

Requirement of Different Grades of Cement for Nominal and Design Mix M20 Grade Concrete

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ABSTRACT: Concrete is one of the most common construction material generally produced by using locally available ingredients with binding material. Ingredients are used as per known or designed proportion, termed as nominal or design mix concrete respectively. In nominal mix concrete, properties of ingredients are not considered and same is limited up-to M20 grade only. For present work, 43 and 53 grade ordinary Portland cement (OPC) was used in nominal and design mixed M20 grade concrete and required cement content was compared. Using 40 mm size graded angular aggregate and zone II river sand, nominal mix concrete (1.0 : 1.5 : 3.0) was prepared. Density and cement content of fresh concrete were 23.45 kN/m³ and 390.83 kg/m³ respectively. Using same ingredients, nominal mix concrete was prepared using ratio given in IS 456 : 2000 table – 9 and the cement content was found 366.30 kg/m³. Nominal mix M20 grade fresh concrete was again prepared by using 20 mm size angular coarse aggregate and cement content was obtained as 366.52 kg/m³.

Design mix proportions were calculated by using 43 and 53 grade OPC with 40 mm size graded angular aggregate and zone II river sand. Cement content was found 49.10 kg/m³ less for 53 grade ordinary Portland cement and cement saving was 4.08% over 43 grade cement. In design mix M20 grade concrete, with 40 mm CA, zone III river sand and 43 grade OPC, cement content was 347.37 kg/m³ and in comparison to nominal mix concrete cement saving was 38.46 kg/m³. In M20 grade design mix concrete with 20 mm CA, 43 grade OPC, and zone II river sand, cement content was 383.51 kg/m³ against 366.52 kg/m³ required for nominal mix concrete proportioned by ratio suggested by IS 456 : 2000. aggregate, river sand, cement saving.

KEYWORDS: Nominal and design mix, OPC, angular

I. INTRODUCTION

In concrete, cement is the most common binding material and cement mortar acts as a suspension media for aggregates. For higher grade concrete, cement content increases and maximum use of OPC is limited to 450 kg/m³ of concrete (IS 456: 2000, 8.2.4.2). For a particular grade of concrete, cement content varies with respect to its type, w/c ratio, water content, properties of aggregates such as mineralogical composition, parent rock, shape, size, grading, zoning, fineness modulus, angularity number, surface features, specific gravity etc. Nominal mix concrete is permitted for M20 and lower grade concrete and from durability aspect, use of M20 grade reinforced concrete is limited in mild exposure condition with maximum free w/c 0.55 and minimum cement content 300 kg/m³ of concrete^[1]. Maximum free w/c is affected by grade of concrete, type of coarse aggregate, workability requirement, exposure condition and use of mineral /chemical admixtures etc. For nominal mix M20 grade concrete proportion of the ingredient in field is taken as cement (1.0) : FA (1.5) : CA (3.0) with suitable water content to meet the workability requirement. As per Table-9, of IS 456: 2000, in nominal mix M20 grade concrete 50 kg cement and 30 litre water are to be mixed with 250 kg aggregates. The proportion of CA and FA varies between 1:1.5 to 1:2.5 with respect to coarse aggregate size and sand zoning. Effects of other properties like specific gravity of ingredients, their types, shapes,

surface textures etc. are not taken into consideration. In design mix concrete, cement content reduces with the use of higher grade of cement.^[2,3] For meeting workability requirements proportion of ingredient may need appropriate adjustment which in turn affects w/c and cement content also. Within codal provisions, w/c is also selected by experience or data available in laboratory.

Properties of hardened concrete depend upon properties of ingredients, their proportion, quality control, functioning machineries, skill of manpower and their involvement, effectiveness of production stages etc. These factors result uncertainty in uniformity of samples and for the same, failure of 5% samples below required strength is acceptable. On testing, samples have different strength within acceptable range and for the same assumed or calculated standard deviation is used in calculating target strength.

Accordingly, for a given characteristics compressive strength (f_{ck}), concrete mix is designed for higher target strength (f_t) including the concept of standard deviation and percentage failure of samples. As per provisions of IS 456 : 2000 and IS 10262 : 2009^[4] proportion of ingredients for design mix concrete is calculated. Proportion of trial mix-I is calculated and fresh concrete is checked for workability. On satisfying the workability requirement, it is termed as trial mix-II otherwise recalculated with suitable adjustment(s) and same is designated as trial mix-II. As the various properties of ingredients are not considered in mix design calculation, trial mix-III and trial mix-IV are calculated by keeping water content as constant and changing w/c by $\pm 10\%$. Cubes are casted from trial mixes and after 28 days' curing, samples of all three trial mixes are tested for compressive strength. Test results satisfying acceptance criteria, are used for finding average strength for all three trial mixes. Graph plot between w/c and average compressive strength of trial mixes is used for calculating final w/c required for target strength. By using the same w/c, final mix proportion is calculated and designated as the design mix concrete of requisite grade.

II. MATERIALS AND METHODOLOGY

For this study, 43 grade and 53 grade ordinary Portland cement were used. Graded angular aggregates of nominal size 40 mm and 20 mm; and river sand

confirming to zone II and zone III were used. Specific gravity of CA and FA was 2.6 and 2.65 respectively. Mix proportion was calculated on saturated surface dry (SSD) condition of aggregates. Workability of fresh concrete was selected as 25-50 mm slump value for normal concreting in mild exposure condition. Yield of nominal mix M20 grade concrete was determined by specific gravity method and the same was verified by density of fresh concrete. Cement content was calculated from verified yield of concrete. Based on codal provisions of IS 456 : 2000 and IS 10262 : 2009, design mix proportions for M20 grade concrete for different ingredient compositions were calculated.

III. NOMINAL MIX M20 GRADE CONCRETE

In nominal mix M20 grade concrete, graded angular aggregate of nominal size 40 mm, zone II river sand, 53 grade OPC were used in conventional ratio 1.00 (cement) : 1.5 (sand) : 3.0 (CA). For required workability, w/c was maintained as 0.50. Density and cement content of the fresh concrete were found 23.45 kN/m³ and 390.83 kg/m³ respectively. As per provisions in IS 456 : 2000 Table – 9, for nominal mix M20 grade concrete, selected proportion was 1.00 (zone II river sand) : 2.50 (40 mm graded angular aggregate) and w/c adjusted to 0.50 for required workability. For 50 cement, 250 kg aggregates and 25 litre water, yield of concrete was 136.49 litre and cement content was 366.33 kg/m³ of concrete. Using 20 mm graded angular aggregate in the same nominal mix concrete, cement content was found 366.52 kg/m³ of concrete.

IV. DESIGN MIX M20 GRADE CONCRETE PROPORTION

For design mix M20 grade concrete, trial and final mix proportions were calculated by using graded angular aggregate of nominal size 40 mm, zone II river sand and 43 grade OPC in the following steps:

Calculation of target strength (f_t) for mix proportioning:

This was calculated for characteristic compressive strength at 28 of days (f_{ck}) and standard deviation (s) by the expression

$$f_t = f_{ck} + 1.65*s.$$

From table-1 (IS:10262:2009) value of standard deviation was taken as 4.0 N/mm² and accordingly target strength was to 26.6 N/mm².

Selection of free water cement ratio (w/c) and water content

From table-5 of IS 456: 2000, free w/c for M20 grade concrete in mild exposure condition was selected 0.55. However from experience and data available in laboratory w/c was reduced to 0.50. For saturated surface dry (SSD) aggregates, water content in concrete mix was decided. As per table-2, IS 10262:2009, maximum water content for 40 mm nominal maximum size aggregate with 25 to 50 mm slump was kept as 165 kg/m³ of concrete.

Calculation of cement content

From table-5 and 6 (IS 456:2000) minimum cement content required for durability aspect for mild exposure conditions with 40 mm aggregate was 270 kg/m³. For water content 165 kg/m³ and free water cement ratio 0.50, cement content was 330 kg/m³; higher than the minimum requirement.

Proportion of volume of coarse aggregate and fine aggregate content

From table – 3 (IS 10262:2009) volume of coarse and fine aggregates for 40 mm size coarse aggregate, fine aggregate zone II, and water cement ratio 0.50 was 0.71 and 0.29 respectively.

Calculation of mass of CA and FA

For one m³ of concrete, volume of cement, water and all in aggregate was 0.1048 m³, 0.165 m³ and 0.7302 m³ respectively. For specific gravity of CA and FA being 2.6 and 2.65, mass of CA and FA, in 0.7302 m³ volume of total aggregate was 1348.02 kg/ m³ and 561.19 kg/ m³ respectively. Proportion of ingredients, water : cement : sand : coarse aggregate was 0.50 : 1.00 : 1.70 : 4.08 respectively.

Checking for workability

Using ingredients in the above proportion, fresh concrete was prepared and its slump value was found 33 mm. On satisfying workability requirements, it was designated as trail mix II and separate sets of cubes were casted using 43 and 53 grade cement for testing after 28 days curing.

Trial Mix-III & IV and final mix

Using same ingredients, trial mix-III was calculated by maintaining water content as constant and using w/c as 0.55. For one m³ of concrete, mass of water, cement, FA and CA was 165 kg, 300.00 kg, 588.11 kg and 1346.37

respectively. Mass of ingredients for trial mix-IV was also calculated using w/c 0.45 and same was given in Table-1. Cubes were casted for trail mix-III and trial mix IV for both grades of cement. After 28 days curing, samples of three trial mixes with 43 grade OPC were tested. Using average of acceptable four test results of all three trial mixes, a graph was plotted (Fig.-1) and from the same graph w/c for target strength (f_t) was calculated as 0.49. Using same w/c ratio final mix proportion was calculated and mass cement, sand and coarse aggregate for one m³ of concrete was 336.73 kg, 555.69 kg and 1347.86 kg respectively. Similarly proportion of final mix was calculated using 53 grade OPC with same ingredients and cement content was 323.53 kg/m³ concrete. Trail mixes and final mixes were calculated using 20 mm graded angular aggregate, zone II sand with 43 grade and 53 grade OPC and required ingredients for one m³ of concrete and their proportions were given in table – 1. Using zone III river sand, 20 mm and 40 mm graded angular aggregates with 43 grade and 53 grade OPC, trial and final mix proportions were calculated and given in Table – 1.

V. RESULTS AND DISCUSSION

Cement content in nominal mix concrete with conventional ratio was highest among all mixes. For nominal mix concrete proportioned by codal ratio, cement content was approximately same for both sizes of coarse aggregate. In design mix concrete with 53 grade OPC, 40 mm graded angular aggregate and zone II river sand, cement content was minimum as 323.53 kg/m³ of concrete, which resulted maximum cement saving (63.97 kg/m³ of concrete) over nominal mix concrete. For design mix concrete maximum cement content (387.50 kg/m³) was found in concrete with ingredients 43 grade OPC, 20 mm sized CA and zone III river sand. For design mix concrete with materials; 40 mm size CA, 43 grade OPC and zone II river sand; and same CA with 53 grade OPC and zone III sand, cement content was same (336.73kg/m³). In design mix concrete with 20 mm sized CA, 43 grade OPC and zone II sand, cement content was found 16.99 kg higher than nominal mix as per codal ratio. Design mix concrete with 20 mm CA, zone III sand and 43 grade OPC resulted 5.79% higher cement content over nominal mix concrete as per codal provisions. Cement content in nominal mix concrete with conventional ratio was 7.32 kg/m³ and 3.33 kg/m³ higher than the same for design mix concrete with 20 mm CA, 43 grade OPC and; zone II

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and zone III sand respectively. As the cement content in nominal mix concrete with codal provisions was less than the design mix M20 concrete, use of design mix M20 grade concrete was found more appropriate for lower size aggregates.

- 4.
5. IS 10262 : 2009, "Indian standard concrete mix proportioning – guidelines", Bureau of Indian Standard, New Delhi-02.
6. IS 383 : 1983/1997, "Coarse and fine aggregate from natural sources for concrete", Bureau of Indian Standard, New Delhi-02.

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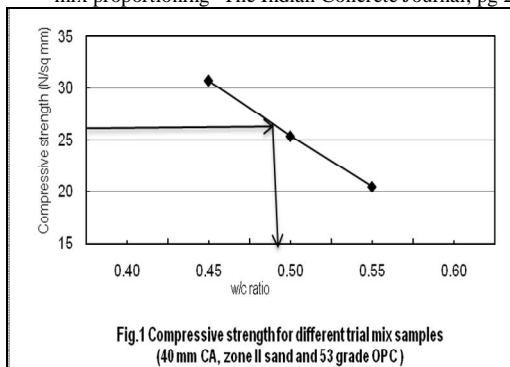


Table - 1. Ingredients and proportions of nominal and design mix M20 grade concrete

Aggregates	Type of mix	Materials	Water (kg)	Cement (kg)	Sand (kg)	Coarse agg (kg)
CA: 40 mm angular and FA: zone II sand	Conventional nominal mix	per cu-m	195.413	390.33	386.243	1172.490
	Proportions		0.30	1.00	1.30	3.00
CA: 40 mm angular and FA: zone II sand	Nominal mix as per IS 456 : 2000	per cu-m	183.130	366.30	323.283	1308.214
	Proportions		0.30	1.00	1.43	3.37
CA: 20 mm angular and FA: Zone II Sand	Nominal mix as per IS 456 : 2000	per cu-m	183.28	366.33	610.838	1221.717
	Proportions		0.30	1.00	1.87	3.33
M20 design mix concrete (CA: 40 mm angular and FA: zone II sand)	Total Mixes (TM)	per cu-m	165.00	330.00	361.19	1348.02
	TM II	Proportions	0.30	1.00	1.70	4.08
	TM III	per cu-m	165.00	300.00	388.11	1346.37
	Proportions		0.33	1.00	1.96	4.49
	TM IV	per cu-m	165.00	366.67	333.20	1345.22
	Proportions		0.45	1.00	1.45	3.67
	Final mix (43 grade OPC)	per cu-m	165.00	336.73	353.69	1347.36
	Proportions		0.49	1.00	1.65	4.00
	Final mix (53 grade OPC)	per cu-m	165.00	323.33	366.63	1348.00
	Proportions		0.31	1.00	1.73	4.17
M20 design mix concrete (CA: 20 mm angular graded and FA: zone II sand)	TM II	per cu-m	186	372.00	700.78	1121.80
	Proportions		0.30	1.00	1.83	3.02
	TM III	per cu-m	186	338.18	730.31	1120.73
	Proportions		0.33	1.00	2.16	3.31
	TM IV	per cu-m	186	413.33	669.47	1118.40
	Proportions		0.45	1.00	1.82	2.71
	Final mix (43 grade OPC)	per cu-m	186.00	383.31	691.59	1121.31
	Proportions		0.435	1.00	1.80	2.92
	Final mix (53 grade OPC)	per cu-m	186.00	364.71	706.31	1121.90
	Proportions		0.310	1.00	1.94	3.08
M20 design mix concrete (CA: 40 mm angular graded and FA: zone III sand)	TM II	per cu-m	165.00	330.00	322.49	1385.99
	Proportions		0.30	1.00	1.53	4.20
	TM III	per cu-m	165.00	300.00	348.00	1384.83
	Proportions		0.33	1.00	1.83	4.62
	TM IV	per cu-m	165.00	366.67	495.11	1382.38
	Proportions		0.45	1.00	1.35	3.77
	Final mix (43 grade OPC)	per cu-m	165.00	347.37	508.94	1384.95
	Proportions		0.48	1.00	1.47	3.99
	Final mix (53 grade OPC)	per cu-m	165	336.73	517.10	1385.72
	Proportions		0.49	1.00	1.54	4.12
M20 design mix concrete (CA: 20 mm angular graded and FA: zone III sand)	TM II	per cu-m	186.00	372.00	663.89	1157.99
	Proportions		0.30	1.00	1.73	3.11
	TM III	per cu-m	186.00	338.18	692.36	1157.48
	Proportions		0.33	1.00	2.03	3.42
	TM IV	per cu-m	186.00	413.33	633.23	1153.90
	Proportions		0.45	1.00	1.53	2.79
	Final mix (43 grade OPC)	per cu-m	186.00	387.50	651.37	1156.93
	Proportions		0.480	1.00	1.68	2.99
	Final mix (53 grade OPC)	per cu-m	186	368.32	666.36	1158.12
	Proportions		0.305	1.00	1.81	3.14