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Flexural Strength – A Measure to Control Quality of Rigid Concrete Pavements

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Abstract- Flexural strength is a measure of the tensile strength of an unreinforced concrete beam or slab to resist failure in bending. It is useful in knowing the quality of concrete work done in road construction. Because of low initial cost, flexible roads are preferred, to concrete road pavement, but bituminous roads gets deteriorated during rainy season and maintenance becomes costly, therefore

Government agencies have decided to go for concrete roads. Generally limestone as coarse aggregates for concrete roads are preferred but sometimes may not be easily available at all places nearby, therefore its replacement is necessary. Impact test, abrasion test & water absorption test were performed on demolished building waste concrete also, to recommend its suitability in making concrete roads as per Indian Standards Importantly boiling water curing has been done on some samples before flexural strength test for determining early strength of concrete, for predicting later age strength of concrete in roads. Behavior of flexural strength of concrete roads with lime stone, locally available is studied in this paper for concrete pavements. Flexural strength is measured by loading 700 x 150 x 150 mm concrete beams with a span length of at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading). Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design.

Keywords – Impact test, abrasion test, Flexure test, demolished waste, concrete roads .

1 INTRODUCTION

In New Delhi, recently elected Minister of transport & shipment Mr.Nitin Gadkari noticed that during rainy season the flexible pavement roads gets deteriorated due to water logging, (apparent from photographs attached). Therefore government has resolved that in future all National Highways should be made with rigid pavements. Earlier during Congress government rule also Delhi Chief Minister Dr.Sheela Dixit favoring concrete roads over bitumen roads in capital, invited chamber members CII and ACC and other largest companies agreed to explore the possibility of workable solution of conversion of all flexible pavement roads into rigid pavement. In the seminar organized by CII along with department of Industrial policy and promotion, Government of India favored concrete roads construction for its long lasting nature and low cost maintenance.

In India over 626 million tones of construction and demolition waste is produced every year, which is 52 times more than the ministry of environment and forests estimate of construction and demolition waste. Thus huge quantity of demolished building waste is being generated by large infrastructure projects across the country with serious environment consequences. To make value added reuse of concrete waste the authors carried out various tests on demolished concrete waste for testing its suitability in concrete beams for concrete road pavements decreasing the requirement to use virgin non-renewable resources so that fresh lime stone can be replaced by demolished concrete waste. The results are found encouraging as discussed in this report.

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Photo 1 Water logging problems with Flexible Pavements

Photo 2 Cracks in Rigid Pavement

As discussed earlier flexible pavement are not preferred now a days in road construction because it gets damaged in rainy season (Photo 1) due to heavy rain and also due to heavy traffic it gets detoriated hence continuous maintenance is required . Also there is expansion and contraction of bitumen in flexible pavement which also reduces its life. Construction cost of concrete pavement is high as compared to flexible pavement even though it is preferred due its low maintenance cost and long life .

Also it has been proved that driving on concrete roads offer significant fuel savings compared to other type of roads, which ultimately results in reduction in Co_2 emission ,hence reduction in global warming. The reason for the lower fuel consumption is due to the concrete surfacing lower rolling resistance value. This can be attributed to differences associated with macro texture and pavement stiffness ,

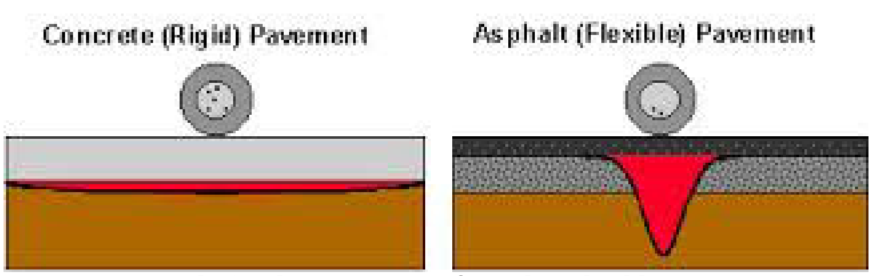

Fig.1 Load Distribution in case of Rigid & Flexible Pavements

A rigid concrete pavement distributes heavy loads over a relatively wider area, with minimal pressure on the sub-grade – the natural soil under the roadway. On the other hand, flexible asphalt material concentrates weight and transmits it deeper into the in upper flexible layer, hence resulting in its failure, where as concrete pavement acts as bridge over the sub-grade, hence less stress on sub-grade also less effect of water .

roadbed (Fig.1). Therefore flexible pavements fail also due to impact load if proper settlement is not done also during rainy season if water seeps under the flexible pavement and if soil is loose ,make the sub-grade soil weak resulting in overstress Widespread use of concrete roadways produces a significant positive economic impact on the movement of goods due to construction of smoother and quieter concrete pavements in recent years.

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Also it has been seen concrete pavement reflects light in a diffuse manner, compared to the slightly spectral (somewhat mirror-like) reflectiveness of asphalt pavement. As a result, a concrete highway requires fewer lights per unit length of pavement to achieve the same level of illumination. The report concludes that the light colour of concrete results in a cost-saving of up to 31 percent for night-lighting, including construction, energy consumption and maintenance, when compared with the lighting requirements of asphalt pavement.

2 Theory of Flexure Test

When an object formed of a single material, like a wooden beam or a steel , is bent it experiences a range of stresses across its depth (Fig.2). At the edge of the object on the inside of the bend (concave face) the stress will be at its maximum compressive stress value. At the outside of the bend (convex face) the stress will be at its maximum tensile value. These inner and outer edges of the beam are known as the 'extreme fibers'. Most materials fail under tensile stress before they fail under compressive stress, so the maximum tensile stress value that can be sustained before the beam or rod fails is its flexural strength.

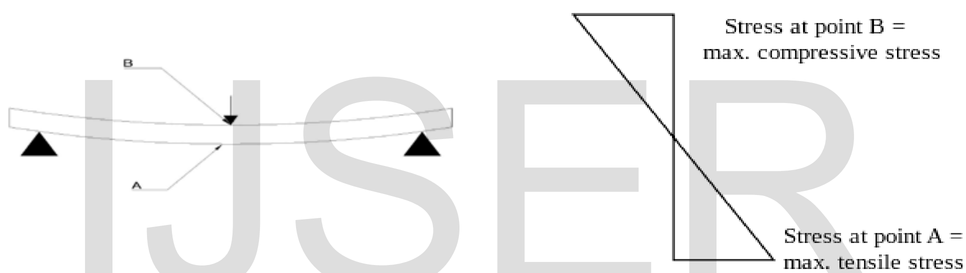

Fig. 2 - Beam of material under Bending & Stress distribution across beam

Why Flexure Strength test is required?

Designers of pavements use a theory based on flexural strength. Therefore, laboratory mix design based on flexural strength tests may be required, or a cementitious material content may be selected from past experience to obtain the needed design MR. Some also use MR for field control and acceptance of pavements. Very few use flexural testing for structural concrete. Agencies not using flexural strength for field control generally find the use of compressive strength convenient and reliable to judge the quality of the concrete as delivered

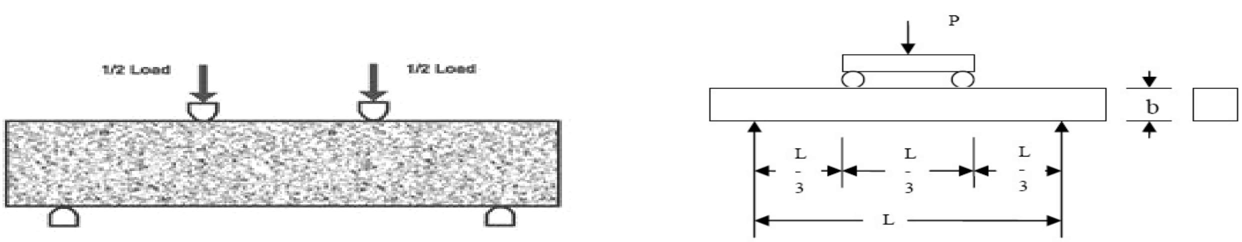

Fig. 3 – Third point loading – half the load is applied at each third of span length

3. Problems with Flexure Strength?

Flexural tests are extremely sensitive to specimen preparation, handling, and curing procedure. Beams are very heavy and can be damaged when handled and transported from the jobsite to the lab. Allowing a beam to dry will yield lower strengths. Beams must be cured in a standard manner, and tested while wet. Meeting all these requirements on a jobsite is extremely difficult, often resulting in unreliable and generally low MR values. A short period of drying can produce a sharp drop in flexural strength.

Many state highway agencies have used flexural strength, but are now changing to compressive strength or maturity concepts for job control and quality assurance of concrete paving. The data point to a need for a review of current testing procedures. They also suggest that, while the flexural strength test is a useful tool in research and in laboratory evaluation of concrete ingredients and proportions, it is too sensitive to testing variations to be useable as a basis for the acceptance or rejection of concrete in the field

NRMCA and the American Concrete Pavement Association (ACPA) have a policy that compressive strength testing is the preferred method of concrete acceptance and that certified technicians should conduct the testing. ACI Committees 325 and 330 on concrete pavement construction and design and the Portland Cement Association (PCA) point to the use of compressive strength tests as more convenient and reliable.

The concrete industry and inspection and testing agencies are much more familiar with traditional cylinder compression tests for control and acceptance of concrete. Flexure can be used for design purposes, but the corresponding compressive strength should be used to order and accept the concrete. Any time trial batches are made, both flexural and compressive tests should be made so that a correlation can be developed for field control.

4. Flexural Strength Calculation -

Flexure Strength Test (ASTM C78)

Used for measuring Modulus of Rupture (MR)

Important test for road and airport concrete pavements.

Beam specimen of square cross-section is loaded into a 3-point loading apparatus(Fig 3).

Apparatus

The testing machine (Photo 3) may be of any reliable type of sufficient capacity for the tests and capable of applying the load at the rate of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm . The permissible errors shall be not greater than ± 0.5 percent of the applied load where a high degree of accuracy is required and not greater than ± 1.5 percent of the applied load for commercial type of use. The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span, that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints. One suitable arrangement which complies with these requirements is indicated in Fig.4.

Procedure -Test specimens stored in water at a temperature of 24° to 30°C for 48 hours before testing, shall be tested immediately on removal from the water whilst they are still in a wet condition. The dimensions of each specimen shall be noted before testing. No preparation of the surfaces is required.

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Placing the Specimen in the Testing Machine -The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen shall then be placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould, along two lines spaced 20.0 or 13.3 cm apart. The axis of the specimen shall be carefully aligned with the axis of the loading device. No packing shall be used between the bearing surfaces of the specimen and the rollers. The load shall be applied without shock and increasing continuously at a rate such that the extreme fiber stress increases at approximately 7 kg/sq cm/min, that is, at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

Calculation — The flexural strength of the specimen shall be expressed as the modulus of rupture *f*b, which, if '*a*' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5 kg/sq cm as follows:

$$\textbf{Flexural Strength } (f_b) = \frac{p \times l}{b \times d^2}$$

when '*a*' is greater than 20.0 cm for 15.0 cm specimen, or greater than 13.3 cm for a 10.0 cm specimen, or

$$\textbf{Flexural Strength } (f_b) = \frac{3p \times a}{b \times d^2}$$

when '*a*' is less than 20.0 cm but greater than 17.0 cm for 15.0 cm specimen, or less than 13.3 cm but greater than 11.0 cm for a 10.0 cm specimen

b = measured width in cm of the specimen,
d = measured depth in cm of the specimen at the point of failure,
l = length in cm of the span on which the specimen was supported, and
p = maximum load in kg applied to the specimen.

where , If '*a*' is less than 17.0 cm for a 15.0 cm specimen, or less than 11.0 cm for a 10.0 cm specimen, the results of the test shall be discarded.

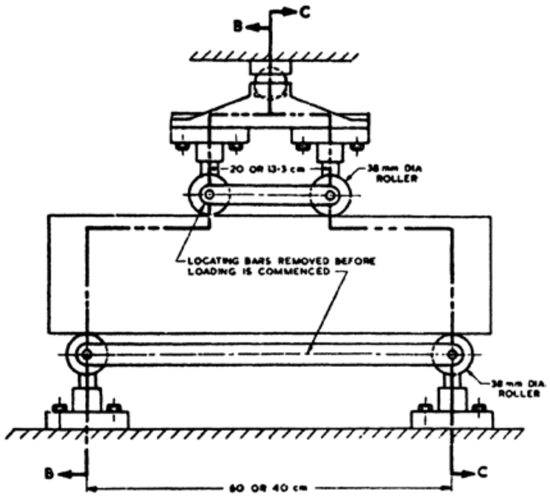

Fig. 4–Arrangement of Beam in Flexure Test Machine

Photo 3-Hand operated Flexure Test Machine

5. Similitude Models for flexure Strength of beam with natural lime stone as coarse aggregate

Photo 4 -Accelerated curing of beam (BWC)

Photo 5 –Thermometer measuring water temperature

Photo 6- Failure of concrete beam

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Concrete pavement is preferred to flexible pavement and its benefits are also discussed above , but due to its heavy cost of construction there is need to determine its strength at early ages. It has been decided to carry out test of flexural strength of concrete beams for determining the quality of concrete used in concrete roads. Generally test for flexural test of concrete beam is performed after 28 days of curing , but it has been observed 28 days strength determination test is too late for determining quality of concrete . If proper amount of ingredients are not added according to concrete mix design or proper casting of concrete is not done, concrete pavement damages due to formation of cracks (Photo 2) which cannot be repaired to give its full strength, for which it has been constructed.

So, boiling water curing test on concrete beam has been performed and correlation has been done which can predict 28th day strength of concrete after 1st day of casting when the concrete is in green state and when not much concrete work has been done over weak concrete , which will enable the site supervisor to make changes in quantity of ingredients if required, so that desired strength can be achieved after 28 days .

The test is simple and can be performed by unskilled labour also, because only water temperature is to be maintained at 100^{0}C (boiling) (Photo 4) which is to be measured time to time with the help of thermometer (Photo 5) for 3½ hours . Also no need to carry heavy beams to laboratory because testing can be done at site by hand operated flexural testing machine . This is very important for the concrete pavement work done in remote areas where there is no lab facility for checking the quality of concrete during construction.

Total 12 beams of concrete grade M40 [(1:1.125:2.95) w/c ratio 0.52 and cement used is OPC 43 grade] of size 700x150x150mm (l x b x h) were casted for performing flexural test of concrete for road pavement as per IS 516-1959. 3 concrete beams were casted in moulds and are removed from mould after 23 hours and are cured in Boiling Water (100^{0}C) for 3½ hours and are tested (Photo 6) immediately after removal from boiling curing tank . Another 3 beams were casted and cured in normal water for 3 days and are cured in Boiling Water (BWC) for 3½ hours and are tested immediately , Remaining 3-3 beams were allowed to cure in normal water for 7 days and 28 days respectively in normal curing (NC) at room temperature and then tested .Test results are as under:

Determination of Flexural Strength in Tons

S.No	23Hours NC + 3½ BWC	3 DAY NC + 3½ BWC	7 DAY NC	28 DAY NC
1	3.70 Tons	3.50 Tons	5.0 Tons	5.0 Tons
2	3.70 Tons	2.50 Tons	4.5 Tons	6.0 Tons
3	3.65 Tons	2.50 Tons	4.5 Tons	6.0 Tons

3.70 Tons x 9.81 = 36.29KN = 36.29 x 1000 = 36290 N,

$$\textbf{Flexural Strength } (f_b) = \frac{\mathbf{p \, X \, l}}{\mathbf{b \times d^2}} = \frac{36290 \text{ N} \times 400 \text{ mm}}{150 \text{ mm} \times 150 \text{ mm} \times 150 \text{ mm}} = 4.30 \text{ N/mm}^2$$

Table 1 Determination of Flexural Strength in N/mm^2

S.No	23Hours NC + 3½ Hours BWC	3 DAY NC + 3½ Hours BWC	7 DAY NC	28 DAY NC
1	4.30 N/mm^2	4.069 N/mm^2	5.81 N/mm^2	5.81 N/mm^2
2	4.30 N/mm^2	2.90 N/mm^2	5.32 N/mm^2	6.976 N/mm^2
3	4.25 N/mm^2	2.90 N/mm^2	5.32 N/mm^2	6.976 N/mm^2
	23Hours NC + 3½ Hours BWC	**3 DAY NC + 3½ Hours BWC**	**7 DAY NC**	**28 DAY NC**
Average	4.38 N/mm^2	3.28 N/mm^2	5.48 N/mm^2	6.587 N/mm^2

OPC 43 Grade Cement		
M40 Mix 23Hours NC + 3½ BWC	4.38 N/mm^2	(4.38 / 6,587) x 100 = 66.49%
M40 Mix 28 Days Normal curing	6.587 N/mm^2	

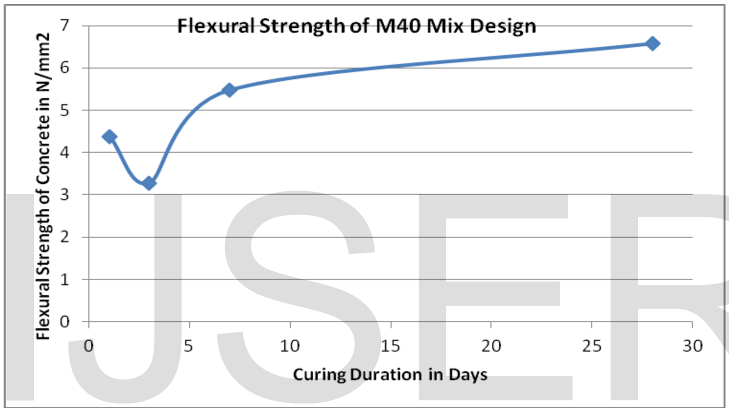

Fig.5 Flexure Strength of Concrete M40 Mix Design

Flexural strength in concrete of OPC Cement 53 grade with M40 mix proportions, gains approx 65-70 % on 1st day by accelerated curing (boiling water curing) of its 28 days strength by normal curing. With average values of flexure strength determined above graph is plotted as shown in Fig.5. The formula to predict the flexural strength of beam is derived from experimental results as explained below:

Let the Flexure strength gain shown by mean values in Fig.(5) be given by the equation:

$$\boxed{y = a(b)^x} \qquad \text{------- (1)}$$

Where y – Flexure Strength after particular number of days of curing

a - factor comprising parameters of different mix design of concrete,

b - Coefficient of number of days the system is subject to curing, type of curing and different water cement ratio used in the mix

x - Number of days the cubes are subject curing in lab

The parameters ‘a’ and ‘b’ can be determined by substituting the standard values in the equation (1).

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Flexure Strength Curve $y=ab^x$

Let the strength variation equation be:

Concrete Grade	**Days of Curing**	**23Hours NC + 3½ Hours BWC (N/mm^2)**	**3 Days NC + 3½ Hours BWC (N/mm^2)**	**7 Days NC (N/mm^2)**	**28 Days NC (N/mm^2)**
M40	Stress	4.38	3.28	5.48	6.58

Solution for a and b constants of the required equation

No.	x	y	Y	x^2	xY
			$\log_{10}y$		
1	1	4.38	0.64147	1	0.64147
2	3	3.28	0.51587	9	1.54762
3	7	5.48	0.73878	49	5.17146
4	28	6.58	0.81823	784	22.9103
	39	19.72	2.71435	843	30.27

Eqn. $4A+39B = 2.7144$

$39A+843B = 30.271$

On solving $A = 0.5984$ Therefore $a = 3.9664$

$B = 0.00822$ and $b = 1.0191$

and final equation is $y = 3.97(1.019)^x$ -- (4)

Targeted strength of 28^{th} day $= 3.97(1.019)^x = 6.7246$

Check for 1. strength after 7 days 4.5291

Check for 2. strength after 28 days 6.7246

(i) Above equation (4) shows that the full flexure strength will be achieved after 28 days casting of the concrete beam .

(ii) Boiling water curing gives higher values of Flexure strength over normal curing method at initial stages.

(iii) The variation of flexural strength from 7 to 28 days curing in immersed water is identical to results of normal conditions.

6. Demolished building waste concrete V/s Lime stone from mines –

Also following tests have been conducted with demolished waste concrete collected from Bhilai Steel Plant township demolished quaters to determine its suitability as coarse aggregate and quality assessment of concrete in road pavements :

Table 2. <u>Los Angeles Abrasion Test</u> - <u>Demolished concrete waste</u> as coarse aggregate in concrete road construction (IS:2386 Part-IV-1963)

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Sr.No	Description	**Sample 1**	**Sample 2**	**Sample 3**	**Average**
1	Weight of Specimen = w1 grams .	5000	5000	5000	
2	Weight of specimen after abrasion test , coarser than 1.70mm IS sieve = w2 grams	3604	3650	3590	
3	Percentage wear = [(w1-w2)/w1] x 100	27.92%	27.00%	28.20%	**27.70**%

Remark : The above sample satisfies with the specifications required (Max = 40%)

Table 2(a) **Los Angeles Abrasion Test** - **Natural lime stone** as coarse aggregate in concrete road construction

Sr.No	Description	**Sample 1**	**Sample 2**	**Sample 3**	**Average**
1	Weight of Specimen = w1 grams .	5000	5000	5000	
2	Weight of specimen after abration test , coarser than 1.70mm IS sieve = w2 grams	3955	3980	3993	
3	Percentage wear = [(w1-w2)/w1] x 100	20.90%	20.40%	20.14%	**20.48**%

Remark : The above sample satisfies with the specifications required. (Max = 40%)

Table 3. Aggregate Impact Value Test (IS:2386 Part-IV-1963)

Size of sample 10 mm **Demolished concrete waste**

Sr.No	Description	**Sample** 1	**Sample** 2	Average
1	Weight of Surface dry sample passing through 12.5 mm and retained on 10 mm IS sieve = A grams .	344	352	
2	Weight of fraction passing through 2.36mm IS sieve after the test = B grams	78	85	
3	Percentage wear = (B/A) x 100	22.67 %	24.14 %	23.40 %

Remark : The above sample satisfies with the specifications required. MAX= 30%

Table 3(a) Size of sample 10 mm **Natural Lime Stone**

Sr.No	Description	**Sample** 1	**Sample** 2	Average
1	Weight of Surface dry sample passing through 12.5 mm and retained on 10 mm IS sieve = A grams .	366	369	
2	Weight of fraction passing through 2.36mm IS sieve after the test = B grams	70	71	
3	Percentage wear =(B/A) x 100	19.13 %	19.24 %	19.19 %

Remark : The above sample satisfies with the specifications required. MAX= 30%

Table 4. Water Absorption Test of Coarse Aggregates as per IS: 2386 (Part III)–1963
Water Absorption Test of Coarse Aggregates - for **Demolished concrete waste** as coarse aggregate in concrete road construction (IS:2386 Part-IV-1963)

Sr.No	Description	Sample 1	Sample 2	Sample 3
1	Weight of saturated surface dried sample in grams (A)	2410	2380	2493
2	Weight oven- dried sample in grams (B)	2375	2341	2455
3	Water absorption = [(A-B) / B] x 100 %	35/2375 x 100 = 1.47%	39/2341 x 100 = 1.66%	38/2455 x 100 = 1.54%
	Average valve	1.55 %		

Remark : The above sample satisfies with the specifications MAX= 2% Water absorption permitted

Table 4(a) Water Absorption Test of Coarse Aggregates - for **Natural Lime Stone** as coarse aggregate in concrete road construction (IS:2386 Part-IV-1963)

Sr.No	Description	Sample 1	Sample 2	Sample 3
1	Weight of saturated surface dried sample in grams (A)	2155	2258	2163
2	Weight oven- dried sample in grams (B)	2145	2246	2151
3	Water absorption = [(A-B) / B] x 100 %	10/2145 x 100 = 0.46%	12/2246 x 100 = 0.53%	12/2151 x 100 = 0.55%
	Average valve	0,51%		

Remark : The above sample satisfies with the specifications MAX= 2% Water absorption permitted

7. Conclusion –

From the experimental work carried out on concrete beams the following conclusion can be drawn:

1. The gain of flexure strength of concrete is high during initial stages (Table 1) i.e (1^{st} day) if boiling water curing is done because it has been found hydration process becomes fast when water temperature is increased , hence 1^{st} day strength can guide in determining ultimate 28^{th} day strength .

2. Abrasion test, aggregate impact value test, water absorption test values(Table 2 , 3 & 4) of RCA is higher than natural aggregate but within the range as per IS recommendations.

3. By applying more advanced and sophisticated treatment process the usage of RCA in concrete mixture can be found to have strength in close proximity to that of natural aggregate and can be used effectively as a full value component of new concrete.

From foregoing study the similitude model for M40 grade concrete is determined:

$y= 3.97(1.019)^x$ for natural lime stone

Where y – flexural strength to be determined for mix of concrete in-situ,

x – Number of days the curing is done

Above equations can give the value of flexural strength for M40 grade concrete with respect to time.

4. Boiling water curing method for predicting 28^{th} day tensile strength can be applied any where without much difficulty , as at present there is no such method is adopted for determining strength of concrete pavement .

5. By knowing suitability of demolished concrete waste in fresh concrete as coarse aggregates for concrete road pavements, major problem of extracting and transporting the coarse aggregates from quarry to site can be minimized, also problem of transporting and depositing of demolished concrete is also reduced , hence reduction in cost of transportation , which causes reduction in environmental pollution due to burning of fuels, which ultimately causes reduction in global warming .

References

1. How Should Strength be Measured for Concrete Paving? Richard C. Meininger, NRMCA TIL 420, and Data Summary, NRMCA TIL 451, NRMCA, Silver Spring, MD.

2. Concrete Strength Testing, Peggy Carrasquillo, Chapter 14, ASTM STP 169C, Significance of Tests and Properties of Concrete and Concrete-Making Materials, American Society for Testing and Materials, West Conshohocken, PA.

3. "Studies of Flexural Strength of Concrete, Part 3, Effects of Variations in Testing Procedures," Stanton Walker and D. L. Bloem, NRMCA Publication No. 75, NRMCA, Silver Spring, MD.

4. Variation of Laboratory Concrete Flexural Strength Tests, W. Charles Greer, Jr., ASTM Cement, Concrete and Aggregates, Winter, 1983, American Society for Testing and Materials, West Conshohocken, PA.

5. "Concrete Mixture Evaluation and Acceptance for Air Field Pavements" Richard C. Meininger and Norm Nelson, NRMCA Publication 178, September 1991, NRMCA, Silver Spring, MD.

6. Compression vs. Flexural Strength for Quality Control of Pavements, Steve Kosmatka, CTT PL 854, 1985, Portland Cement Association, Skokie, IL.

7. Time to Rein in the Flexure Test, Orrin Riley, ACI Concrete International, August, 1994, American Concrete Institute, Farmington Hills, MI.

8."PREDICTIVE MODEL OF COMPRESSIVE STRENGTH FOR CONCRETE IN-SITU" , Jayant Supe & Dr. M.K.Gupta, IJSCER , Vol-3, No-1, 2014 , Pages 90-102.

9. "Suitability of demolished concrete waste in modern construction & its 28th day strength prediction", Jayant Supe & Dr. M.K.Gupta , IJCSEIERD Vol. 4, Issue 4, Aug 2014, 75-86

10. "Role of heat of hydration in attaining early strength gain of cement in concrete" , Supe J & Dr.Gupta MK , IJPRET, 2014; Volume 3 (2): 94-106 .