gaps between the coarse aggregates, remaining gaps in fine aggregates fills by the cement paste. The used coarse aggregates also increasing the bulk density of the concrete. Normally from production of the concrete, cement is the most expensive material about 55% to 60% of the total cost of the production of concrete material. The paste content only 25% to 35% of the total volume of the concrete. The properties of the concrete can be improved by using well graded aggregates, the well gradation in aggregate can be attained by optimization of aggregate gradation in these views the importance of optimization of the aggregate is arises. The most suitable of aggregates gradation for concrete mix, however will depends up on actual grading, particle sizes and surface texture.

The optimization of aggregate grading is the most advantage technique for economical and technical reasons. By using of this optimization combined gradation of aggregates mixing cement content is reduced up to 10% to 15% of the total volume of the concrete and durability of concrete increased by decreasing the permeability, decreasing drying shrinkage and cracking of the concrete. By increasing the volume of aggregates in total volume of concrete porosity and voids will be decreased it will lead to increasing the structural performance of concrete.

The optimization of the combined aggregate gradation provides the densest arrangement of aggregates in given volume of concrete, it also decreases the volume of cement paste required for sufficient workability.

The optimization results to improve in the workability, finish ability, pumpability and reduced segregation, when compare to the concrete poorly graded aggregate gradation. It also reduced the shrinkage was directly reducing the cement paste in cement concrete with possible of the increasing the aggregate content in concrete and reduced the shrinkage translates into reduced concrete.

2. LITERATURE REVIEW

The Fuller and Thompson has given groundbreaking work on optimization gradation to the concrete on greatest strength and workability. They concluded to attain high density, aggregates should be well graded in sizes and combined with cement paste. An ideal maximum density curve was developed. The maximum density achieved was mainly due to the greatest density of the

aggregates only and not necessarily the greatest density when combined with the cement paste because of the way the cement particles fit into the smaller pore (Fuller and Thompson 1907). The idea that aggregate gradation could be controlled and thus affect concrete properties led to other research and ultimately to specification governing aggregate gradation. Wig et al. suggested that Fuller and Thompson's conclusions could not necessarily be extrapolated to aggregate different from the ones used in the original study. It was shown that the Fuller curve may not always give the maximum strength or maximum density (Wig et al. 1916).

Their work indicated that for a given maximum particle size, D, the equation produces the maximum density when $n=0.5$. It concluded that aggregate so graded would produce concrete mixture that will be harsh and difficult to place and were not really usable (Talbot and Richart 1923). Other authors are in agreement with conclusion, and eventually maximum density proportioning method fell out of favor (McMillian 1929; Walh 1933; Besson 1935; Blanks et al 1940; Frost 1967)

Shilstone in 1970, found several factors on concrete properties depends on the aggregate gradation. A methodology was developed for well graded aggregates which includes the fine aggregate, intermediate aggregate and coarse aggregate particle sizes. Coarseness factor chart was developed in 1990, which identifies the individual size percent retained in excessive or in deficient. (Shilstone 1970).

3. PROPERTIES OF MATERIAL AND METHODOLOGY

The physical properties of all the materials used in the present experimental investigation on cement, fine aggregate, coarse aggregate based on the standard experimental procedures as per IS code provisions. The experimental work conducted are Sieve Analysis, Specific gravity, crushing value, impact value, water absorption, shape test (flakiness and elongation), Los-Angeles abrasion, bulk density on coarse aggregate and fine aggregate and bulking of fine aggregate tests. Concrete Mix design was designed using the optimization techniques and IS10262:2009. Three concrete mixes were prepared with three different sands based on the fineness modulus and conducted destructive test for Compressive Strength.

4. MATERIALS

Cement is a good substance which acts as a binding agent for materials like sand, coarse aggregate and water. In this experimental investigation the Ultra Tech cement of PPC cement was used. The coarse aggregate sused are 20 mm and 12.5 mm crushed aggregates. The coarse aggregate was taken from Chandragiri quarry near Chandragiri Kota Chittoor (Dist), Andhra Pradesh. The physical properties of the coarse aggregate are shown Table: 1 The fine aggregates used are river sand which was from Swarnamukhi river banks near Sri Kalahasthi, Chittoor (Dist), Andhra Pradesh. The river sand used are classified into coarse, medium and fine depending upon the grain size. The physical properties of the river sand are shown Table 2. Further, the portable water was used for mixing and curing.

Table: 4.1 Physical Properties of Cement

S.NO	Particulars	Cement
1	Normal Consistency	32 %
2	Fineness of cement	6 %
3	Specific gravity of cement	3.10

Table: 4.2 Physical Properties of Coarse Aggregate

S. No	Particulars	Coarse aggregate
1	Crushing value	24.16%
2	Impact value	16.80%
3	Los angel's abrasion test on coarse aggregate	27.41%
4	Shape test	
	Flakiness index	12.87 %
	Elongation index	12.86 %
5	Bulk density	
	Bulk density of aggregate	14.81 KN/ m ³
6	Specific gravity	2.65
7	Water absorption	0.5%

Table: 4.3 Physical Properties of Sand

S.No	Particulars	Sand
1	Specific gravity	2.66
2	Bulk density	16.35 KN/m ³
3	Water absorption	1.2 %

5. METHODOLOGY

In this experimental investigation are used in the optimization of aggregate gradation such as Talbot's grading curve or power curve, coarseness factor chart and fineness modulus and also IS 10262:2009 prepared six concrete mix designs normal strength concrete of 20 MPa on based on the physical properties of the materials. The six concrete mixes are prepared by using different in N value 0.45,0.55,0.65 and 0.75 are calculated mix proportions. Themix prepared with cement, coarse aggregates, fine aggregates and water. The proportion of the volume of aggregates in concrete (Coarse and Fine) are not fixed based on the Zone confirming. Based on the optimization of combined aggregate gradation technique of power curve fixing the trail proportions to the volume of the concrete. The well grade concrete is prepared based on the coarseness factor chart.

MIX DESIGN

The mix design is designed based on Absolute volume method, the volume of the aggregate proportions is taken by trail, by optimization technique of Power curve. The Table shows the values of proportioning and material test data.

Table 5.1 Mix Design Proportioning

Specifications For Proportioning	
Grade of designation	M20
Type of cement	PPC
Max. size of the aggregate	20 mm
Min. cement content	322 Kg/m ³
Max. cement content	450 Kg/m ³
Max. water cement ratio	0.59
Exposure condition	Severe (for reinforced concrete)
Method of concrete placing	Pumping
Type of the aggregates	Crushed angular aggregates

Table 5.2 Specific gravity and Water absorption values for Aggregates

	Cement	water	Coarse Aggregates	Fine Aggregates
Sp. Gravity	3.1	1	2.65	2.65
Water Absorption			0.50%	1.20%

Table: 5.3 Combined Aggregate Grading Analysis for Aggregate Proportion

(0.167:0.384:0.45) for N = 0.45(0)

S. No	Sieve Size (mm)	Aggregate 1 20 mm	Aggregate 2 10 mm	Aggregate 3 4.75 mm	Combined passing (%)	Combined retaining (%)	Individual retaining (%)	0.45 Power curve	Coarseness factor	Workability factor
1	25	100	100	100	100	0.00	0.00	100	72.63	41.50
2	20	89.25	100	100	98.20	11.80	1.80	86.5		
3	16	36.27	100	100	89.29	10.71	8.91	74.8		
4	12.5	5.42	83.53	100	77.88	22.12	1.41	63.7		
5	10	0.78	32.51	100	57.51	42.49	2.37	55.1		
6	4.75	0	1.39	100	54.72	55.28	12.80	34.0		
7	2.36	0	0.15	92.3	41.40	58.50	3.22	21.6		
8	1.18	0	0.12	76.6	34.44	65.56	7.06	13.5		
9	0.6	0	0	48.1	22.05	77.95	12.39	8.9		
10	0.3	0	0	13.2	5.93	94.07	16.12	5.6		
11	0.15	0	0	2.9	1.30	98.70	4.62	3.6		
Combined Fineness Modulus of CA						5.3				

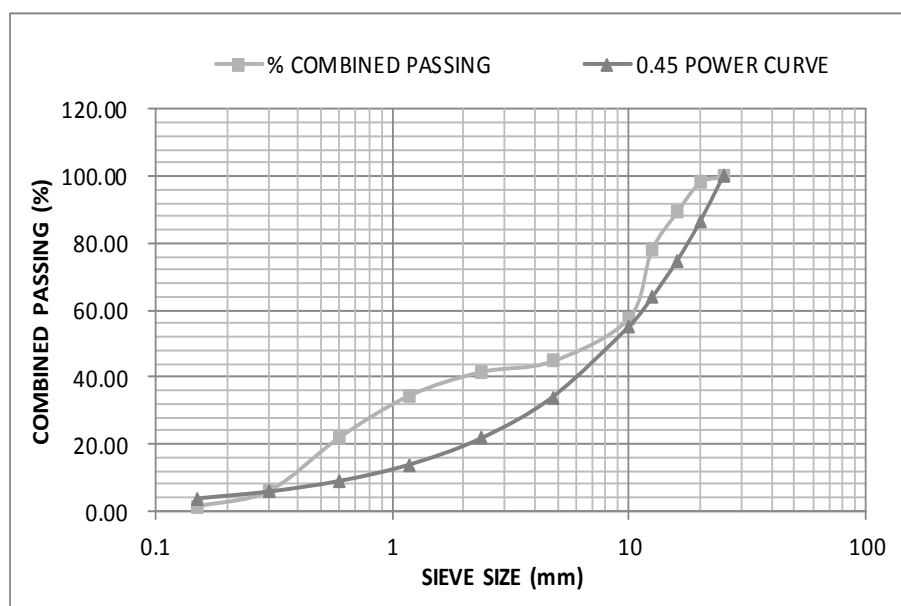


Figure: 5.1 Combined Passing with 0.45 Power Curve for Aggregate

Proportion (0.167:0.384:0.449)

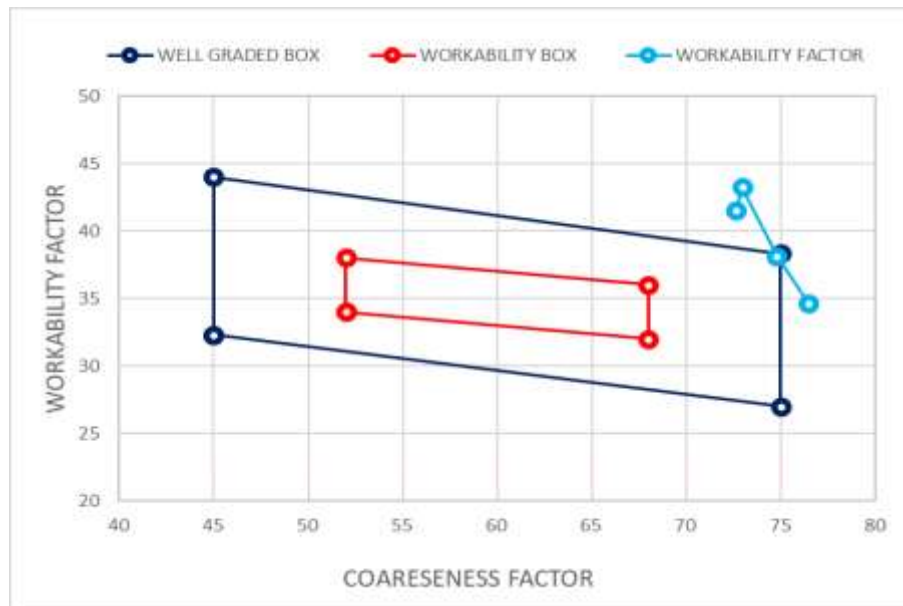


Figure: 5.2 The coarseness Factor Chart for N = 0.45,0.55,0.65,0.75(300).

6. MIX PROPORTIONS

The mix percentages of aggregate are given in Table: 6 and mix proportions of the material are given in Table: 6

Table: 6.1 Mix Proportions with different N values

Mixes	N Values	W/C Ratios	% of Sand	Cement Kg/m ³	Water Kg/m ³	20 mm Aggregate Kg/m ³	10 mm Aggregate Kg/m ³	Fine Aggregate Kg/m ³	Total
M1	0.65	0.59	45%	322.03	190	361.05	655.40	833.55	2362
M2	0.65	0.59	41%	322.03	190	385.95	700.60	763.45	2362
M3	0.65	0.59	37%	322.03	190	410.85	745.80	693.35	2362
M4	0.45	0.59	45%	322.03	190	308.95	710.40	830.65	2362
M5	0.55	0.59	47%	322.03	190	320.85	663.40	865.75	2362
M6	0.75	0.59	37%	322.03	190	454.15	703.70	692.15	2362

7. TESTS CONDUCTED

In this experiment we study the concrete prepared by different N values 0.65, 0.45, 0.55 and 0.75. The different sand percentages are 45%, 41%, 37%, 45%, 47% and 37% for all the six mixes of the concrete but different N values are taken 0.65, 0.45, 0.55 and 0.75. The N value 0.65 are different ratios of the increases the sand improves good workability of the concrete. The sand taken 200, 300 and 400 kg's are added to the mix because the workability can be improved this N values 0.65 and the remaining N values are 0.55, 0.75 are sand added only 300 kgs and can be improve the good workability of the concrete. The N values 0.45 are not added to the increase of the sand but its standard values. In this experimental work the tests may be conducted slump test, bulk density of concrete, destructive and non-destructive tests. The destructive test is conducted by compressive strength on prepared by concrete by using the standard cubes of a dimensions are 15 cm × 15 cm × 15 cm and the volume of the cube is 3375 cm³ according to IS codes. The nondestructive tests conducted by Rebound hammer and ultrasonic pulse velocity, water absorption on cubes.

8. RESULTS AND DISCUSSIONS

The tests results and the test conducted on fresh concrete and hardened concrete. The tests conducted on fresh concrete are slump test and bulk density of concrete and the tests conducted on hardened concrete are destructive test and

nondestructive tests, such as Rebound hammer, compressive strength, ultrasonic pulse velocity, water absorption tests are respectively.

8.1 SLUMP TEST

In this experimental to study the slump test on conducted for fresh concrete by using the slump cone for all the six concrete mixes. The respective values of the slump with percentages of the sand are 45%, 41%, 37%, 45%, 47% and 37% for all the six mixes of the concrete but different N values are taken 0.65, 0.45, 0.55 and 0.75.

The N value 0.65 are different ratios of the increases the sand can be improve good workability of the concrete. The sand taken 200, 300 and 400 kg's are added to the mix because the workability can be improved this N values 0.65 and the remaining N values are 0.55, 0.75 are sand added only 300 kg's and can be improve the good workability of the concrete. The N values 0.45 are not added to the increase of the sand but its standard values.

Table: 8.1 Slump test for different N values

S.No	N Values	Sand (%)	Slump(mm)
1	0.45(0)	45.00	25
2	0.65(200)	37.47	190
3	0.65(300)	41.26	150
4	0.65(400)	45.00	110

Table: 8.2 Slump test for different N values

S.No	N Values	Sand (%)	Slump(mm)
1	0.45(0)	45.00	25
2	0.55(300)	46.8	15
3	0.65(300)	41.26	150
4	0.75(300)	37.47	130

8.2 BULK DENSITY OF CONCRETE

In this experiment we study about bulk density of the concrete test conducted for fresh concrete by using the 3 lit of cylinder for all the six concrete mixes. The Table: 8.3 and Table: 8.4, shows the respective values of the bulk density of the concrete.

Table: 8.3 Bulk density of concrete for Different N values

SNo	N Values	Sand (%)	Bulk Density(KG/lit)
1	0.45(0)	45.00	2.587
2	0.65(200)	37.47	2.608
3	0.65(300)	41.26	2.559
4	0.65(400)	45.00	2.419

Table: 8.4 Bulk density of concrete for Different N values

SNo	N Values	Sand (%)	Bulk Density(KG/lit)
1	0.45(0)	45.00	2.587
2	0.55(300)	46.8	2.563
3	0.65(300)	41.26	2.559
4	0.75(300)	37.47	2.568

8.3 COMPRESSIVE STRENGTH

In this experiment we study about the compressive strength test conducted for hardened concrete on the cubes by using the compressive machine of 2000 KN. The cubes are prepared based on the mix design and the test is conducted under curing period of 7 days and 28 days test on cubes.

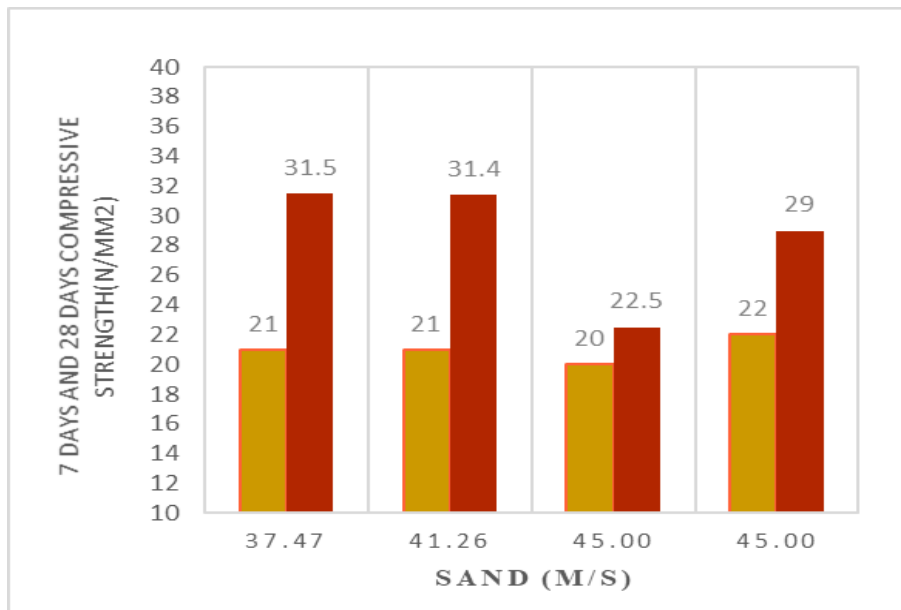


Figure: 8.1 combined values for 7 Days and 28 Days Compressive Strength for different N value are 0.65 (37.74,41.26 and 45.00) and 0.45(0)

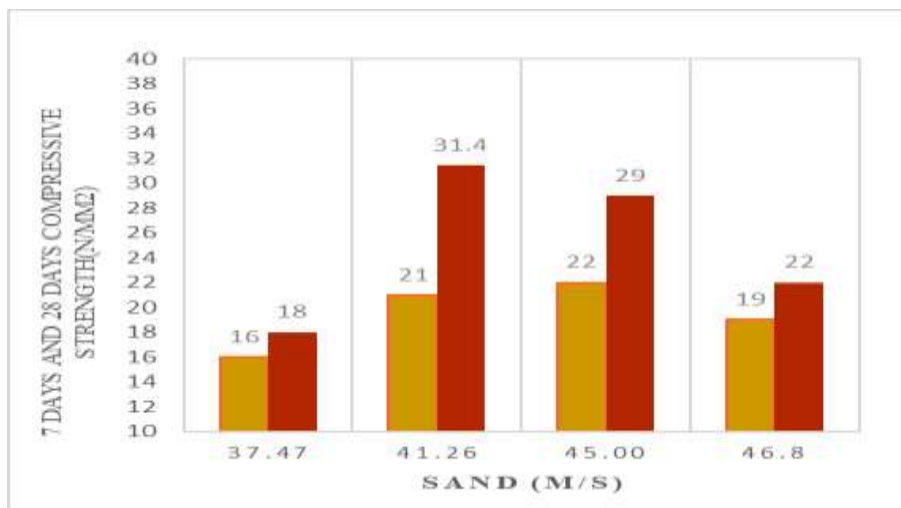


Figure: 8.2 .combined values for 7 Days and 28 Days Compressive Strength for different N value are 0.75(37.47),0.65(41.26),0.55(46.8) and 0.45(45.00)

8.4 REBOUND HAMMER

Rebound hammer is the one of the nondestructive tests on the hardened concrete. In this experimental to be study on the test is conducted on a specimen with a curing period of 7 days and 28 days for all the six mixes by using the rebound hammer.

Table: 8.5 Combined values of Rebound Hammer Numbers for 7 Days and 28 Days

Compressive Strength with Different Percentage of Sand

SNo	N Values	Sand (%)	7 Days Rebound Hammer	28 Days Rebound Hammer
1	0.45(0)	45.00	20.4	27.0
2	0.65(200)	37.47	24.0	26.0
3	0.65(300)	41.26	25.4	28.9
1	0.65(400)	45.00	22.1	21.9

Table: 8.6 Combined values of Rebound Hammer Numbers for 7 Days and 28 Days

Compressive Strength with Different Percentage of Sand

SNo	N Values	Sand (%)	7 Days Rebound Hammer	28 Days Rebound Hammer
1	0.45(0)	45.00	20.4	27.0
2	0.55(300)	46.8	23.8	25.1
3	0.65(300)	41.26	25.4	28.9
4	0.75(300)	37.47	23.78	27.3

8.5 ULTRASONIC PULSE VELOCITY

Ultrasonic pulse velocity is the one of the nondestructive tests on the hardened concrete. In this experimental to be study on the test is conducted on the specimens with a curing period of 7 day and 28 days for all the six mixes.

Table: 8.7 Ultrasonic Pulse Velocities for 7 Days and 28 Days Compressive Strengths with Different N Values

SNo	N Values	Sand (%)	7 Days Compressive strength(N/mm ²)	7 Days UPV (m/s)	28 Days Compressive strength(N/mm ²)	28 Days UPV (m/s)
1	0.45(0)	45.00	22	4392	29	4702
2	0.65(200)	37.47	21	4286	31.5	4725
3	0.65(300)	41.26	21	4273	31.4	4703
4	0.65(400)	45.00	20	4316	22.5	4634

Table: 8.8 Ultrasonic Pulse Velocities for 7 Days and 28 Days Compressive Strengths with Different N Values

SNo	N Values	Sand (%)	7 Days Compressive strength(N/mm ²)	7 Days UPV (m/s)	28 Days Compressive strength(N/mm ²)	28 Days UPV (m/s)
1	0.45(0)	45.00	22	4392	29	4702
2	0.55(300)	46.8	19	4209	22	4616
3	0.65(300)	41.26	21	4273	31.4	4703
4	0.75(300)	37.47	16	4209	18	4583

8.6 WATER ABSORPTION TEST

The water absorption test can be conducted on the specimens with a curing period of 7 day and 28 days for all the six mixes. The experimentally to be study the normal strength of the concrete cubes are prepared all six mixes in the test are conducted to the water absorption after the 28 days of curing period of concrete cubes.

Table: 8.9 Water absorption for after 28 Days with different N Values

SNo	N Values	Sand (%)	After 28 Days water absorption (%)
1	0.45(0)	45.00	1.88
2	0.65(200)	37.47	1.71
3	0.65(300)	41.26	1.85
4	0.65(400)	45.00	1.98

Table: 8.10 Water absorption for after 28 Days with different N Values

SNo	N Values	Sand (%)	After 28 Days water absorption (%)
1	0.45(0)	45.00	1.88
2	0.55(300)	46.80	2.05
3	0.65(300)	41.26	1.85
4	0.75(300)	37.47	0.46

9. CONCLUSIONS

The following conclusions are drawn based on the results obtained from the tests.

1. Based on the test results the compressive strength gained more than the target strength of the concrete for different fineness modulus of the sands and different n values like 0.65, 0.45, 0.55 and 0.75.
2. The n value 0.65 of the compressive strength for 5.3 fineness modulus and percentages of 45% of sand are 22.5 N/mm² respectively.
3. The n value 0.65 of the compressive strength for 5.5 fineness modulus and percentages of 41% of sand are 31.4 N/mm² respectively.
4. The n value 0.65 of the compressive strength for 5.7 fineness modulus and percentages of 37% of sand are 31.5 N/mm² respectively.
5. The n value 0.45 of the compressive strength for 5.3 fineness modulus and percentages of 45% of sand are 29 N/mm² respectively.
6. The n value 0.55 of the compressive strength for 5.2 fineness modulus and percentages of 47% of sand are 22 N/mm² respectively.
7. The n value 0.75 of the compressive strength for 5.7 fineness modulus and percentages of 47% of sand are 20.6 N/mm² respectively.
8. The maximum compressive strength, Slump, Bulk density, Rebound hammer number, water absorption and UPV are obtained with 45 % of the Sands for n value 0.65.
9. The maximum compressive strength, Slump, Bulk density, Rebound hammer number, water absorption and UPV are obtained with 41 % of the Sands for n value 0.65.
10. The maximum compressive strength, Slump, Bulk density, Rebound hammer number, water absorption and UPV are obtained with 37 % of the Sands for n value 0.65.
11. The maximum compressive strength, Slump, Bulk density, Rebound hammer number, water absorption and UPV are obtained with 45 % of the Sands for n value 0.45.
12. The maximum compressive strength, Slump, Bulk density, Rebound hammer number, water absorption and UPV are obtained with 47 % of the Sands for n value 0.55.
13. The maximum compressive strength, Slump, Bulk density, Rebound hammer number, water absorption and UPV are obtained with 37 % of the Sands for n value 0.75.

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