Evaluation of Drying Shrinkage on PQC and HVFAC with and without Steel Fibers

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***Abstract*-In this paper Drying shrinkage and Moisture movement test is conducted confirming to IS 1199 and IS 4031 for Pavement Quality Concrete and High Volume Fly Ash Concrete.**

The integrity of such properties can be assessed by using material non-destructive test method — by using Ultra Sonic Pulse Velocity Test. In continuation with above studies to correlate for the compressive strength of the concrete, Static Flexure test is also conducted for the beams cast at the laboratory.

***Keywords*- PQC- pavement quality concrete. HVFAC- High volume fly ash concrete. UPV- Ultra sonic pulse velocity**

I. INTRODUCTION

Drying shrinkage is defined as the contracting of a hardened concrete mixture due to the loss of capillary water. The volume reduction that concrete suffers as the consequence of moisture mitigation when exposed to lower relative humidity environment than the initial one in its own pore system. This shrinkage causes an increase in tensile stress, which may lead to cracking, internal warping, and external deflection, before the concrete is subjected to any kind of loading.

1.1 Mechanism of drying shrinkage

Just as the hydration of cement is an everlasting process, the drying shrinkage is also an ever lasting process when concrete is subjected to drying conditions. The drying shrinkage of concrete is analogous to the mechanism of drying of timber specimen. The loss of free water contained in hardened concrete, does not result in any appreciable dimension change. It is the loss of water held in gel pores that causes the change in the volume. Under drying conditions, the gel water is lost progressively over a long time, as long as the concrete is kept in drying condition. Cement paste shrinks more than mortar and mortar shrinks more than concrete. Concrete made with smaller sized aggregate shrinks more than concrete made with bigger size aggregate. The magnitude of drying shrinkage is also a function of the fineness of gel. **THE FINER THE GEL MORE IS THE SHRINKAGE.**

II. LITERATURE REVIEW

Shrinkage is the decrease in volume of concrete with time. Unlike creep, another long-term property of concrete, shrinkage is independent of the external actions to the concrete. There are some types of shrinkage in the concrete which should be distinguished. Gilbert (2002) divided them into plastic shrinkage, chemical shrinkage, thermal shrinkage and drying shrinkage.

Plastic shrinkage is type manifests itself soon after the concrete is placed in the forms while the concrete is still in the plastic state. Loss of water by evaporation from the surface of concrete or by the absorption by aggregate or subgrade, is believed to be the reasons of plastic shrinkage. The loss of water results in the reduction of volume. The aggregate particles or the reinforcement comes in the way of subsidence due to which cracks may appear at the surface or internally around the aggregate or reinforcement.

In case of floors and pavements where the surface area exposed to drying is large as compared to depth, when this large surface is exposed to hot sun and drying wind, the surface of concrete dries very fast which results in plastic shrinkage.

Chemical shrinkage is caused by various chemical reactions within the cement paste, including the hydration shrinkage. While thermal shrinkage is related to the liberation of the heat of hydration as Portland cement reacts with water.

Drying shrinkage is the reduction in volume which is primarily caused by the loss of water during the drying process. Drying shrinkage normally accounts for the biggest proportion of the total long-term shrinkage. Factors which affect the drying of concrete also affect the magnitude and rate of development of drying shrinkage. Those factors include the type and content of cement or binder, water content and water to cement ratio, type of aggregate, maximum size and its proportion in the concrete, relative humidity and the size and shape of the member.

The aggregates plays a significant role in affecting the shrinkage of concrete (de Larrard et. al., 1994; Neville, 2000). This is related to the restraining effect of the aggregate on shrinkage. The higher aggregate content results in smaller shrinkage and also concrete with aggregates of higher modulus or rougher surfaces is more resistance to the shrinkage process.

The higher water to cement ratio normally results in higher shrinkage due to interrelated effects. As water to cement ratio increases, paste strength and stiffness decrease and as the water content increases, shrinkage potential increases because it also reduces the volume of restraining aggregates.

III. EXPERIMENTAL STUDIES

3.1 General

The experimental work is carried out in two stages. In the first stage shrinkage test was conducted on the specimen casted in laboratory for cubes of size 75mmX75mmX300mm. Secondly strength test are conducted using Ultrasonic Pulse Velocity test and Static flexure testing equipment. In the Concrete mix proportioning was done as per the ACI method and cubes of size 150mmX150X150mm,are casted for UPV test and compression test.

3.2.Material Testing

3.2.1 Fly Ash

In this study fly-ash used for casting the specimen is obtained from Raichur thermal power station, shaktinagar, this fly ash is class C-type. The physical tests conducted on fly-ash are shown in Table3.1

Table 3.1 Tests Conducted on Fly Ash

SL. No.	Test	Test Results	Requirements
1.	Normal Consistency	26%	Not Specified
2.	Specific Gravity	2.46	Not Specified
3.	Fineness (Using 90µ sieve size)	5%	Not to exceed 7%

3.2.2 Cement

In the present study Ultratech 53 grade OPC cement conforming to IS: 12269-1987 is used.

Brand of Cement : Ultra Tech

Type : OPC

Grade : 53

Table 3.2 Tests on Cement

SL. No.	Test	Test Results	Requirements as per IS: 12269-1987
1.	Normal Consistency	37%	-
2.	Initial Setting Time	45 min	Shall not be less than 30 minutes
3.	Final Setting Time	280 min	Shall not be more than 600 minutes
4.	Specific Gravity	3.1	2.99-3.15
5.	Fineness	3%	Not to exceed 10%
6.	Compressive strength a) 72±1hours(3days)	32.0Mpa	27 Mpa
	b) 168±1Hours(7day)	47.0Mpa	37 Mpa
	c) 672±4hours(28day)	56.0Mpa	53 Mpa

The results shown that the cement selected is conforming to the requirements as per IS: 12269-1987.

3.2.3 Fine aggregate

Locally available river sand is used as fine aggregate. The properties of the fine aggregates are determined by conducting tests as per IS: 2386-part 1. The test results are shown in Table3.3. Sieve analysis is conducted as per IS: 383-1970 on the fine aggregate sample to determine the particle size distribution and the test results are shown in Table3.4

Table 3.3 Tests on Fine Aggregates

Zone	Zone –II
Specific gravity	2.56
Bulk density	1.56 g/cc
Bulking of sand at 3% moisture content	21.15%

Table 3.4 Sieve-Analysis on Fine Aggregates

Sieve size	% passing	% retained	Percentage passing as per IS 383:1970 (2002)			
Mm	%	%	Zone-I	Zone-II	Zone-III	Zone-IV
4.75	98.40	1.60	100	100	100	100
2.36	94.40	5.60	90-100	90-100	90-100	95-100
1.18	83.40	16.60	30-70	75-100	85-100	95-100
0.6	55.80	44.20	15-34	35-59	60-79	80-100
0.3	9.20	90.80	5-20	8-30	12-40	15-50
150	0.80	99.20	0-10	0-10	0-10	0-15
Total Cumulative % retained		258.00				
Fineness Modulus		2.58				

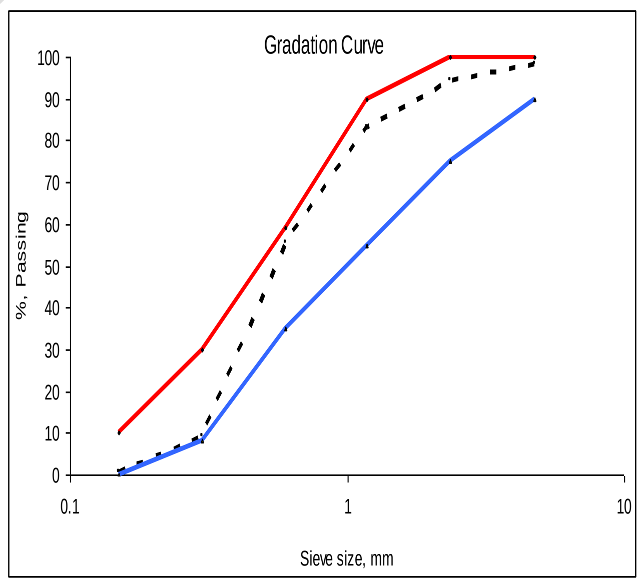


Figure 3.1. Grading of Fine Aggregate Confirming to Zone II of IS 383 1970

3.2.4 Coarse Aggregates

Coarse aggregates are those which are retained on IS sieve size 2.36 mm. The common coarse aggregates are crushed stone. Locally available crushed granite coarse aggregates are used in this study the tests for physical properties on coarse aggregates are conducted as per Is:383-1970 the test results are shown in Table3.5.

Proper grading of aggregates is essential to get required strength as per design mix. Test on combined coarse aggregates grading is conducted as per IRC 44-1976. The test results are shown in Table 3.5 the combined grading proportion of type-1 and type-2 aggregates obtained is 67:33.

Table 3.5 Tests on Coarse Aggregate

Sl No	Property	Test Results	Requirements as per IS 383-1970/ MoRTH 4th Revision Specifications
1.	Aggregate Impact Value %	24.3	Shall not exceed 45 percent by weight for aggregates used other than for wearing surfaces and 30 percent by weight for concrete for wearing surfaces
2.	Abrasion Value %	27.24	For aggregates to be used in concrete for wearing surfaces not exceed 30 percent For aggregates to be used in other than for wearing surfaces not exceed to 50 %.
3.	Aggregate Crushing Value %	22.89	Shall not exceed 45% for aggregate used other than for wearing surfaces, and 30 percent for wearing surfaces.
4.	Combined EI &FI Values %	28.44	Not to exceed 30%.
5.	Specific Gravity	2.65	-

3.2.5 Mix Proportion

In the present study ACI 211.4R method is used for arriving at the mix proportion. The design method is shown in annexure-1. The mix proportion arrived at is 1:1.85:2.65

The mix proportion for conventional concrete and fly ash admixed concrete is shown in Table3.6.

Table 3.6 Table showing different mix proportions.

Mix	Pavement Quality concrete	High volume Fly ash Concrete
Fly ash %	0	50
Water / binder ratio	0.37	0.37
Super plasticizer %	0	1.0
Cement kg/m3	405	202.5
Fly ash kg/m3	0	202.5
Fine aggregate kg/m3	750	750
Coarse aggregate type-I kg/m3	720.25	720.25
Coarse aggregate type-II kg/m3	354.75	354.75
Water kg/m3	150	150
Slump-mm	10	5
Compaction factor	0.79	0.81

3.2.6 Casting of Test Specimen

Cube specimen and beam specimen are cast as per IS: 516-1978, specimens of conventional cement concrete were removed after 24hours and immersed in water tank for a required period.

The specimens were removed from curing tank and tested immediately. Similarly for High Volume fly-ash specimen is removed after 48 hours and immersed in water tank for a required period. The specimen were removed from curing tank and tested immediately. Number of specimens casted is as shown in Table3.7.

Table3.7 Types and number of specimens casted

1	Cubes of Pavement Quality concrete,M40	6
2	Cubes of Pavement Quality concrete,M40	6
3	Cubes of High volume Fly ash Concrete M40,	6
4	Cubes of Pavement Quality concrete,M40 (with steel fibres)	6
5	Cubes of Pavement Quality concrete,M40(with steel fibres)	6
6	Cubes of High volume Fly ash Concrete M40,(with steel fibres)	6
7	Flexure beams of Pavement Quality Concrete M40	6
8	Flexure beams of HVFAC M40	6
9	Flexure beams of Pavement Quality Concrete M40(with steel fibres)	6
10	Flexure beams of HVFAC M40(with steel fibres)	6

3.3 Cube Compressive Strength Test

Cube specimen of both conventional concrete and high performance concrete were prepared using the design M-40 concrete mix with a water-binder ratio of 0.37. The cubes were tested in a compressive testing machine of 200 tonne capacity, as per IS: 516-1976 for determining compressive strength after 3, 7, and 28 days of curing.

The Cube specimen of M40 grade conventional cement concrete, and fly ash admixed cement concrete mixes are tested for compressive strength at 3, 7 and 28 days of curing. The cube compressive test results for all mixes are shown in Table 3.10 It is observed that there is an increase in cube compressive strength with increase in number of days of curing, fly ash admixed concrete gain more compressive strength compared in M-40 grade conventional cement concrete only at 56day curing.

3.4 Drying Shrinkage and Moisture Movement Test

The moulds shall be thinly covered with mineral oil. After this operation, the stainless steel or non-corroding metal reference inserts with knurl heads shall be set to obtain an effective gauge length of 250 mm, cart being taken to keep them clean and free of oil.

After filling the moulds, place them immediately in a moist room or moist closet for 24 ± 2 hours. Then remove the specimens from the moulds and immediately immerse in water at 27 ± 2°Cand allow them to remain there for six days. Remove the specimens from the water and measure its length using a length comparator. Protect specimens against loss of moisture prior to reading for initial length. The temperature of the test specimens at the time of initial measurement shall be 27 ± 2°C Store the specimens in a control cabinet maintained at 27 ± 2°C and 50± 5 percent relative humidity. Measure the length of the specimens again 28 days after the initial measurement. Place the specimens in the comparator with the same end uppermost with respect to the position of the specimens as when the initial measurement was made.When making the measurements, the specimens, the comparator, and the reference bar shall be at a temperature of 27 ± 2°C.After the specimens are measured for length as mentioned above at the age of 7 and 35 days, calculate the average difference in length of three specimens to the nearest 0.01 percent of the effective gauge length and report this difference as the drying shrinkage.

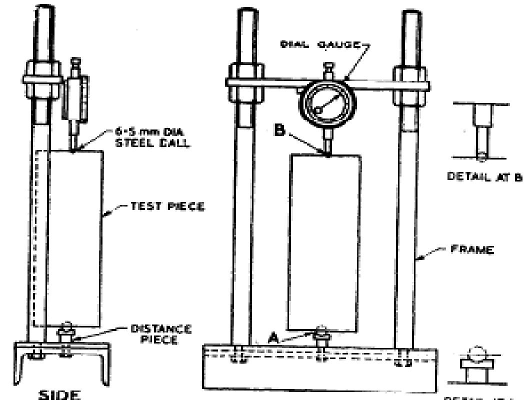


Fig 3.3. Length Comparator (Side and Frontal View)

IV. EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Drying Shrinkage and Moisture Movement

The results of drying shrinkage and moisture movement test conducted as per IS 1199 are tabulated as below.

Table 4.1.Drying Shrinkage and Moisture Movement for M-40 Controlled mix.

Sl. No.	Initial Length (mm)	Dry Measurement (mm)			Final Length (mm)	**Drying Shrinkage (%)**	Wet Measurement (mm)	(Dry - Wet) Measurement (mm)	**Moisture Movement (%)**
		44 hr	88 hr	132hr					
1	300.00	0.30	0.32	0.32	299.68	**0.00106**	0.22	0.10	**0.0333**
2	300.00	0.31	0.32	0.33	299.67	**0.00111**	0.21	0.12	**0.0400**
3	300.00	0.31	0.33	0.33	299.67	**0.00111**	0.21	0.12	**0.0400**
4	300.00	0.30	0.31	0.32	299.68	**0.00106**	0.21	0.11	**0.0400**
5	295.00	0.32	0.33	0.33	294.67	**0.00111**	0.22	0.11	**0.0373**

Table 4.2. Drying Shrinkage and Moisture Movement for M-40 High Volume Fly Ash Admixed Mix.

Sl. No.	Initial Length (mm)	Dry Measurement (mm)			Final Length (mm)	**Drying Shrinkage (%)**	Wet Measurement (mm)	(Dry - Wet) Measurement (mm)	**Moisture Movement (%)**
		44 hr	88 hr	132hr					
1	300.00	0.19	0.20	0.20	299.80	**0.00066**	0.12	0.08	**0.0266**
2	295.00	0.24	0.24	0.24	294.76	**0.00081**	0.13	0.11	**0.0287**
3	300.00	0.23	0.23	0.23	299.77	**0.00076**	0.11	0.12	**0.0302**
4	300.00	0.25	0.24	0.24	299.76	**0.00080**	0.12	0.12	**0.0293**
5	298.00	0.23	0.24	0.25	297.75	**0.00083**	0.13	0.12	**0.0275**

Table 4.3 Drying shrinkage and moisture movement for M-40 Controlled mix with steel fibres

Sl. No.	Initial Length (mm)	Dry Measurement (mm)			Final Length (mm)	**Drying Shrinkage (%)**	Wet Measurement (mm)	(Dry - Wet) Measurement (mm)	**Moisture Movement (%)**
		44 hr	88 hr	132hr					
1	300.00	0.19	0.23	0.23	299.77	**0.000766**	0.11	0.12	**0.0400**
2	295.00	0.22	0.22	0.22	294.78	**0.000745**	0.12	0.10	**0.0339**

3	300.00	0.23	0.23	0.23	299.77	**0.000766**	0.13	0.10	**0.0336**
4	300.00	0.22	0.23	0.24	299.76	**0.000800**	0.11	0.13	**0.0433**
5	298.00	0.21	0.25	0.25	297.75	**0.000838**	0.12	0.13	**0.0433**

Table 4.4 Drying Shrinkage and Moisture Movement for M-40 High Volume Fly ash With steel fibres

Sl. No.	Initial Length (mm)	Dry Measurement (mm)			Final Length (mm)	**Drying Shrinkage (%)**	Wet Measurement (mm)	(Dry - Wet) Measurement (mm)	**Moisture Movement (%)**
		44 hr	88 hr	132hr					
1	300.00	0.19	0.20	0.20	299.80	**0.00066**	0.12	0.08	**0.0266**
2	295.00	0.24	0.24	0.24	294.76	**0.00081**	0.13	0.11	**0.0373**
3	300.00	0.23	0.23	0.23	299.77	**0.00076**	0.11	0.12	**0.0400**
4	300.00	0.25	0.24	0.24	299.76	**0.00080**	0.12	0.12	**0.0400**
5	298.00	0.23	0.24	0.25	297.75	**0.00083**	0.13	0.12	**0.0403**

4.2 Static Flexure Test

For the same Beam specimens used for Static Flexure test was conducted and following results were obtained. Analysis has also been made to arrive at a mathematical relation between Flexure strength and Compressive strength.

Table 4.5.Static Flexure Test on M40 Controlled mix Beams

Sl. No.	Load in KN	Flexural Strength in N/mm^2	Compressive Strength in N/mm^2
1	8.73	4.37	38.88
2	9.10	4.55	42.25
3	8.90	4.45	40.41
4	8.67	4.34	38.35
5	8.54	4.27	37.21
6	8.83	4.42	39.78

Chart 4.1.Mathematical Relation Between Flexural Strength and Compressive Strength for M-40 Controlled mixBeams

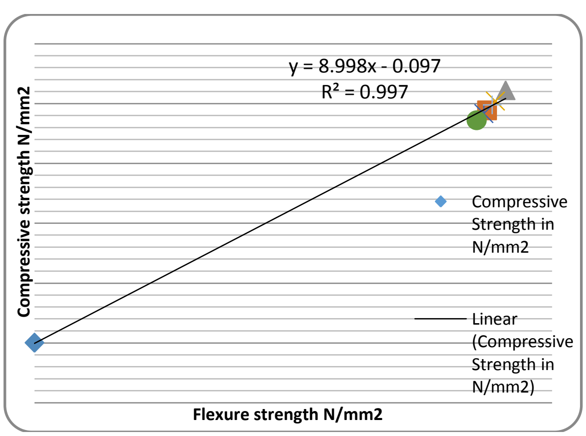
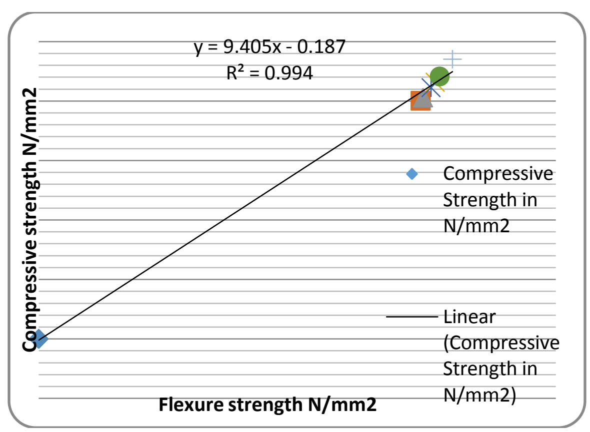


Table 4.6.Static Flexure Test on M-40 High Volume Fly Ash Admixed Concrete Beams

Sl No.	Load in KN	Flexural Strength in N/mm^2	Compressive Strength in N/mm^2
1	8.86	4.43	40.05
2	8.92	4.46	40.60
3	9.20	4.60	43.18
4	9.10	4.55	42.25
5	9.30	4.65	44.13
6	9.60	4.80	47.02

Chart 4.2.Mathematical Relation between Flexural Strength and Compressive Strength for M-40 High Volume Fly Ash Admixed Concrete Beams



4.3 Ultrasonic pulse velocity test

Table 4.7 Ultra Sonic Pulse Velocity Test on M-40Controlled mixCubes

Cube No	UPV Value in m/sec
1	4800
2	4800
3	5100
4	5000
5	4800
6	4500

Chart 4.4. Mathematical Relation Between Ultrasonic Pulse Velocity value and Compressive Strength for M40 Controlled mixCubes

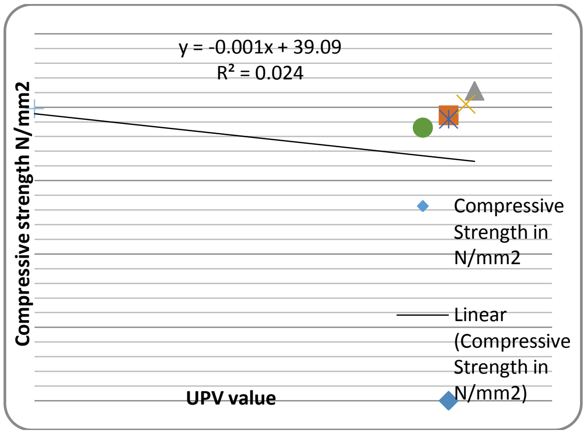
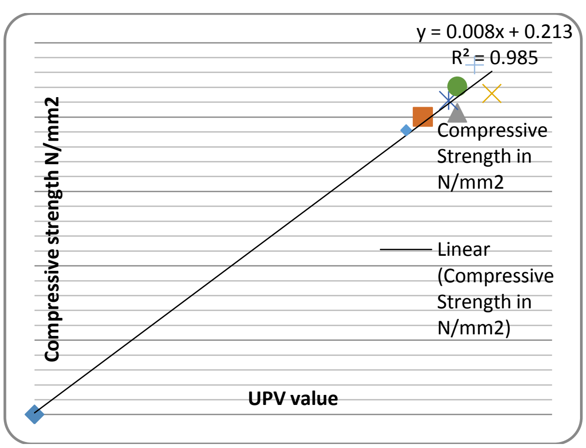


Table 4.8 Ultra Sonic Pulse Test on M-40 High Volume Fly Ash Admixed Concrete Cubes

Cube No	UPV Value in m/sec
1	4500
2	4900
3	5300
4	4800
5	4900
6	5100

Chart 4.5. Mathematical Relation Between Ultrasonic Pulse Velocity value and Compressive Strength for M-40High Volume Fly Ash Admixed Concrete Cubes



V. CONCLUSIONS

1. From the studies, the regression model was developed for strength evaluation which can be used to estimate concrete strength.
2. Combination of methods produces trustworthy results which are closer to true values while compared with individual methods. Acceptable concrete strength estimation was accepted.
3. From the experimental values, drying shrinkage and moisture movement values were evaluated and found that concrete strength estimated to an acceptable level.
4. Best fit curve was obtained by regression model for results obtained for UPV and static flexure test.
5. Importance of many influences on concrete shrinkage cannot be too highly emphasized including concrete constituents, construction practices ambient conditions, geometry and design and detailing of concrete elements.
6. The use of combined methods produces more trustworthy results that are closer to the true values when compared the use of above methods individually an acceptable level of precision was additionally appreciated for concrete strength estimation.
7. Therefore for engineering investigation, the resulting regression model for strength evaluation could be used securely for concrete strength estimation.

ANNEXURE-1

The ACI mix design method ACI 211.4R method is used to arrive the mix design. The mix proportioning arrived at is 1:1.85:2.65

Design Data

Characteristic compressive strength at 28 days= 40 N/mm^2
Maximum aggregate size = 20mm
Cement type= 53 grade OPC ULTRATECH
Specific gravity cement=3.12
Fine aggregate specific gravity=2.58
Fine aggregate confines to zone II of IS383:1970
Coarse aggregate specific gravity=2.60

i) TARGET MEAN STRENGTH

Fck= fck+(txs)

For more than 34.5 Mpa fck the value of txs becomes 9.70

Fck=40+9.7
=49.70Mpa- Target mean Strength

ii) SELECTION OF MAXIMUM SIZE OF COARSE AGGREGATE

The Maximum size of Coarse aggregate is selected from table 2 of ACI code
Required concrete strength less than 62 Mpa= Maximum aggregate size 20-25mm

Maximum size of Coarse=20mm

iii) ESTIMATION OF FREE WATER CONTENT

Super plasticizer Saturation point = 1.2%
Minimum water dosage (l/CM) = 145-155
Water content = (145+155)/2
=150Lt/cm

iv) ESTIMATION OF WATER CONTENT

Table 4 Entrapped air content
Aggregate size max. = 20mm
Entrapped air content=1.5%

v) SELECTION OF COARSE AGGREGATE CONTENT

Particle shape= cubic =1050-1100.
= (1050+1100)/2
Coarse aggregate dosage =1075kg/m^3

vi) SELECTION OF W/B RATIO

W/b ratio= 0.37

vii) QUANTITY OF CEMENT

W/C=0.37
150/cement=0.37
=150/0.37
Cement = 405.40 kg/m^3

viii) ESTIMATION OF FINE AGGREGATE.

V=1000-[Vm+ (cem/Sc) + (CA/Sca) +Vca]

=1000-[150+ (450/3.12) + (1075/2.60) +15]
=290.89x2.60
=750.050 kg/m^3
Fine aggregate =750.050 kg/m^3

	Cement:	Fine Aggregate:	Coarse Aggregate:	Water
Kg/m3	**405**	**:750**	**:1075**	**:150**
Ratio	**1**	**:1.85**	**:2.65**	**:0.37**

As per clause 602.3.2 of MORTH " specifications for Roads and Bridges" -2001 cement Quantity for PQC (pavement quality Concrete) should not be less than 350kg/m3 and not more than 425 kg/m3. The quantity of cement obtained is 405kg. Hence it is as per specification.

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