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A Study of Mix Design Adopted in RMC

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Abstract – While concreting, it is important to select suitable ingredients of concrete and to produce concrete of certain minimum strength and durability. To achieve these points it is required to design a concrete mix. Mix Design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportion with the object of producing concrete of certain minimum strength and durability as economically as possible. For ready mix concrete plant, it is required to follow up the good concrete mix design. Therefore, in this seminar an attempt is made to understand the mix design of ready mixed concrete, proportioning, physical and chemical properties of materials and influencing factors of mix design used in RMC. Also, and attempt is made to design a software on concrete mix of RMC. In this paper, following points will be covered: 1.Physical and chemical properties of materials used in RMC. 2. Influencing factors of mix design. 3. Methods used to design concrete mix of RMC.

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INTRODUCTION

Ready mix concrete (RMC) is defined as a concrete manufactured as per the specifications of purchaser at a centrally located batching plant under controlled conditions and delivered at construction, site in a truck mixer, capable of mixing the ingredients of concrete and agitating the mixed concrete during the transportation.

In India, the present consumption of cement through these plants is only 5 per cent of the total production of cement. Whereas, in US, 75% of the cement produced is used in RMC. Though delayed, the acceptance of RMC in India is constantly increasing among the end users. Once it is tried, there is high degree of return of customers.

There are two principal categories of RMC as under.

a) Centrally mixed concrete: In this, the mixing is done at a central plant and the mixed is done at a central plant and the mixed concrete is then transported through a transmit mixer which revolves slowly so as to prevent segregation and undue stiffening of concrete.

b) Truck mixed concrete: In this, the materials are batched at a central plant but are mixed in a mixer truck either in transit to the site or immediately prior to the concrete being discharged. This permits a longer haul and is less vulnerable is case of delays.

HISTORY:

Use of ready mix concrete, RMC as it is popularly known, started only in early 90's in India. Although this concept was very old in developed countries, but it took off in India after the decontrol of cement. Plants that were setup initially were producing RMC for the specific projects only. But now RMC is available to any individual interested to use it in most of the major towns. There are about 90 RMC plants in existence in India producing approximately 40 lakh cubic meter of concrete, setting up of many more plants is in pipe line. Still we can say that RMC is in its infancy in India.

MIX DESIGN DEFINITION:

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

PURPOSE OF MIX DESIGN:

The purpose of designing of mix is two-fold. The first object is to achieve the stipulated minimum strength and durability. The second object is to make the concrete in the most economical manner. Cost wise all concretes depend primarily on two factors, namely cost of material and cost of labor. Labor cost, by way of formworks, batching, mixing, transporting, and curing is nearly same for good concrete and bad concrete. Therefore attention is mainly directed to the cost of materials. Since the cost of cement is many times more than the cost of other ingredients,

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attention is mainly directed to the use of as little cement as possible consistent with `strength and durable.

GRADING OF AGGREGATES-

The advantages due to good grading of aggregate can also be viewed from another angle. If concrete is viewed as a two phase material, paste phase and aggregate phase, it is the paste phase which is vulnerable to all ills if concrete. Paste is weaker than average aggregate in normal concrete with rare exceptions when very soft aggregates are used. The paste is more permeable than many of the mineral aggregate. It is the paste that is susceptible to deterioration by the attack of aggressive chemicals. In short, it is the paste which is a weak link in a mass of concrete. The lesser the quantity of such weak material, the better will be the concrete. This objective can be achieved by having well graded aggregates. Hence, the importance of good grading.

SIEVE ANALYSIS:

Grading pattern of a sample of coarse aggregate or fine aggregate is assessed by sieving a sample successively through all the sieves mounted one over the other in order of size, with larger sieve on the top. The material retained on each sieve after shaking, represents the fraction of the aggregate coarser than the sieve in question and finer than the sieve above. Sieving can be done either manually or mechanically. In the manual operation the sieve is shaken giving movements in all possible direction to give chance to all particles for passing through the sieve. Operation should be continued till such time that almost no particle is passing through. Mechanical devices are actually designed to give motion in all possible direction, and as such, it is more systematic and efficient than hand sieving. For assessing the gradation by sieve analysis, the quantity of material to be taken on the sieve is given Table 1.1

Table 1.1: Minimum Weight of Sample for Sieve Analysis

Maximum size present in substantial proportions in mm	Minimum weight of sample is to be taken for sieving in kg
63	50
50	35
40 or 31.5	15
25	5
20 or 16	2
12.5	1
10	0.5
6.3	0.2
4.75	0.2
2.36	0.1

From the sieve analysis the particle size distribution in a sample of aggregates is found out. In this connection a term known as "Fineness Modulus" is being used. F.M. is a ready index of coarseness or fineness of the material. Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves ranging from 80mm to 150micron and dividing this sum by an arbitrary number 100. The larger the figure, the coarser is the material.

The following limits may be taken as guidance.

Fine sand	Fineness modulus	: 2.2-2.6
Medium sand	Fineness modulus	: 2.6-2.9
Coarse sand	Fineness modulus	: 2.9-3.2

Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete.

STANDARD GRADING CURVE:

The grading patterns of aggregate can be shown is table or charts. Expressing grading limits by mean of a chart gives a good pictorial view. The comparison of grading pattern of a number of samples can be made at one glance. For this reason, often grading of aggregate is shown by means of grading curves. One of the most commonly referred practical grading curves are those produced by Road Research Laboratory (U.K.) On the basis of large number of experiments in connection with bringing out mix design procedure, Road Research Laboratory has prepared a set of type grading curve for all in aggregate graded down from 20mm 40mm. they are shown in fig. 1.1 and fig. 1.2 respectively .Similar curves for aggregate with maximum size of 10mm and downward have been prepared by McIntosh and Erntory. It is shown in fig.1.3, fig. 1. 4 show the desirable grading limit for 80mm aggregate.

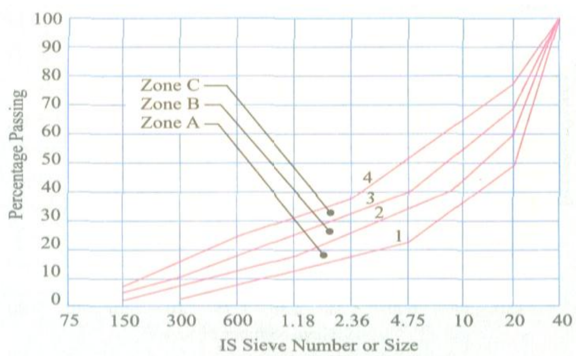

FIG. 1.1 Type Grading Curves for 20 mm Aggregate

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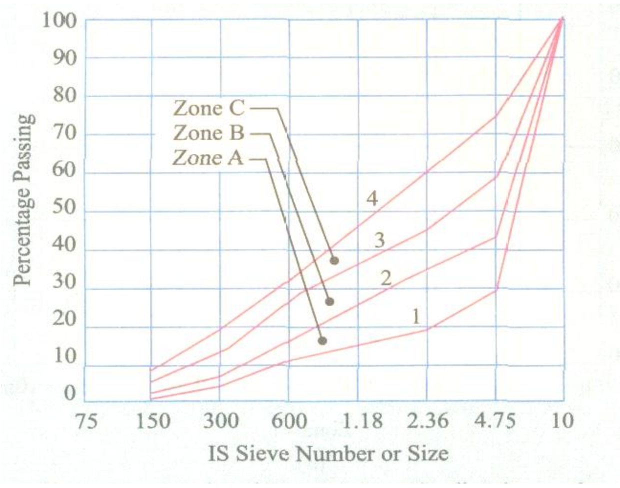

FIG.1.2 Type Grading Curves for 40 mm Aggregate

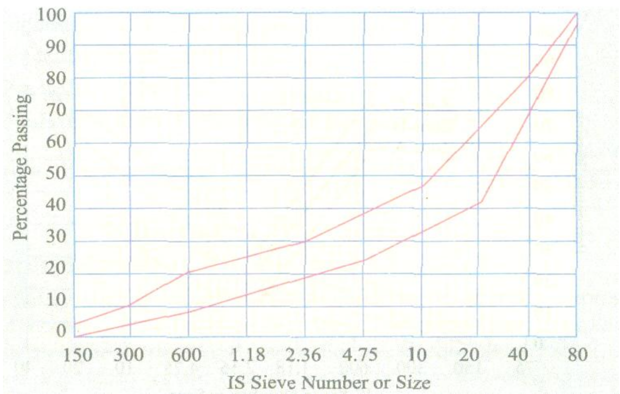

Fig 1.3 Mcintosh and Erntroy's Type Grading Curves for 10 mm Aggregate

PROPERTIES OF MIX INGREDIENTS- While designing the concrete mix it is very essential to consider the different properties of mix ingredients.

AGGREGATE:

Size: The largest maximum size of aggregate practicable to handle under a given set of conditions should be used. Perhaps, 80 mm size is the maximum size that could be conveniently used for concrete making. Using the largest possible maximum size will result in:

- Reduction of the cement content
- Reduction in water requirement
- Reduction of drying shrinkage.

However, the maximum size of aggregate that can be used in any given condition may be limited by the following conditions;

- Thickness of section
- Spacing of reinforcement;
- Clear cover
- Mixing, handling and placing techniques.

Generally, the maximum size of aggregate should be as large as possible within the limits specified, but in any case not greater than one-fourth of the minimum thickness of the member. Aggregates are divided into two categories from the consideration of size

- Coarse aggregate and
- Fine aggregate.

The size of aggregate bigger than 4.75 mm is considered as coarse aggregate and aggregate whose size is 4.75 mm and less is considered as fine aggregate.

Shape: The shape of aggregates is an important characteristic since it affects the workability of concrete. It is difficult to really measure the shape of irregular body like concrete aggregate which are derived from various rocks. Not only the characteristic of the parent rock, but also the type of crusher used will influence the shape of aggregates, *e.g.,* the rocks available round about Pune region are found to yield slightly flaky aggregates, whereas, good granite rock as found in Bangalore will yield cubical aggregate.

The shape of the aggregate is very much influenced by the type of crusher and the reduction ratio *i.e.,* the ratio of size of material fed into crusher to the size of the finished product. From the standpoint of economy in cement requirement for a given water/cement ratio, rounded aggregates are preferable to angular aggregates

WATER: Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

In practice, very often great control on properties of cement and aggregate is exercised, but the control on the quality of water is often neglected. Since quality of water affects the strength, it is necessary to go into the purity and quality of water.

The permissible limits for solids as per IS 456 of 2000 are as follows:

Table 1.2 Permissible Limits for Solids

Material	Tested as per	Permissible limit Max
Organic	IS 3025 (pt 18)	200 rng/l
Inorganic	IS 3025 |pt 18)	3000 mg/i
Sulphates	IS 3025 (pt 24]	400 mg/l
(as SO_3)		
Chlorides	IS 3025 (pt32)	2000 mg/l for concrete work not con
|as Cl]		taining embedded steel and 500 mg/
		for reinforced concrete work
Suspended	IS 3025 |pt 17)	2000 mg/l

SUPPLEMENTORY CEMENTITIOUS MATERIALS-

A mineral additive also called a supplementary cementitious material (pozzolana*)* is a finely ground siliceous material which, as such, does not possess cementitious property in itself, but reacts chemically with calcium hydroxide Ca $(OH)_2$ released from the hydration of Portland cement at normal temperature to form compounds of low solubility having cementitious properties. The action is termed pozzolanic action. These materials are often added to concrete to make concrete mixtures more economical, reduce permeability, increase strength, or influence other concrete properties, which can be used individually or in combination with Portland or blended cement or as a partial replacement of Portland cement. The pozzolanic materials can be divided into two groups namely, natural pozzolanas and artificial pozzolanas. The typical examples of natural pozzolana are: clay, shales, opaline cherts, diatomaceous earth, and volcanic tuffs and pumicites. The commonly used artificial pozzolanas are: fly ash, blast-furnace-slag, silica fume, rice husk ash, metakaoline, and surkhi.

WATER CEMENT RATIO:

Strength of concrete primarily depends upon the strength of cement paste. The strength of cement paste depends upon the dilution of paste or the strength of paste increases with cement content and decreases with air and water content. In 1918 Abrams presented his classic law in the form:

$S=A/B^{x}$

Where,

x =water/cement ratio by volume and for 28 days results the constants A and B are

14,000 Ibs/sq. in. and 7 respectively.

Abrams water/cement ratio law states that the strength of concrete is only dependent upon water/cement ratio provided the mix is workable.

METHODS USED TO DESIGN CONCRETE MIX

The methods that are commonly used to design a concrete mix are:

- American concrete institute method
- Indian standard recommended method
- Department of environment, UK method
- Road note no.4 method
- IRC 44 method

In these most favorable method used to design ready mixed concrete method is DOE method using fly ash as a mineral additive.

DOE (DEPARTMENT OF ENVIRONMENT,U.K.) METHOD

The DOE method was first published in 1975 and then revised in 1988. The DOE method is applicable to concrete for most purposes, including roads. The method can be used for concrete containing fly ash. DOE method presently is the standard British method of concrete mix design, the procedure involved in this method is described as follows. The following are the steps to design a concrete mix:

Step 1:

Find the target mean strength from the specified characteristic strength

Target mean strength = specified characteristic strength + Standard deviation x risk factor.

Risk factor is on the assumption that 5 percent of results are allowed to fall less than the specified characteristic strength.

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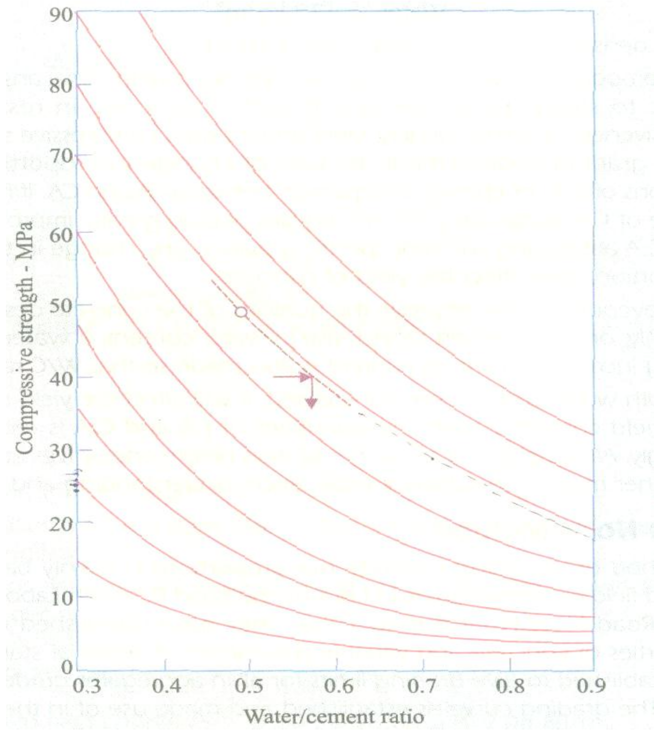

Fig 1.5 Relation Between Compressive Strength & W/C Ratio

Step 2:

Calculate the water/cement ratio. This is done in a rather round about method, using Table 1.3 and fig. 1.5. Table 1.3 gives the approximate compressive strength of concretes made with a free w/c ratio of 0.5.Using this table find out the 28 days strength for the approximate type of cement and types of C.A. Mark a point on Y axis in fig.1.5.equal to the compressive strength read from the table 1.3. Through this intersection point, draw a parallel dotted curve nearest to the intersection point. Using this new curve, we read off the w/c ratio as against target mean strength.

Step 3:

Next decide the water content for required workability, expressed in terms of slump or vebe time, taking into consideration the size of aggregate and its type from Table 1.4.

Step 4:

Find the cement content knowing the water/cement ratio and water content, Cement content is calculated simply dividing the water content by W/C ratio. The cement content so calculated should be compared with the minimum cement content specified from the durability consideration and higher of the two should be adopted. Sometime maximum cement content is also specified. The calculated cement content must be less than the specified maximum cement content.

Step 5:

Next find out the total aggregate content. This requires an estimate of the wet density of the fully compacted concrete. This can be found out from fig. 1.6for approximate water content and specific gravity of aggregate. If specific gravity is unknown, the value of 2.6 for uncrushed aggregate and 2.7 for crushed aggregate can be assumed. The aggregate content is obtained by subtracting the weight of cement and water content from weight of fresh concrete.

Step 6:

Then, proportion of fine aggregate is determined in the total aggregate using Fig. 1.7. Fig. 1.7(*a)* is for 10 mm size, 1.7(*b)* is for 20 mm size and Fig. 1.7(c) is for 40 mm size coarse aggregate. The parameters involved in Fig. 1.7 are maximum size of coarse aggregate, the level of workability, the water/cement ratio, and the percentage of fines passing 600 micron sieve. Once the proportion of FA is obtained, multiplying by the weight of total aggregate gives the weight of fine aggregate. Then the weight of the C.A. can be found out. Course aggregate can be further divided into different fractions depending on the shape of aggregate. The proportion so worked out should be tried in a trial mix and confirmed about its suitability for the given concrete structure. Table 1.5 gives the reduction of free water contents from the figures given in Table 1.4 when fly ash is used in the mix.

Table 1.3 Approximate Compressive Strength of Concrete Made with A Free W/C Ratio OF 0.5.

Type of Cement	Type OF C.A.	Compressive Strength at The Age of (Cube) Days mpa			
		3	7	28	91
Ordinary Portland cement Sulphate resisting cement	Uncrushed	22	30	42	49
	Crushed	27	36	49	56
Rapid hardening Portland cement	Uncrushed	29	37	48	54
	Crushed	34	43	55	61

Table 1.4 Approximate Free Water Content required to Give Various Levels of Workability

Aggregate	Water Content kg/m³				
Max. Size mm	Type	Slump 0-10	10-30	30-60	60-180
		VEBE> 12 sec	6-12	3-6	0-3
10	Uncrushed	150	180	205	225
	Crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	Crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	Crushed	155	175	190	205

Table 1.5 Reduction in the Free Water Content Of Table 1.3 When Using Fly Ash

Percentage of Fly Ash in Cementations Material	Reduction in Water Content kg/m³			
	Slump 0-10	10-30	30-60	60-180
	VEBE > 12 sec	6-12	3-6	0-3
10	5	5	5	10
20	10	10	10	15
30	15	15	20	20
40	20	20	25	25
50	25	25	30	30

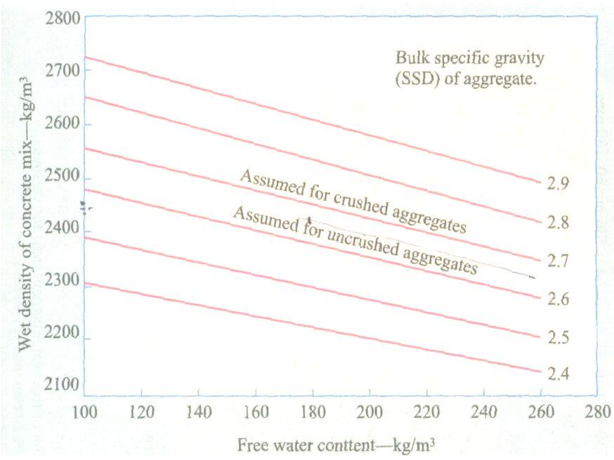

Fig.1.6 Estimated Wet Density For fully Compacted Concrete

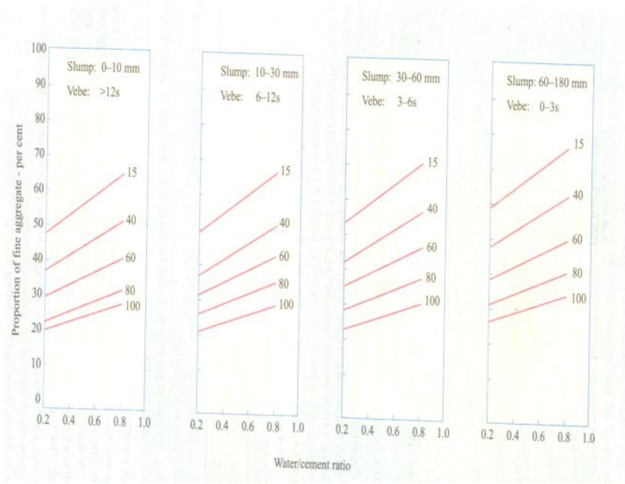

Fig.1.7 (A) Recommended Percentage of Fine Aggregate in Total Aggregate as a Function of Free W/C Ratio for Various Values of Workability

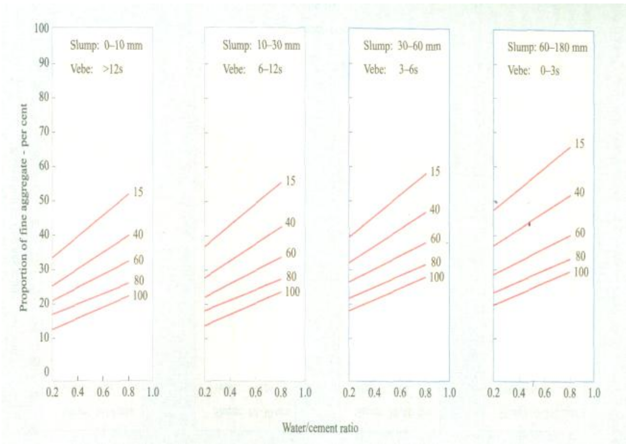

Fig 1.7 (B)

Design of concrete mix by DOE method using Fly Ash:

DATA:

M20 Grade concrete

Crushed Aggregate are used slump = 80mm

Cover of Reinforcement = 25mm

Grading F.A. shows that 40% passes through 600micron sieve

Moderate exposure conditions.

Sp. Gravity of FA = 2.6

CA = 2.7

Fly ash used = 25%

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DESIGN:

Cement content C = (100-P) W/ {(100-0.7P)(W/C+0.3F)}

Fly Ash Content F = PC/ (100-P)

Where, P = 100F/(C+F)

P is the percentage of flyash in total cementitious material W is free water content.

W/(C+0.3F) is the free water/ cementitious ratio for design strength.

From table 9. 1 compressive strength of ordinary cement with fly ash with a free W/(C+0.3F) ratio of 0.5 is 4.9 Mpa.

Target mean strength = 20+1.65*4.2

= 27Mpa

For target mean strength of 27Mpa, fig. 11.3 gives, a free W/(C+0.3F) ratio of 0.7

Referring to Table 9.2,

For slump of 80mm, for maximum size of aggregate of 20mm, in case of crushed sand, the approximate water content is 225 kg/m^3

Since 25% of fly ash is used, referring to table 9.3 water content is reduced by, 17.5kg/m^3

The water content = 225-17.5 = 207.5 kg/m3

Cement content = (100-25) 207.5/ {(100-.7*25)(0.7)}

Cement content = 270kg/m3

And the fly content = 25*270/(100-25)

= 90.0 kg/m3

Hence, total cementitious material content is 270+90 = 360kg/m3

The free water/ cementitious material ratio is,

270/360 = .58

For moderate exposure condition, concrete cover of 25mm the maximum free water/ cementitious material ratio is 0.5 and minimum cement content is 350 kg/m3

Cement content satisfies the durability requirement

But water/ cementitious material ratio does not satisfies durability requirement. Therefore adopt as 0.5.

Water content = 360*0.5 = 180 l/m3

From fig 9.2 for water content 180 l/m3, average specific gravity of 2.65 of aggregate, wet density of concrete comes to 2445 kg/m3

Total weight of aggregate = 2445 – (270+90+180)

= 1905 kg/m3

From fig 9.3 (b)

For water/ cementitious material ratio of 0.5 and for FA, 40% passing through 600 micron sieve and for slump of 80mm the proportions of FA is = 40%

Weight of FA = 40/100*1905

= 762 kg/m3

Weight of CA = 1905-762

= 1143 kg/m3

Estimated quantities of materials in kg/m3

Cement = 270kg/ m3

Fly ash = 90 kg/m3

Fine aggregate = 762 kg/m3

Coarse aggregate = 1143 kg/m3

Water = 180 l/m3

Since, required w/c ratio is 0.58 and provided w/c ratio is 0.5. therefore, it will be harsh concrete. Therefore, for workable concrete, proper dosage of water reducing admixture is used.

PUMPABLE CONCRETE MIX DESIGN

Concrete which can be pushed through a pipe line is called a pumpable concrete. It is proportioned in such a manner that its friction at the inner wall of the pipeline does not becomes so high to prevent its movement at the pressure applied by the pump. A pump concrete is no special concrete. It is a standardized good concrete with certain content of fines to offer lubrication at the inner wall of pipe line.

The pump able concrete has:

- a minimum content of FINES (cement + fine aggregate particle smaller than 0.25 mm size) of approximately 400 kg/m^3 for maximum size of 32 mm C.A.. In case of very angular, flaky aggregates this quantity is to be increased by approximately 10%.

- a minimum cement content of approximately 240 kg/m^3 for maximum size of 32 mm C.A.. It must be increased by 10% in case of maximum size aggregate of 16 mm.

- a water/cement ratio of 0.42 to 0.65.

- a slump of 75 mm to 150 mm or a consistency determinable by means of the flow table spread in the range of k_2 and k_3

- a grading of aggregate typically as shown in Fig. 10.1 is to be used.

Assuming the pump is mechanically sound, there are two reasons why blockage occur. The plug of concrete will not move because either

(a) Water is being forced out of the mix creating bleeding and blockages by jamming, or

(b) There is too much frictional resistance due to the nature of ingredients of the mix.

A good grading is very important to produce pumpable concrete. Elongated and flaky aggregate will make the concrete harsh for the given cement content and water/cement ratio.

The typical grading curves are shown in Fig. 1.8 for pumpable mixes. The aggregates for the proposed mix should have a grading parallel to these curves, but not coarser than a *2.* Adjustments to bring the grading parallel to the curves can be made by altering proportions between C.A and FA.

It is recommended that 10-20% of the fine aggregate should pass through 300 micron sieve. Sometimes 3-4% extra sand is added to safeguard against understanding.

Table 1.6 Fines Quantities and Aggregate Size

Maximum Size of Coarse Aggregate mm	Fines Per Cubic Meter of Concrete kg
8	525
16	450
32	400
63	325

Table 1.7 Limits of Fines Content (Calculated on the Absolute Density of Cement Equal To 3100 kg/m^3

Free Water Content l/m^3	Fine Solids kg/m^3	
	Minimum	Maximum
150	260	365
160	280	390
170	295	415
180	315	440
190	330	465
200	350	490
210	365	515
220	385	540
230	400	565
240	420	590

Table 1.8 Mix Proportions for 75-100 mm Slump

Material	Quantity In kg
Fine aggregate	880
Coarse aggregate	930
OPC	310
Water	190
Total	2310

Table 1.9 Absolute Densities of Materials

Material	Quantity In kg/m^3
OPC	3100
FA	2650
CA	2550

Table 1.10 Aggregate Grading (For Mix Proportions in Table 10.3

Sieve Size mm	Percentage Passing	
	C.A.	F.A.
20	100	
14	60	
10	37	100
5	6	94
2.4	1	84
1.2	-	70
0.6		53
0.3		18
0.15		5

Table 10.1 Calculation of all in aggregate Grading, Based on F.A. content of 880 kg and C.A. Content of 930 kg/m^3

Sieve Size mm	Percentage Passing		
	C.A.	F.A.	Combined Grading
20	51.5	48.5	100
14	31	48.5	79.5
10	19	48.5	67.5
5	3	45.5	48.5
2.4	0.5	41	41.5
1.2	-	34	34
0.6		25.5	25.5
0.3		9	9
0.15		2.5	2.5

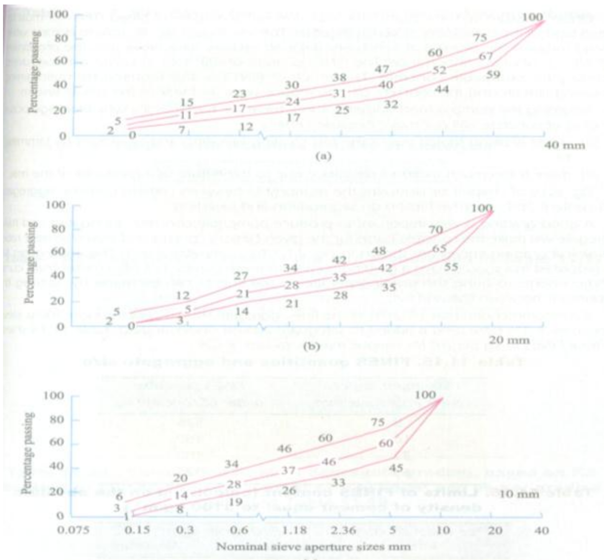

Fig 1.8 Typical Grading Curves for Pumpable Mixes

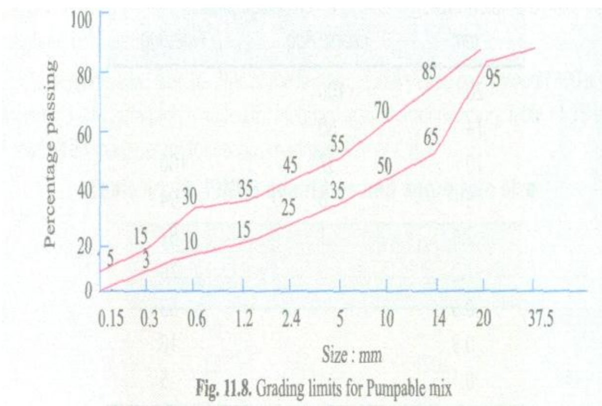

Fig. 1.9 Basic Design Calculations for a Pump able Concrete Mix:

The following is the procedure:

- While Fig. 1.8 shows the typical grading limits. Fig. 1.9 shows the more acceptable grading limits for pumpable concrete using 20 mm maximum size aggregates. The grading pattern should fall within the curve envelope of Fig. 1.9. If necessary the proportions of fine and coarse aggregate can be readjusted.
- The limits of the FINES content should be as given in Table 1.7.
- Mix proportions for 75 to 100 mm slump, are given in Table 1.8.
- The mix proportions given in Table 1.8 is based on the grading of aggregate as given in Table 1.10.
- The absolute density of material used is given in Table 1.9.
- The calculation of grading of combined aggregate on the basis of proportions given in Table 1.8 is given in Table 1.10 These combined grading figures should fall within the limits indicated in Fig. 1.9.
- The FINES content should then be worked out.
- Cement content = 310 kg (From Table 10.3)
- Fine aggregate grading shows that 18% passing through 0.3 mm sieve and 5% passing through 0.1 5 mm by interpolation probable percentage passing through 0.25 mm sieve = 15%.
- Fine particles in sand =15/100 *x* 880 = 132 kg/m^3
- Therefore, Total FINES =310+ 132 = 442 kg/m^3
- Referring to Table 10.2 for 190 l/m^3 of water content, the range of FINES is 330 to 465 kg/m^3.

Therefore, FINES of 442 kg/m^3 is considered suitable.

CONCLUSION

Ready mixed concrete plant has to follow up the good concrete mix design. It can be achieved by proper grading of aggregates and designing concrete mix using appropriate method. DOE (Department of Environment, U.K.) method using fly ash and water reducer admixture gives better result. To design a concrete mix there should be a thorough knowledge of properties of mix ingredients and fresh concrete. By proper designing concrete mix, stipulated strength and durability can be achieved. At the RMC plant, it is possible to achieve the concrete mix under close quality control.

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