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A Comparison Between The Old And New Indian Codes For Concrete Mix Design

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----------ABSTRACT ----------
Mix design is the process of determining the appropriate proportions of cement, fine aggregate, coarse aggregate, water and admixtures if any which will satisfy the requirements of compressive strength, workability and durability. Many established methods are reported in the literature for the design of concrete mixes. IS 10262 - 1982 is the relevant code for the design of Concrete mixes. Bureau of Indian Standards has revised this code in the year 2009. The parameters to be considered in the mix design based on the guidelines given in IS 10262 - 2009 are maximum size of aggregates, type of cement, grade of concrete, zone of sand, specific gravity of fine aggregate, specific gravity of coarse aggregate, specific gravity of cement, workability, durability and quality control. An attempt has been made to determine the effect of revision on the proportioning concrete the mixes. Concrete of grades M_{20}, M_{25}, M_{30}, M_{35}, M_{40} were designed by varying all the parameters as per the old code and new codes. For each grade of concrete, four slump values (25mm,50mm, 75mm and 125mm), four zones of sand (zone 1, zone 2, zone 3, zone 4, two grades of cement (43 grade and 53 grade), five values of specific gravity of fine aggregate (2.2, 2.4, 2.6, 2.8 ,3), four values of specific gravity of coarse aggregate (2.6, 2.7, 2.8, 2.9) and three sizes of aggregates (10mm,20mm,40mm) were considered. Nineteen thousand two hundred mixes were designed. The materials requirements for each grade of concrete were compared and the results are presented in the paper.

Keywords*-compressive strength, workability, durability*

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I. INTRODUCTION

Modern concrete mix designs can be complex. The choice of a concrete mix depends on the need of the project both in terms of strength and appearance and in relation to local legislation and building codes. The design begins by determining the requirements of the concrete. These requirements take into consideration the weather conditions that the concrete will be exposed to in service and the required design strength. Many factors need to be taken into account while designing concrete mixes .Grade of cement, Grade of concrete, size of aggregate slump value, exposure conditions and degree of quality control are some of the key factors considered in concrete mix design. After selecting appropriate values for these key factors mixes will be designed either with admixtures or without admixtures Concrete mixes can also be designed using software programs. Such software provides the user an opportunity to select their preferred method of mix design and enter the material data to arrive at proper mix designs.

1.1. LITERATURE REVIEW

- Prince Arulraj.G and velusamy.K (2009) carried out a parametric study on concrete mix design as per IS: 10262-1982. They reported that there will be a saving of about 10 % in the cement content. If 20 mm aggregate is used instead of 10mm if 40 mm aggregate is used instead of 20mm, the saving in the cement content will be around 11 %.
- Ashraf W.B and Noor M.A (2011) made a parametric study for assessing the effects of coarseness factor and workability factor on compressive strength of concrete. They reported that there might me relationship between the coarseness factor and the workability factor with compressive strength.
- Wadud .Z and Ahmad. S made a parametric study on ACI method of concrete mix design. They reported that an inter particle void which is a function of a coarse aggregate grading is an important parameter in the mix design. They also reported that the ACI method has no adequate parameter to take this aspect into

account and this could be the reason for the failure of mixes designed by ACI method to gain the required strength when coarse aggregate of higher voids are used.

II. COMPARISION BETWEEN IS10262-1982 & IS10262- 2009

The changes made in the new code can be broadly classified in to two categories namely the major changes and the minor changes. The minor changes are the change in the title of the code, relationship between w/c ratio and compressive strength. The major changes are estimation of the volume of coarse aggregate based on the zone number of fine aggregate, standard deviation values, measure of workability, inclusion of chemical and mineral admixtures.

A. Title of the Code

The title of the old code is "IS: 10262-1982recommended guidelines for concrete mix design." This has been modified as "IS: 10262-2009Concrete Mix proportioning Guidelines." The modified title of the code makes the designer feel little flexible.

B. Water-Cement Ratio

The old version suggests that selection of preliminary free w/c ratio may be obtained from established relationships presented in form of graph as generalized w/c ratio curves for different grades of cement. Accordingly six ready reference curves namely A to F for a wide range of cement strengths from 32.5N/mm^2 to 62.5N/mm^2 were used. This selected w/c ratio is to be checked against limiting w/c ratio for durability.
The revised version encourages establishing the relationships for actually used materials based on experiments or experience.

C. Estimation of Coarse & Fine Aggregate

The 1982 publication specifies ratio of fine aggregates to coarse aggregates for all zones of fine aggregate from which coarse aggregate content can be derived. The percentage contents of fine aggregate are given in Table 1 and Table 2

Table 1 Approximate Sand and Water Contents per Cubic Metre of Concrete for Grades up to M35

NOMINAL MAXIMUM SIZE OF AGGREGATE mm	WATER CONTENT PER CUBIC METRE OF CONCRETE kg	SAND AS PERCENT OF TOTAL AGGREGATE BY ABSOLUTE VOLUME
10	208	40
20	186	35
40	165	30

Table 2 Approximate Sand and Water Contents per Cubic Meter of Concrete for Grades above M35

NOMINAL MAXIMUM SIZE OF AGGREGATE mm	WATER CONTENT PER CUBIC METER OF CONCRETE kg	SAND AS PERCENT OF TOTAL AGGREGATE BY ABSOLUTE VOLUME
10	200	28
20	180	25

In revised code, the volume of coarse aggregates per unit volume of total aggregates for different zones of fine aggregates and different maximum nominal size of aggregates has been tabulated from which the fine aggregates content has to be derived. The volumes of C.A per unit volume of total aggregate are given in Table 3

Table 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate

S.NO	NOMINAL MAXIMUM SIZE OF AGGREGATE mm	VOLUME OF COARSE AGGREGATE PER UNIT VOLUME OF TOTAL AGGREGATE FOR DIFFERENT ZONES OF FINE AGGREGATE			
		ZONE IV	ZONE III	ZONE II	ZONE I
i	10	0.50	0.48	0.46	0.44
ii	20	0.66	0.64	0.62	0.60
iii	40	0.75	0.73	0.71	0.69

D. Standard Deviation

Standard deviation values are given in the old code based on the degree of quality control and grade of concrete. However in the new code, the values are based on the grade of concrete alone. The comparison between the standard deviation values between the old and the new codes are given in Table 4.

Table 4 Comparison of the Standard Deviation Values between the Old & New Codes

GRADE OF CONCRETE	STANDARD DEVIATIONS AS PER IS : 10262-1982 N/mm^2			STANDARD DEVIATIONS AS PER IS :10262-2009 N/mm^2
	VERY GOOD	GOOD	FAIR	
M10	2	2.3	3.3	3.5
M15	2.5	3.5	4.5	3.5
M20	3.6	4.6	5.6	4
M25	4.3	5.3	6.3	4
M30	5	6	7	5
M35	5.3	6.3	7.3	5
M40	5.6	6.6	7.6	5
M45	6	7	8	5
M50	6.4	7.4	8.4	5
M55	6.7	7.7	8.7	5
M60	6.8	7.8	8.8	Not given.

From Table 4, it can be seen that there is a large variation in the standard deviation values. Assuming good quality control, it can be seen that the standard deviation values as per the old code is higher than that of the new code for grades higher than M 15. Hence if mixes are designed as per the new code, the cement requirement will be less.

In the view of these changes, an attempt has been made to carry out a parametric study on the old code and new codes respectively

III. PARAMERTIC STUDY

3.1 Effect Of Grade Of Concrete On Requirement Of Cement,Fine Aggregate And Coarse Aggregate

Grade of concrete is an important parameter in the mix design process. Grade of concrete decides the quantity of cement, coarse aggregate, fine aggregate and water. In order to determine the influence of grade of concrete on the requirements of materials, the material requirements were worked out as per the old and new codes for the following by varying all the parameters

The requirement of cement needed for $1m^3$ of concrete with respect to grade of concrete is given in Table 5 for the following conditions Grade of cement 53,compaction factor 0.9,specific gravity of fine aggregate is 2.6,specific gravity of coarse aggregate is 2.6,zone no 2,size of aggregate is 10mm.

Table 5 Quantity of Cement Required with Respect to Grade of Concrete

GRADE OF CONCRETE	CEMENT REQUIREMENT AS PER NEW & OLD CODE		% DECREASE
	NEW CODE	OLD CODE	
20	389.53	392.9	0.858
25	428.48	444.9	3.691
30	486.22	501.9	3.124
35	534.2	555	3.75
40	560.9	583.9	3.94

These values are calculated for the following condition. From Table 5, it can be seen that these is a slight reduction in the requirement of cement when the mixes are designed as per the new code. The requirements of fine aggregate with respect to the grade of concrete are given in Table 6.

Table 6 Fine Aggregate Requirement With Respect to Grade of Concrete

GRADE OF CONCRETE	REQUIREMENT OF FINE AGGREGATE AS PER NEW & OLD CODE		% INCREASE
	NEW CODE	OLD CODE	
20	774.7	648.4	19.5
25	777.1	611	27.2
30	764.7	576.1	32.6
35	768.7	547.5	40.4
40	779.33	352.9	120.8

From Table 6, it can be seen that, there is a large variation in the requirement of fine aggregate with respect to the grade of concrete. When mixes are designed by old and new codes the percentage increase is as high as 120 for M40 concrete.

The requirements of coarse aggregate with respect to grade of concrete are given in Table 7

Table 7 Coarse Aggregate Requirement with Respect to Grade of Concrete

GRADE OF CONCRETE	Requirement of C.A per m^3 of Concrete		
	NEW CODE	OLD CODE	% REDUCTION
20	946.8	1018.2	7.01
25	912.227	1012.7	9.92
30	866.99	1000.6	13.35
35	833.41	958.3	13.00
40	822.27	1177.6	30.17

From Table 7, it can be seen that, the requirement of coarse aggregate is less when mixes are designed as per the new code. The reduction increases as the grade of concrete increases. The maximum reduction is around 30 % for M40 concrete

3.2 Effect Of Grade Of Cement On Requirement Of Cement,Fine Aggregate And Coarse Aggregate

The variation in the requirement of 43 grade and 53 grade cement with respect to the grade of concrete is given in Table 8

Table 8 Requirement of Cement with Respect to Grade of Cement

Grade of Concrete	Requirement of Cement per m^3				% saving while using 53 grade cement instead of 43 grade cement	
	Old code 43 grade cement	Old code 53 grade cement	New code 43 grade cement	New code 53 grade cement	old code	New code
20	401.7	351.3	382.6	348.3	12.5	8.96
25	460.0	397.9	423.5	383.1	13.5	9.54
30	516.7	448.8	514.2	434.7	13.1	15.45
35	566.9	496.3	583.0	471.6	12.4	19.1
40	601.2	525	627.	504.	12.	19.7

These requirements were calculated for the following conditions. Compaction factor 0.9, specific gravity of fine aggregate is 2.6, specific gravity of coarse aggregate is 2.6, zone no 2, size of aggregate is 20mm.. The requirement of cement needed for $1m^3$ of concrete with respect to grade of concrete. From Table 8, it can be seen that, the requirement of cement decreases when 53 grade cement is used instead of 43 grade cement. The percentage saving in cement content is almost the same and the saving is around 13 % for all grades of concrete when 53 grade of cement is used for mixes designed as per the old code. The percentage saving in the cement content increases as the grade of concrete increases when mixes are designed as per the new code.

Table 9 Fine Aggregate Requirements with Respect to Grade of Cement

Grade of Concrete	Requirement of Fine Aggregate per m^3 of Concrete				% increase in the requirement of fine aggregate	
	Old code 43 grade cement	Old code 53 grade cement	New code 43 grade cement	New code 53 grade cement	old code	new code
20	559.0	648.4	1106.1	1106.8	15.9	0.06
25	523.2	561.7	1101.7	1107.1	7.3	0.48
30	493.7	529.7	1082.7	1101.4	7.2	1.72
35	470.7	503.9	1060.3	1092.5	7	3.03
40	300.8	327.4	1057.5	1100.2	8.8	4.03

From Table 9, it can be seen that the requirement of fine aggregate increases when 53 grade cement is used for the mixes designed as per the old code. However when mixes are designed as per the new code, there is not much variation in the requirement of fine aggregate when 53 grade cement is used instead of 43 grade cement.

The requirements of coarse aggregate with respect to grades of cement are given in Table 10

Table 10 Coarse Aggregate Requirements with Respect to Grade of Cement

Grade of Concrete	Requirement of Coarse Aggregate per m^3 of Concrete				% increase in the requirement of coarse aggregate	
					old code	new code
	Old code 43 grade cement	Old code 53 grade cement	New code 43 grade cement	New code 53 grade cement		
20	1159.2	1163.2	678.9	707.6	0.34	4.215
25	1146.9	1159.8	643.1	678.5	1.123	5.51
30	1129.6	1149.8	594.6	641.6	1.786	7.89
35	1111.1	1136.4	560.2	615.1	2.27	9.79
40	1268.8	1304.9	542.6	601.7	2.84	10.89

From Table 10, it can be seen that, there is a slight variation in the requirement of coarse aggregate with the respect to the grades of cement when the mixes are designed by old code. The increase in the requirement of coarse aggregate ranges between 0.34 % to 2.84% when 53 grade cement is used instead of 43 grade cement. The increase in the requirement of coarse aggregate increases as the grade of concrete increases in case of mixes designed by new code.

3.3 Effect of Size of Coarse Aggregate

Aggregates are available in different sizes. Normally 40mm, 20mm, 12mm, 10mm, 6mm aggregates are available in the market. Larger sizes aggregates will result in reduction in cement requirement.

In order to understand the effect of size of coarse aggregate on requirement of materials, the requirements were found out for the following conditions and the requirements of cement, fine aggregate and coarse aggregate are given in Table 11, Table 12, Table 13 respectively. 53 grade cement, specific gravity of fine aggregate 2.6, specific gravity of coarse aggregate 2.6

Table 11 Cement Requirement with Respect to Size of Coarse Aggregate

SIZE OF AGG	Requirement of Cement per m^3 of Concrete		% DECREASE
	Old code	New code	
10	392.9	389.53	0.85
20	351.3	348.33	0.84
40	311.7	309	0.86

From the Table 11, it is seen that there the requirement of cement decreases as the size of the aggregate increases for the mixes designed by both old and new codes. The variation between the old and new codes is almost same.

Table 12 Fine aggregate Requirement with respect to Size of Coarse Aggregate

SIZE OF AGG	Requirement of F.A per m^3 of concrete		% increase
	Old code	New code	
10	673.4	740.23	9.92
20	623.1	1070.49	71.8
40	562.2	1294.1	130.18

From Table 12, it can be seen that the requirement of fine aggregate decrease as it size of the aggregate increase for the mixes designed by old code. However for the mixes designed by the new code, the requirement of fine aggregate increases as the of size of aggregate increase. it can also been that there is a large variation in the requirement of fine aggregate between the mixes designed by the old and new codes. The variation in the requirement of fine aggregate for the mixes designed by the old and new codes is as high as 130% for 40 mm aggregate

Table 13 Requirement of coarse aggregate with the Respect to Size of Coarse Aggregate

SIZE OF AGG	Requirement of C.A per m^3 of Concrete		% Decrease
	Old code	New code	
10	993.2	981.23	1.20
20	1136.8	743.9	34.56
40	1286.7	608.99	52.67

From Table 13, it can be seen that the requirement of coarse aggregate increase as it size of the aggregate increase for the mixes designed by old code. However for the mixes designed by the new code, the requirement Of coarse aggregate decreases as the of size of aggregate increase. it can also been that there is a large variation in the requirement of coarse aggregate between the mixes designed by the old and new codes. The variation in the requirement of coarse aggregate for the mixes designed by the old and new codes is as low as 53% for 40 mm aggregate

3.4 Effect Of Slump

Workability of concrete is a composite property. The mixability, placeability, mobility, compactability and finishability are collectively known as workability. A number of tests are available for measuring the workability of concrete, slump test, compacting factor test, Vee Bee consistency test and the flow test are some of the commonly used tests for the measurement of workability. The old code used compaction factor as a measure of workability. However slump test is the easiest test that can be used in the field for the measurement of workability. Hence the new code incorporated slump as a measure of workability instead of compaction factor..In order to understand the effect of slump on requirement of materials, the requirements were found out and the requirement of fine aggregate and coarse aggregate are given in Table 14 and Table 15 respectively.

Table 14 Effect of Slump on Requirement of Fine Aggregate

SLUMP	Requirement of F.A per m^3 of Concrete		% increase in the requirement of F.A
	Old code	New code	
25	604.5	1083.99	79.32
50	600.6	1083.99	80.48
75	596.7	1070.49	79.40
125	592.8	1043.49	76.02

From Table 14, it can be seen that, the requirement of fine aggregate increases when the mixes are designed as per the new code. The percentage increase is almost same for all slump values.

Table 15 Effect of Slump on Requirement of Coarse Aggregate

Slump	Requirement of C.A per m^3 of Concrete		% Decrease in the Requirement of C.A
	Old code	New code	
25	1178.4	753.28	36.07
50	1170.8	753.28	35.66
75	1163.192	743.9	36.04
125	1155.6	725.13	37.25

From Table 15 it can be seen that, the requirement of coarse aggregate decreases when mixes are decreased as per the new code. The percentage reduction is around 36 % for all slump values.

3.5 Effect of Zone

The grading of fine aggregate of fine aggregate has much influence on the workability of concrete than the grading of coarse aggregate. IS: 383-1970 classifies the sand in to four zones 1,2,3,4. From zone 1 to zone 4, fine aggregate becomes progressively finer. In order to understand the influence of sand belonging to different zones, mixes were designed with different zones are compared.The requirements were found for the conditions 53 grade cement, M_{20} grade of concrete, size of coarse aggregate 10mm, Slump 75mm, specific gravity of coarse aggregate 2.6, specific gravity of fine aggregate 2.6 The requirements of fine aggregate with respect to zone number are given in Table 16

Table 16 Requirement of fine aggregate for Different Zones of Sand

Zone	Requirement of F.A per m^3 of Concrete		% Increase in the Requirement of F.A
	Old code	New code	
1	673.4	740.23	9.92
2	648.4	774.7	19.47
3	623.4	809.09	29.78
4	598.4	843.52	40.96

From Table 16 it can be seen that as the zone number increases the requirement fine aggregate decreases when mixes are designed as per the old code However the requirement of fine aggregate increases when the mixes designed as per the new code. It can also be seen that, when mixes are designed as per the new code, the requirement of fine aggregate increases. The increase is around 10 % for zone 1 and 41 % for zone 4.

The requirements of fine aggregate with respect to zone number are given in Table 17

Table 17 Requirement of coarse aggregate for Different Zones of Sand

Zone	Requirement of C.A Per m^3 of Concrete		% Decrease
	Old Code	New Code	
1	993.2	984.23	0.90
2	1018.2	946.8	7.01
3	1043.2	912.37	12.52
4	1068.2	877.95	17.81

From Table 17 it can be seen that as the zone number increases the requirement coarse aggregate increases. When mixes are designed as per the old code. However the requirement of coarse aggregate decreases when the mixes designed as per the new code.

3.6 Effect of Specific Gravity of F.A and C.A

Specific gravity is defined as the ratio of the weight of solid in a given volume of sample to the weight of equal volume of water.Specific gravity is required for estimating the quantity of aggregates in concrete. Specific gravity of aggregate gives valuable information on its quality and properties. Higher values of specific gravity will indicate harder and stronger aggregate. It can also be seen that, when mixes are designed as per the new code, the requirement of fine aggregate decreases. The increase is around 1% for zone 1 and 18% for zone 4.The requirements of fine aggregate with respect to specific gravity of fine aggregate are given in Table 18The requirements were found for the conditions 53 grade cement, M_{20} grade of concrete, size of coarse aggregate 10mm, Slump 75mm, specific gravity of coarse aggregate 2.6, specific gravity of fine aggregate 2.6

Table 18 Requirement of Fine Aggregate per $m^3$of Concrete with respect to Specific Gravity of Fine Aggregate

SG OF FA	Requirement of F.A per m^3 of Concrete		% Increase
	Old code	New code	
2.2	**548.7**	**655.5**	19.46
2.4	**598.6**	**715.1**	19.46
2.6	**648.5**	**774.7**	19.46
2.8	**698.33**	**834.3**	19.47
3	**748.21**	**893.84**	19.46

From Table 18, it can be seen that requirement of fine aggregate increases as the specific gravity of fine aggregate increases. The requirement of fine aggregate is around 19 % more when the mixes are designed as per the new code.The requirements of coarse aggregate with respect to specific gravity of coarse aggregate are given in Table 19.

The requirements were found for the conditions 53 grade cement, M_{20} grade of concrete, size of coarse aggregate 10mm, Slump 75mm, specific gravity of coarse aggregate 2.6, specific gravity of fine aggregate 2.6

Table 19 Requirement of Coarse Aggregate per $m^3$of Concrete with respect to Specific Gravity of Coarse Aggregate

SG OF C.A	Requirement of C.A per m^3 of Concrete		% Decrease
	Old code	New code	
2.6	1163.2	707.6	39.17
2.7	1207.93	734.83	39.17
2.8	1252.67	762.04	39.17
2.9	1297.41	789.26	39.17

From Table 19, it can be seen that the requirement of coarse aggregate increases as the specific gravity of coarse aggregate increases. The requirement of coarse aggregate is around 39 % less when the mixes are designed as per the new code.

V.CONCLUSIONS

A detailed comparison has been made between the old and new Indian codes for concrete mix design. It is found that quantity of cement required slightly decrease when mixes are designed as per the new code for all grades of concrete. The requirement for fine aggregate increases for all grades of concrete when mixes are designed as per the new code, the maximum increase in the requirement of fine aggregate is around 121 % for M40 concrete. the requirement of coarse aggregate decreases for all the grades of concrete when mixes are designed by new code it is found that the size of the coarse aggregate has a great impact on the requirement of fine and coarse aggregate. The requirement of fine aggregate increases when the mixes are designed by new code . The increase is as high as 130 % when 40 mm aggregate are used.The requirement of coarse aggregate decreases when mixes are designed by new code. The reduction in the requirement is around 53 % for 40 mm

aggregate. For the same slump, the requirement of fine aggregate is more and coarse aggregate is less when the mixes are designed by the new code. It is also found that ,for the same specific gravity of fine aggregate, the requirement of fine aggregate is more when the mixes are designed as per the new code. For the same specific gravity of coarse aggregate, the requirement of coarse aggregate is less for the mixes designed by the new code.

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