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Analysis on Mix Design of M25 Grade of Concrete- A Case Study on Modification of Terminal Building at Silchar Airport

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Abstract: Concrete mix design is art of civil engineering, which is most widely use in construction work in the world. A good quality of concrete starts with proper quality of materials, cost effective design which results the valuable construction practice. A concrete mix design mainly carried out the characteristics of workability, durability and strength of concrete in fresh and hardened state.

This study investigates for determining most suitable concrete mix in order to achieve the target mean strength. In this research work 43 grade of ordinary Portland cement, the locally available fine aggregate i.e. sand, 20mm and 10mm graded coarse aggregate were selected based on IS:456-2000 and IS 10262-2009 standard for determining quantities and proportions for concrete having grade M25.

A total of six trial mixes were carried out for getting suitable selection for M25 grade of concrete in a better way of proportioning. Each mix were tested by slump instantly and a set of 6 numbers of cubical specimen having size 150mm X 150mm X 150mm were casted and kept in curing tank after 24 hours from casting time period. After age of 7 days of curing, the specimens of 3 numbers and after 28 days of curing, the specimens of remaining 3 numbers of each mix were tested. After observing of the variation of each mix design, the appropriate mix proportion were selected for further construction.

Keywords: Mix design, Compressive strength, Water/cement ratio, Curing, Target mean strength, Aggregates, IS method.

I. INTRODUCTION

A mix design is mostly economically, preparing with raw materials such as cement, fine aggregate or river sand, coarse aggregate, water, in a proper batching and mixing proportion which results the better quality of concrete work of required strength, durability workability, and prevent from failure of construction practice which is termed as concrete mix design. In mix design of concrete, the basic ingredients compare with nominal concrete are slightly same but their proportioning may vary. A fresh concrete which is workable and cohesive at its initial setting time.

When it becomes hardened, it should be strong enough and durable. Sometimes, concrete fails due to low quality of materials, more silt content, improper batching and mixing, transporting, placing, compacting and curing, etc. Concrete mix design is very useful in quality control in construction.

Improper or without curing of concrete results plastic shrinkage cracking as well as drying shrinkage and other side effects. Characteristics strength of concrete is the value of compressive strength which must be satisfy for concrete grade selection with respect to its ingredients properties. Different mix design methods carried out for target mean strength or design strength in a different way. Here, the concrete mix design of M25 grade is use to estimate parameters like compressive strength, cost effective at the stage of design for a given target strength, in addition to ingredients of concrete to carried out the R.C.C work for construction and modification of terminal building at Silchar Airport.

A. Purpose of Mix Design

The aim of concrete mix design is to use the proper ingredients proportion of M25 grade of concrete to fulfil the necessary requirements of the construction of R.C.C work in building at Silchar Airport with the features of quality control in order to maintain-

1) To control the desired workability in the plastic stage.
2) To achieve the appropriate strength when concrete is in hardened stage.
3) It should maintain the better durability in case of environmental factors.
4) To be carried out the good quality of construction practice as much as possible.
5) It should produce concrete as economically as possible.

B. *Necessary Consideration and basic factors*

1) Specification of Materials: For the designing of concrete mix, it should necessary to observe at least the basic properties of each and every ingredients such as cement, fine aggregate, coarse aggregate, admixture, water.
2) *Cement*: Ordinary Portland Cement (OPC)

Table 1: Properties of cement

Sl. No	Particulars	Value	Specification
1.	Brand	Dalmia Bharat Cement	As per IS 8112-2013
2.	Specific Gravity	3.12	
3.	Consistency	26	
4.	Initial Setting Time (Minute)	60	
5.	Final Setting Time (Minute)	328	
6.	Soundness, (mm)	1	
7.	Fineness, (Percentage)	3	
8.	Compressive strength at 28 days, (MPa)	43	

3) *Water*: Water is using in mix design as a ingredients. Potable water is important for batching and mixing to produce concrete as because it reacts with cement and hence results in hydration.
4) *Fine Aggregate*: Normally river sand is use in here as fine aggregate from Madura river, Silchar local area. The sand is tested as per IS 383:1970 requirement. In addition, sieve analysis has also carried out.
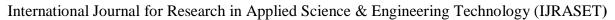
Table 2: Properties of Fine Aggregate (river sand)

Sl. No	Particulars	Value	Specification
1.	Source	Madura River	As per IS383-1970
2.	Zone	IV	
3.	Specific Gravity	2.312	
4.	Water Absorption (Percentage)	2.62	
5.	Bulking (Percentage)	11.11	
6.	Silt Content (Percentage)	3.5	

Table 3: Sieve Analysis for Fine Aggregate

Sl. No	IS Sieve	Passing (Percentage)	Specification
1.	10mm	100	As per IS 2386-1963
2.	4.75mm	100	
3.	2.36mm	93.34	
4.	1.18mm	89.75	
5.	600□	83.60	
6.	300□□	12.72	
7.	150□□	1.42	
8.	75□□	0	

5) *Coarse Aggregate*: Normally crushed stone with having 10mm and 20mm sizes are taken for construction work from Madura river, locality of Silchar area. The aggregate is also tested as per IS 383:1970 standard.

Table 4: Properties of Coarse Aggregate

Sl. No	Particulars	Value		Specification
1.	Source	Madura River		As per IS383-1970
2.	Shape- Angular	10mm	20mm	
3.	Specific Gravity	2.69	2.69	
4.	Water Absorption (Percentage)	1.16	1.09	
5.	Moisture Content (Percentage)	0.44	0.50	
6.	Aggregate Crushing value (Percentage)	20.22	20.39	

Table 5: Sieve Analysis for Coarse Aggregate (10mm size)

Sl. No	IS Sieve	Passing (Percentage)	Specification
1.	20mm	100	As per IS 2386-1963
2.	12.5mm	100	
3.	10mm	85.11	
4.	4.75mm	3.17	
5.	2.36mm	0	

Table 6: Sieve Analysis for Coarse Aggregate (20mm size)

Sl. No	IS Sieve	Passing (Percentage)	Specification
1.	40mm	100	As per IS 2386-1963
2.	25mm	100	
3.	20mm	86.11	
4.	12.5mm	10.17	
5.	10mm	1.35	
6.	4.75mm	0	

6) *Admixture*: Admixture are manufactured from super plasticizer based chemicals naphthalene formaldehyde sulphate polymer are used. Mainly admixtures is used as air-entraining agents, water reducers, water reducing retarders and accelerators. Here, admixture uses as per IS 9103-2003 standards.

Table 7: Properties of Admixture

Sl. No	Particulars	Value	Specification
1.	Brand	SWC	As per IS 9103-2003
2.	Form	Liquid	
3.	Specific Gravity	1.121	
4.	PH value	7.3	
5.	Chloride Content	Nil	
6.	Colour	Brown	

As per IS:456-2000, characteristics compressive strength for M25 grade of concrete and its proportion are mentioned below the table 8. Abram's water/cement ratio states that for any given condition of test, the strength of workability of concrete mix is mainly depending upon of its water/cement ratio. Applicable of lower water/cement ratio results the greater accuracy of compressive strength as well as durability of concrete. Utilization of maximum cement content which avoid shrinkage cracks. Also to be focus for maximum aggregate/cement ratio which can also be economically in nature.

Table 8: Design contraction data for M25 grade of concrete

Sl. No.	Data	Value
1.	Concrete grade	M25
3.	Characteristics Compressive Strength N/mm^2	25
4.	Group for concrete type	Standard concrete
5.	Max, coarse aggregate size	20mm
6.	Slump (mm)	50-75
7.	Exposure Condition	Mild
8.	Quality Control	Good
10.	Workability for compacting factor	0.85
11.	Target Mean Strength	31.60
12.	Standard Deviation	4
13.	Entrapped-Air, (percentage)	2%

C. Method of Mix Design as per IS:456-2000 and IS 10260:2009

The Bureau of Indian Standard code IS:456-2000 and IS 10260:2009 has recommended the process of concrete ingredients and its design mix procedure.

Water/cement ratio is the main fact to get the compressive strength of concrete. With proper assumption of water/cement ratio results the better quality of workable concrete. As per IS standards, depending upon on the grade of concrete as well as the type of exposure, the water/cement ratio is to be selected.

In case of selection of water content, it is also depends upon on the slump value as well as maximum size of coarse aggregate, whereas depending upon the zone of fine aggregate, and the maximum size of coarse aggregate results the variation of coarse aggregate volume.

As per IS 383:1970 standards, there are several factors such as shape and size of coarse and fine aggregate, water content, quality, quantity and grade of cement influence the concrete mix design. Using absolute volume method results the batch wise weight of each ingredient of concrete for design mix whereas trial mix has to be followed for selecting the best mix design for concrete in construction practice. Table 8 is to be follow-up for necessary features of concrete mix design having M25 grade in trial mix procedure. Characteristics compressive strength (F_{ck}) is obtained from the cube test results after the curing of cube specimen(s) place in a dry weather with minimum of 12 hours and hence tested in compressive test machine. The compressive load is found 562.5 KN.

Formula for getting compressive strength of concrete-

Compressive strength of concrete (F_{ck}) = Maximum compressive load (F)/ Cross sectional area of cube (A)

Whereas, A= 150mm X 150mm = 22500mm^2

F = 562.5 KN = 562500N

So, compressive strength of concrete, F_{ck} = F/A = 562500/22500

= 25 N/mm^2

= 25/9.8

= 2.55 Kg/mm^2,

Whereas, 1Kg is equal to 9.8N.

D. Procedure for M25 grade of concrete mix design

1) Step 1: Determination of Target Mean Strength for mix design-

The target mean strength of concrete is found from the characteristics compressive strength of cube at an age of 28 days is-

$$F_{target} = F_{ck} + (t \times s)$$
$$= 25 + (1.65 \times 4),$$

Where, F_{target}: Target mean strength at an age of 28 days of concrete in N/mm^2.

F_{ck}: Characteristics compressive strength at an age of 28 days = 25 N/mm^2.

t: Tolerance factor = 1.65

s: standard deviation (taken from table 8, IS:456-2000) = 4,

whereas standard deviation is depends upon on the selected proportion having low results as well as the number of tests carried out.

2) Step 2: Selection and calculation of water content-

Table 9: IS:456-2000-Durability criteria

Exposure	Plain Concrete			Reinforced Concrete		
	Min cement (Kg/m^3)	Max w/c	Min Grade	Min cement (Kg/m^3)	Max w/c	Min Grade
Mild	220	0.60	-----	300	0.55	M20
Moderate	240	0.60	M15	300	0.50	M25
Severe	250	0.50	M20	320	0.45	M30
Very Severe	260	0.45	M20	340	0.45	M35
Extreme	280	0.40	M25	360	0.40	M40

From the above table of IS:456-2000, minimum cement content for mild exposure condition is 300Kg/m^3.

But the grade of concrete is M25 and water/cement ratio is 0.437 and maximum cement content is 450 Kg/m^3 (as per IS:456-2000, clause 8.2.4.2).

As per table5, IS 10262-2009, water content for 20mm maximum size of aggregate = 186Kg/m^3.

As per IS 10262-2009, clause 4.2, we can increase 3% for every additional 25mm slump, hence water content = 186 + 3% of 186 = 186 + 5.58 = 191.6Kg/m^3.

As admixture is used, the water content can be reduced by 11.3% and above.

From the above figure and table 5 of IS:456-2000, maximum water/cement ratio for mild exposure condition is 0.55 and the zone of fine aggregate is IV.

Considering water/cement ratio as (0.55-0.113) =0.437.

So, 0.437<0.55, hence satisfy.

The actual water content to be used = 191.6 –{(11.3/100) x 191.6}= 169.94 litres/m^3.

3) Step 3: Calculation cement content-

As per table5 of IS:456-2000, for mild exposure condition, minimum cement content = 300Kg/m^3.

Water/cement ratio= 0.437

Water used in = 169.94 litres//m^3.

So, {Water content (W)/ Cement content (C)} = 0.437

C= 169.94/0.437 = 388.88 Kg/m^3 = 390 (aprox.)

4) Step 4: Calculation of volume of coarse and fine aggregate content-

As per table 3 of IS 10262-2009, clause 4.4, A-7 and B-7, Volume of coarse aggregate corresponding to 20mm size of aggregate and zone IV of fine aggregate for water/cement ration of 0.55 is equal to 0.66m^3.

Actual water/cement ratio = 0.437, which is less by 0.55 – 0.437 = 0.113

Reducing water/cement ratio, it is desirable to increase the coarse aggregate proportion reduce fine aggregate in order to satisfy as per IS code provisions.

Hence,

For every decreasing 5% of water/cement ratio, coarse aggregate proportion has increased by 1%.

So, for decreasing 0.113x 100 % = 11.3 % of water/cement ratio, it is desirable to increase coarse aggregate upto = (1/5) 11.3% =0.0226m^3.

Final proportion volume of coarse aggregate = 0.66 + 0.0226 = 0.6826m^3

Volume of fine aggregate = 1- 0.06826 = 0.3174m^3.

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5) *Step 5*: Design mix calculation as per IS method-

Mix design calculation per unit volume of concrete can achieve by-

a) Volume of Aggregate, $V_{Agg} = 1 - (V_w + V_c + V_A + V_{Air})$,....Eq1
b) Volume of concrete, $V = 1m^3$
c) Volume of Cement, $V_c = (W_c)/(S_c \times 1000) = 390/(3.12 \times 1000) = 0.125m^3$
d) Volume of water, $V_w = (W_w)/(S_w \times 1000) = 169.94/(1 \times 1000) = 0.17m^3$
e) Volume of admixture, $V_{Adm} = (W_A)/(S_{Adm} \times 1000)$

Dosage 0.21% by weight of cementation material and also assuming specific gravity as 1.121.

$= [\{(0.21/100) \times 390\} / (1.121 \times 1000)] = 0.000731 \ m^3$.

Where,

V: Volume of concrete

V_c: Volume of cement

C: Weight of cement

S_c: Specific gravity of cement

V_w: Volume of water

W_w: Weight of water

S_w: Specific gravity of water = 1

V_{Adm}: Volume of admixture

W_A: Weight of admixture

S_{Adm}: Specific gravity of admixture

V_{Air}: Volume of air-entrapped

$V_{C.A}$: Volume of coarse aggregate

$W_{C.A}$: Weight of coarse aggregate

$S_{C.A}$: Specific gravity coarse aggregate

$V_{F.A}$: Volume of fine aggregate

$W_{F.A}$: Weight of fine aggregate

$S_{F.A}$: Specific gravity of fine aggregate

f) Volume of air-entrapped, $V_{Air} = 2\%$ for 20mm maximum size of coarse aggregate $= 0.02 \ m^3$.
g) Volume of coarse aggregate, $V_{C.A} = \{(W_{C.A})/(S_{C.A} \times 1000)\}$,...Eq2
h) Volume of fine aggregate, $V_{F.A} = \{(W_{F.A})/(S_{F.A} \times 1000)$,…… Eq3

Putting above values in equation1, results-

$V_{Agg} = 1 - (0.17 + 0.125 + 0.00731 + 0.02) = 0.6843m^3$

i.e. $V_{C.A} + V_{F.A} = 0.6843m^3$

From Eq2,

$W_{C.A} = V_{Agg} \times V_{C.A} \times S_{C.A} \times 1000 = 0.6843 \times 0.6826 \times 2.6832 \times 1000 = 1253.333$

Also, consider-

Coarse aggregate with 20mm size = 60% of $W_{C.A}$

$= 0.6 \times 1253.333 = 752Kg$

Coarse aggregate with 10mm size = 40% of $W_{C.A}$

$= 0.4 \times 1253.333 = 501.34Kg$

From Eq3,

$W_{F.A} = V_{Agg} \times V_{F.A} \times S_{F.A} \times 1000 = 0.6843 \times 0.3174 \times 2.312 \times 1000 = 502.164Kg$.

So weight of admixture,

$W_A = (0.21/100) \times 390 = 0.82ml$

Table 10: Data can be written in tabulated form as-

Sl. No.	Cement (Kg)	Fine Aggregate (River sand, in Kg)	Coarse aggregate (Kg)		Water (Litre)	Admixture (ml)
1	390	502.164	10mm	20mm	169.94	0.82
			752	501.34		

E. Trial Mix Design

For getting better cube strength of M25 grade of concrete with respect to cost economically, the above mix proportion are carried out with the variation of water/cement ratio as follows-

1) *Trial Mix 1*: For cement content having 360 Kg/m^3 , water/cement ratio= 0.437

Water content = 0.437 x 360 = 157.32 litres.

For casting a set of cube 150mm x 150mm x150mm having 6 numbers of specimen for trail mix 1 with the reference of 360 Kg/m^3 of cement content in order to brought a weight of 25Kg of cement weighted by weight machine and other ingredients are also followed in the same manner, such as-

Cement content for cube casting= 25Kg under 360Kg/m^3

Fine aggregate (river sand) = (502.164/ 360)x25 = 34.87Kg

Coarse aggregate (Crushing stone)

10mm: (501.34/360)x25 =34.82Kg

20mm: (752/360)x25 =52.22Kg

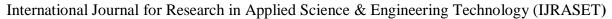Admixture: (0.82/360) x 25 = 0.06ml

Water Content: (157.32/360)x25 = 10.925 litres.

After mixing of all concrete ingredients, instantly slump test has carried out for each trial mix. A slump cone has checked properly before pouring of concrete and fill-up in three steps having equal volume and asset of 25 times has compacted by a temping rod in each steps, as prescribed by IS:1199-1959. Slump value has carried out for getting the workability of concrete in each of trail mix and comparing these values with the data above in tabulated.

Similarly, each cube specimen has casted in three steps having equal volume and a set of 35 times has compacted by a temping rod in each steps of each specimen and placing in a dry weather for 12 hours after casting with providing of each cube ID. After 12 hours, all the trial mix cube specimen (each trial mix has 6 cube casted specimen, a total of 36 cube has casted) placed in water tank for curing purpose. For each trial mix, 3 out 6 cubes specimen are taken out and places in a dry weather condition for few hours and need to carried out for testing in compressive test machine for getting each and every cube specimens. Strength at the age of 7 and 28 days as prescribed in IS516-1959 an acceptance criteria of IS:456-2000 standards.

Figure 1: Slump Testing for workablility

Figure 2: Cube casting (step by step) for trail mix

Table 11: The above trail mix 1 are in tabulated form as-

Sl. No.	Cement (Kg)	Fine Aggregate (Kg)	Coarse aggregate (Kg)		Water (Litre)	Admixture (ml)	Slump (mm)
Trial Mix1	360	502.164	10mm	20mm	157.32	0.82	
			752	501.34			
Sample1	25	34.87	52.22	34.82	10.925	0.06	Nil

Similarly, for other trail mixes, same procedure has been carried out.

2) *Trial Mix 2,3,4,5 and 6*: Similarly, it has followed in the same manner for 370 Kg/m^3, 380 Kg/m^3, 390 Kg/m^3, 400 Kg/m^3 and 410 Kg/m^3 with having 25Kg of each cement sample weighted with respect to its other ingredients-

Table 12: Trial mix 2,3,4,5 and 6 are in tabulated form

Sl. No.	Cement (Kg)	Fine Aggregate (Kg)	Coarse aggregate (Kg)		Water (Litre)	Admixture (ml)	Slump (mm)
Trial Mix2	370	502.164	10mm	20mm	161.69	0.82	
			752	501.34			
Sample 2	25	33.93	50.81	33.87	10.925	0.055	Nil
Trial Mix3	380	502.164	752	501.34	166.06	0.82	
Sample 3	25	33.04	49.47	32.98	10.925	0.05	20
Trial Mix4	390	502.164	752	501.34	169.94	0.82	
Sample 4	25	32.20	48.21	32.14	10.90	0.05	Nil
Trial Mix5	400	502.164	752	501.34	174.80	0.82	
Sample 5	25	31.39	47	31.33	10.925	0.05	48
Trial Mix6	410	502.164	752	501.34	179.17	0.82	
Sample 6	25	30.62	45.85	30.47	10.925	0.05	20

a)   *Step 7*: Results of Trail mix design

It has observe that in all trail mix design whereas sample-4 has provides better strength which is also cost economically compared with sample-5 and sample-6 and satisfied for construction of R.C.C work in terminal building at Silchar Airport with M25 grade of concrete.

Table 13: Selected appropriate trail mix design for further construction

Sl. No.	Cement (Kg)	Fine Aggregate (Kg)	Coarse aggregate (Kg)		Water (Litre)	Admixture (ml)
			10mm	20mm		
Trial Mix2	390	502.164	752	501.34	169.94	0.82
Sample 2	25	32.20	48.21	32.14	10.90	0.05

Figure 3: Cube testing for getting Compressive strength of sampl

Table 14: Cube test results for 390 Kg/m^3, trial mix-4, sample-4

Sl. No	Cube Id	7 Days Cube Strength (N/mm^2)		28 Days Cube Strength (N/mm^2)		Selection	
		Individual	Average	Individual	Average	Yes	No
Trial Mix 4 and Sample4	39/22/1	23.15	23.38			Yes	---
	39/22/2	24.10					
	39/22/3	22.90					
	39/22/4			26.19	26.67		
	39/22/5			26.50			
	39/22/6			27.25			

II.   CONCLUSION

The present study was undertaken to develop the strength characterises from the variation of different strength in design mix methodology for M25 grade of concrete. The appropriate selection of mix design of proper proportion of ingredients of concrete results the better way in construction practices rather than structural failure. We should keep in mind that concrete strength is not only depends upon the water content in a mix proportion but several factors effects on it for the selection of any grade of concrete.

Practically, each and every materials' properties is necessary to obtain and should test for quality of work. Admixture as well as increasing of aggregate with decreasing of water content results the good compressive strength of concrete to the satisfactory target mean strength. We should follow up IS   provisions while selecting of mix design of concrete.

III.   ACKNOWLEDGMENT

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