UTILIZATION OF RAP AGGREGATE IN THE PREPERATION OF CONCRETE TO IMPROVE ITS STRENGTH

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ABSTRACT

Concrete is the basic material in all construction works and coarse aggregates constitute more than 50% of the mix. But the procurement and generation of natural aggregates are getting difficult day by day because of lack of natural source and environmental effects. In search of alternative for natural aggregates, lead to the usage of Reclaimed Asphalt Pavement aggregates, which are produced abundantly due to replacement of Flexible Pavements with Rigid Pavements in India. This study is taken up to determine the variation of different properties of strength and mainly durability of concrete pavements with natural aggregates and RAP aggregates. The cubes and beams are cast and tested for compressive Strength and Flexural Strength. The results can be analyzed to identify the importance of RAP aggregates for its effective and efficient usage for present scenario of India. The RAP Aggregates are procured from college transportation laboratary. RAP aggregates are replaced with Natural Aggregates by 10%, 20%, 30%, 40% and 50% and evaluated.

1. INTRODUCTION

1.1 Problem Description

Now a days the importance of the pavement and its maintenance has been rapidly increasing due to the globalization and industrialization. But the increasing demand is not been met with the supply in an efficient manner due to the non sustainability of the resources. In India the network of roads is managed by the various government agencies under “Ministry of Road Transport and Highways” (MORTH). India's road network is gigantic and said to be only after the United States of America. But one of the striking underlying facts is the condition of the roads. It has been the case since 30 years.

Most of the roads were designed as single lane and quality of construction was also poor due to lack of supervision. The traffic volumes on the primary road system have seen tremendous increases over the last 20 years, leading to earlier-than-expected failures of highway pavements. The distressed pavements are left unmanaged and there is a need to rehabilitate the roads by using the environmental sustainable techniques so as to develop it for future generations. The rehabilitation techniques can be developed by studying the types of distresses, material conditions and environment conditions.

The Recycling of existing bituminous mixes are the only alternatives, through the reuse of aggregates and bitumen. Pavement rehabilitation is a logical and practical way to conserve our diminishing supply of construction materials and to help reduce the cost of preserving our existing pavement network.

Developing a rehabilitation design generally requires extensive investigation into the condition of the existing pavement structure, performance history, and laboratory testing of materials to establish suitability of existing and proposed materials for use in the rehabilitation design. Assessment of residual strength of existing pavement layers including sub-grade in its existing state plays a key role in evolving an economical solution for rehabilitation of old pavements. We have considered use of dismantled pavement materials like Recycling Asphalt Pavements (RAP) materials in the project. The research work deals with the study of reclaimed asphalt materials and usage of RAP material in the concrete.

2. LITERATURE SURVEY

Delwar, Fahmy and Taha (1997) of the University of Washington and Sultan Qaboos University performed one of the first studies on this “green” concrete in 1997. The main goals of their research entailed an investigation on the feasibility of using RAP as aggregate in Portland cement concrete (PCC), and the determination of key material properties and characteristics of the alternative material. RAP millings for use in the concrete test mixtures were obtained from an asphalt producer in Spokane, Washington. The research team processed the material through a set of sieves, removing any aggregate larger than ¾-inch and fractionating the material on the No. 4 sieve. Standard concrete sand and gravel, as well as type I/II cement were purchased from a company in Moscow for use in the study. Mixes containing 10 different aggregate arrangements with two different water &cement (w/c) ratios were tested for compressive strength and stress-strain characteristics. Data on the slump, air content, and unit weight of the wet concrete were also recorded.

Huang, Shu, and Li (2005) of the University of Tennessee and Louisiana State University expanded the available information on concrete containing RAP with their work in 2005. The objective of their study was to further research the effect of the inclusion of RAP aggregates on the toughness and brittle failure behavior of Portland cement concrete. The study hypothesized that the fine layer of asphalt coating the individual pieces of aggregate protects the particles from breakage and facilitates the increased dissipation of energy in the event of a crack.

Huang and Shu (2005) performed additional testing on specimens that included admixtures to help improve the performance of the material (Huang, Shu, & Li, 2005). Both silica fume and a high-range water reducing agent (HRWRA) were added to help reduce the loss of strength accrued by the use of the RAP aggregate. As in prior studies, several mix designs using different percentages of coarse and/or fine RAP aggregate (10, 30, 50, or 100 percent by weight) were used as a replacementfor virgin aggregate.

Hossiney (2008) from the University of Florida worked with the Florida Department of Transportation (FDOT) to study the performance of RAP concrete used in a rigid pavement application. In their study, four concrete mixtures containing reclaimed asphalt pavement were evaluated in a laboratory setting. The tested material properties were then used to create a finite element model to assess how the concretes would behave as a pavement under typical Florida roadway conditions. The natural aggregate for the mixing experiment consisted of a porous limestone coarse rock and a standard silica sand fine material. The mixtures evaluated in the studyincluded mix designs containing 0, 10, 20, and 40 percent RAP aggregate. Laboratory test results indicated that the compressive strength, splitting tensile strength, flexural strength, and elastic modulus of the hardened material were inversely related to the amount of RAP in the mix; these material properties all decreased as the RAP replacement rate was increased.

3. OBJECTIVE AND METHODOLOGY

3.1 Objective

The objective of the project deals with the identification of the distressed pavement and developing the rehabilitation technique utilizing RAP material so that the fatigue life of the road increases in an economic way. The methodology involved in the achievement of this objective is

i) To develop mix design methodology for mix 20 MPa
ii) To study the effect of adding different percentages (0% - 50%) of RAP Aggregates by the weight of fine and coarse aggregates in the preparation of concrete mix.
iii) To determine the workability of freshly prepared concrete by Slump test & compaction factor test.
iv) To determine the compressive strength of cubes at 7, 14, 28 days.
v) To determine the Flexural strength of beams at 28 days.

3.2 Methodology

1. Collect the RAP wastage and dry it.
2. Extract the aggregates and bitumen from RAP. Clean the aggregate thoroughly and oven dry it. Perform the sieve analysis on RAP aggregate.
3. Physical properties of cement, fine aggregate, coarse aggregate and RAP aggregate.
4. Find out the mix design M20 grade of concrete. The concrete, coarse aggregate is replaced with RAP aggregate with various percentages 0%, 10%, 20%, 30%, 40% & 50%.
5. Preparation of Concrete cubes and beams based on mix proportions. Find out the Compressive strength for cubes and flexural strength for beams.
6. Results & discussions

4. EXPERIMENTAL INVESTIGATIONS

4.3 Laboratory Tests on RAP

Bitumen is a mixture of organic liquids that is black, highly viscous, sticky product used for paving roads, waterproofing products (used in sealing roofs). There are many tests which are conducted to check the quality of bitumen. Bitumen is very important component of many construction sites like roads, highways. To check the properties of the RAP sample collected, many tests are conducted to ensure the quality of bitumen such as Binder Content, Gradation.

4.3.1 Extraction of aggregates from RAP

The amount of binder to be added to a bituminous mixture cannot be too excessive or too little. The principle of designing the optimum amount of binder content is to include sufficient amount of binder so that the aggregates are fully coated with bitumen and the voids within the bituminous material are sealed up. As such, the durability of the bituminous pavement can be enhanced by the impermeability achieved. Moreover, a minimum amount of binder is essential to prevent the aggregates from being pulled out by the abrasive actions of moving vehicles on the carriageway.

The binder content of existing RAP found out by the Bitumen extraction test. This test is done to determine the bitumen content. The apparatus needed to determine bitumen content are Centrifuge extractor, bowl, filter paper, balance and commercial benzene. The procedure is as follows

- Take 1000 grams of representative sample and place in the bowl of extraction apparatus.
- Add benzene to the sample until it is completely submerged.
- Dry and weigh the filter paper and place it over the bowl of the extraction apparatus containing the sample.
- Clamp the cover of the bowl tightly.
- Place a beaker under the drainpipe to collect the extracted bitumen.
- Sufficient time is allowed for the solvent to disintegrate the sample before running the centrifuge as shown in Figure 4.8. Run the centrifuge slowly and then gradually increase the speed to a maximum of 3600 rpm.

Figure 4.8: Bitumen Extraction

- Maintain the same speed till the solvent ceases to flow from the drainpipe.
- Run the centrifuge until the bitumen and benzene are drained out completely as shown in Figure 4.9.

Figure 4.9: Centrifuge Bowl

- Stop the machine, remove the cover and add 200ml of benzene to the material in the extraction bowl and the extraction is done in the same process as described above.
- Repeat the same process not less than three times till the extraction is clear and not darker than a light straw colour.
- Remove the filter paper from the bowl and dry in the oven at 110 + 5^{o}C. After 24hours, take the weight of the extracted sample.

4.3.2 RAP Gradation

A combination of well graded coarse and fine aggregates is essential for producing a durable granular mix for pavement courses. The RAP material gradation is required to analyse the size of aggregates used in the material. The procedure for gradation is

- The coarse aggregates used for granular construction are normally of the sizes 80 mm, 40 mm, 20 mm, 10 mm and 4.75 mm. The fractions from 4.75 mm to 150 micron are termed as fine aggregates. The size 4.75 mm is a common size appearing in both the fractions.
- Grading pattern of aggregates coarse, fine or combined is determined by sieving a sample successively through all the sieves mounted one over the other in order of size, with the larger sieve on the top as shown in Fig 3.19.
- The sieve sizes used for DBM mix are 37.5 mm, 26.5 mm, 19 mm, 13.2 mm, 4.75 mm, 2.36 mm, 0.3 mm and 0.075 mm.
- The sieves used for the BC mix are 37.5 mm, 26.5 mm, 22.4 mm, 19 mm, 13.2 mm, 9.5 mm, 4.75 mm, 2.36 mm, 1.18 mm, 0.6 mm, 0.3 mm, 0.15 mm and 0.075 mm.
- The material retained on each sieve after shaking, represents the fraction of aggregate coarser than the sieve in question and finer than the sieve above.
- Sieve analysis gives the gradation and the fineness modulus which is an empirical factor obtained by adding the cumulative percentages of aggregates retained on each of the dividing standard sieves and dividing by 100.
- The larger the figure, the coarser the material. Bring the sample to an air dry condition either by drying at room temperature or in oven at a temperature of 100^{o}C to 110^{0}C. Take the weight of the sample.
- Clean all the sieves and sieve the sample successively on the appropriate sieve starting with the largest. Shake each sieve separately over a clean tray.

- On completion of sieving, note down the weight of the material retained on each sieve. Report the results as percentage by weight of sample passing each of the sieves as in Table 4.14.

Figure 4.11: Sieves for fine and coarse aggregates

Table 4.7 RAP Gradation

IS Sieve Size (mm)	Cumulative Passing (%) 3+500
37.5	100.00
26.5	86.61
19.0	71.06
13.2	62.22
4.75	37.99
2.36	27.04
0.3	7.57
0.075	1.28

4.4 Mix design caluculations

- In this project we are adopted M20 grade of concrete

Table 4.8: Individual weight of materials M20 grade

Item name	For 1 cube (gms)	For 1 beam (gms)

Cement	1496.8 8	2217. 6
Fine aggregates	2494.8	3696
Coarse aggregates	5613.3	8316
water	748.44	1108. 8

4.4.1 Mixed design proportions

In this research work 15 Standard cubic specimens of size 150mm (nine sample for each proportion) were casted for the compressive strength of concrete and it was kept under curing for 7, 14 days & 28 days of age. Total cubes for compressive strength testing was 54 (9 cubes * 6 proportions).

In this research work 10 standard beams of size (3 sample for each proportion) were casted for flexural strength of concrete and it was kept under curing for 28 days of age. Total cubes for flexural strength testing was 18 (3 beams * 6 proportions).

4.5 RAP Based concrete

4.5.1 Sample Production

The RAP was added at 10%, 20%, 30%, 40% and 50% by the load of aggregates and the RAP aggregates replacing in half RAP fine aggregates and half RAP coarse aggregates suppose in the 10% replacement of aggregates means 5% RAP fine aggregates and 5% RAP coarse aggregates. Immediately after mixing, slump test was carried out for all the concrete series mixture. A standard 150×150×150mm cube specimens and 100×100×500mm beam specimen were casted.

The samples were then stripped after 24hours of casting and are then be ponded in a water curing. As casted, a total of (54) 150×150×150mm cubes and (18) 100×100×500mm beams specimens were produced.

4.5.2 Mixing of Concrete

In order to obtain a uniform mix thorough mixing of concrete is necessary. Concrete can be produced in two ways either by hand mixing or machine mixing. Hand mixing can be done on a plane levelled surface such as a wooden platform or a paved surface having tight joints so as to prevent paste loss To do mixing first the surface is cleaned and then moistened after that sand is first poured on the surface and then cement is spread on the sand after that thorough mixing is done. When the cement and sand gets uniformly mixed coarse aggregates are spread over the uniform sand and cement mix and then again mixed thoroughly. Dry materials are mixed until the colour of the mixture is uniform. Having obtained uniform coloured dry mix water is slowly added and the mix is again turned at least three times after completely the entire mixing process fresh concrete is produced which is plastic and can be moulded as per our needs.

In our investigation machine mixing was done to produce the fresh concrete. First the machine drum was cleaned and then moistened so as to prevent any loss of water as we are adding only a calculated amount and no extra water is added. All the dry materials are put in the drum and then dry mixed by rotating the drum when a thorough mix is obtained glass fibres are added as per the calculated which is a percent of total weight of concrete and then the materials are mixed thoroughly. After that water is added and mixed again until a uniform coloured mix is obtained. After completing all this process the concrete is dropped on a flat and clean plate from where we take it and fill our moulds.

4.5.3 Preparation of moulds

All specimens were first filled in their respective moulds and then hand compacted using a rod of 30mm diameter in three layers by tamping more than 35 times on each layer for cubes preparation. The hand compacted using a rod of 30mm diameter in three layers by tamping 35 times on each layer for beams preparation. To attain full compaction the specimens were than vibrated on a vibrator table. The surface was levelled, finished and smoothened by metal trowels.

4.5.4 Curing

The method of curing adopted was the ponding method of curing and produced samples were cured for 7days, 14days, and 28 days for cubes and beams for 28days.

4.6 Testing on RAP based concrete

4.6.1 Fresh properties of concrete

Slump Test: which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor is it always representative of the placability of the concrete. It is not a suitable method for very wet or very dry concrete. It does not measure all factor contributing to workability. The slump test was carried in accordance with B.S:1882 PART2:1970.

4.6.2 Harden properties of concrete

4.6.2.1 Compressive strength

The most important property of concrete is its compressive strength. Concrete is mostly used in construction where load transferred is mostly via compressive strength. In order to check the effect of fibres on the compressive strength of concrete 150mm cubes were cast and tested . The cubes were tested at the age of 7days, 14days and 28 days.

The RAP was added at 10%, 20%, 30%, 40% and 50% by the load of aggregates, when the nominal maximum size of aggregates was 20mm and no admixture was used. The water cement ratio was fixed at 0.5. The workability of the mix was observed to come down but however no extra water was used.

Load was applied gradually at the rate of 140kg/cm^2 per minute till the specimens failed. Load at the failure was divided by area of specimen and this gave us the compressive strength of concrete for the given sample.

Figure 4.16: Compressive Strength test of cube sample

4.6.2.2 Flexural strength

The most important property of concrete is its flexural strength. Concrete is mostly used in construction where load transferred is mostly via flexural strength. In order to check the effect of fibres on the compressive strength of concrete 100 x 100 x 500mm beams were cast and tested . The beams were tested at the age of 28 days. The RAP was added at 10%, 20%, 30%, 40% and 50% by the load of aggregates, when the nominal maximum size of aggregates was 20mm and no admixture was used. The water cement ratio was fixed at 0.5. The two point bending load applied was increased continuously at a constant rate until the specimen breaks down and no longer can be sustained. The maximum load applied on specimen was recorded. The modulus of rupture depends on where the specimen breaks along the span. Beam dimensions are 500mm×100mm×100mm. if the specimen breaks at the middle third of the span then the modulus of rupture is given by,

$$f_{rup} = \frac{Pl}{bd^2}$$

Where; P = load,

d = depth of the beam,

b = width of the beam.

Figure 4.17: Flexural Strength tests of beam samples in UTM

5. RESULTS AND DISCUSSIONS

The results obtained are shown below in tabular form

5.1 Compressive Strength of Concrete (in N/mm^2)

The 7, 14, 28 days compressive strength was studied and the values of 3 samples studied are shown in the tabular form. Table 5.1 shows the data of 7, 14, 28 days compressive strength obtained. Below tables gives the 7, 14, 28 days compressive strength of concrete with maximum nominal size of aggregates 20mm.

Table : 5.1 Compressive strength of concrete

RAP (%)	Avg Compressive strength (N/mm2)		
	7days	**14days**	**28days**
0	14.6	19.6	23.1
10	15.3	20.2	24.2
20	16.3	22.43	25.7
30	14.3	19.45	22.9
40	13.78	18.91	22.3
50	13.1	18.5	20.4

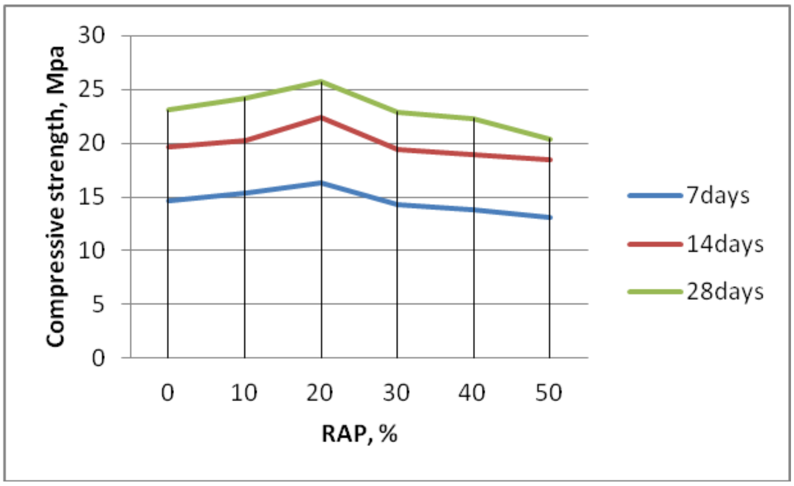

Figure 5.1 Effect of RAP on 7, 14 and 28 days compressive strength

5.2 Flexural Strength Test

The Flexural test was performed on the beams of size 50 x 10 x 10 cm to check the flexural strength of the concrete and the results obtained while performing the flexural test on UTM are given in Table 5.2. The beam specimens were tested on universal testing machine for two-point loading to create a pure bending. The bearing surface of machine was wiped off clean and sand or other material is removed from the surface of the specimen. The two point bending load applied was increased continuously at a constant rate until the specimen breaks down and no longer can be sustained. The maximum load applied on specimen was recorded. The modulus of rupture depends on where the specimen breaks along the span. Beam dimensions are 500mm×100mm×100mm. if the specimen breaks at the middle third of the span then the modulus of rupture is given by

$$f_{rup} = \frac{Pl}{bd^2}$$

Where; P = load,

d = depth of the beam,

b = width of the beam

Table 5.2: Result of flexural strength

S.No	% of RAP	Flexural Strength for 28 days (N/mm^2)
1	0	2.12

2	10	2.32
3	20	2.4
4	30	2.05
5	40	1.87
6	50	1.74

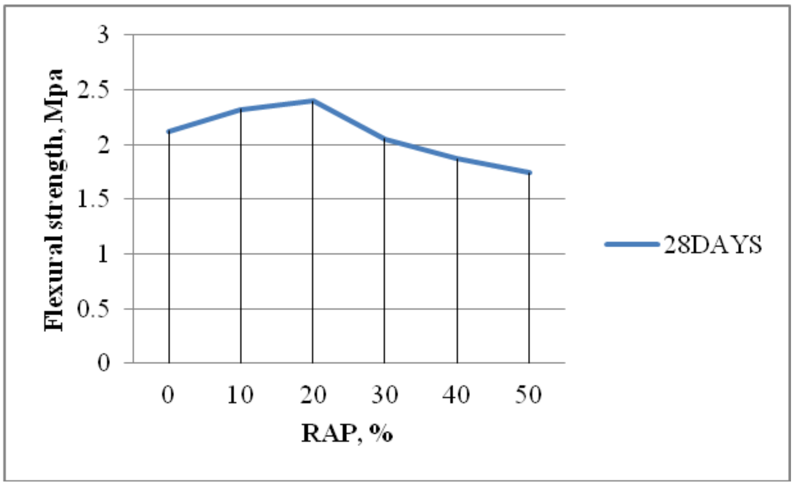

Fig 5.2: Flexural strength v/s % of MSWA

5.3 Workability of concrete (Slump cone test)

Table 5.3: Result of slump test

S. No	**% of RAP**	**Slump (mm)**
1	0	90
2	10	94
3	20	97
4	30	100
5	40	102
6	50	105

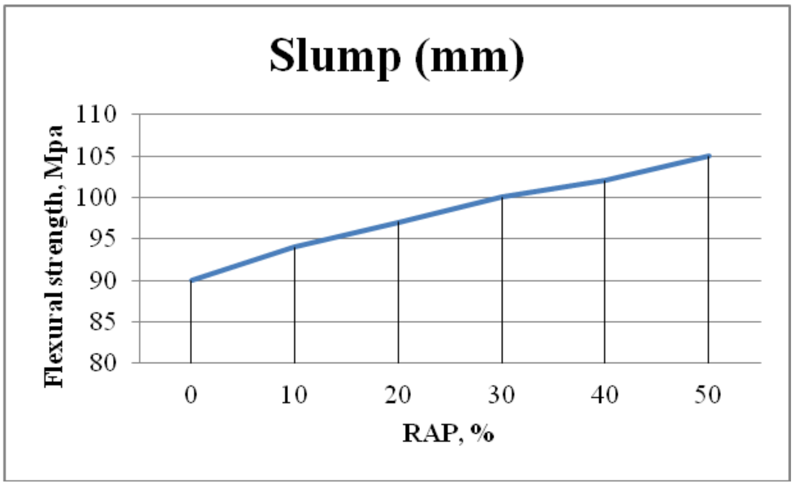

Fig 5.3 : Slump test results

The above figure shows the slump results. It was observed that, the slumps increases as the RAP content were increased in the mix.

6. CONCLUSIONS

Following observations were made through this study,

1. Replacement of 20% RAP gives maximum compressive strength than other replacement percentages, compared to the normal concrete mix

2. Normal concrete mix shows maximum flexural strength more than the RAP replaced mixes. But the 20% RAP replacement is giving the strength very nearer to that of control mix.

3.The other supporting factors to justify the use of RAP Mix are,

a. Easy to remove flexible pavement and use its material for placing of concrete pavement. Thus reducing transportation cost and the cost of natural aggregates.

b.The use of RAP aggregate also reduces the burden on the natural course aggregate for increasing aggregate demand for construction of roads.

c.It helps to reduce environmental imbalances and pollution while removing natural aggregate in the quarry.

REFERENCES

[1] International Journal of scientific research and management (IJSRM) ||Volume||2||Issue||8||Pages||1271 1278||2014||Website: www.ijsrm.in ISSN (e): 2321- 3418

[2] Delwar, M., Fahmy, M., &Taha, R. (1997),Use of Reclaimed Asphalt Pavement as an Aggregatein Portland Cement Concrete. ACI Materials Journal (May - June 1997), 251-256.

[3] Huang, B., Shu, X., & Li, G. (2005), Laboratory Investigation of Portland Cement Concrete Containing Recycled Asphalt Pavements. Cement and Concrete Research , 2008-2013.

[4] Huang, B., &Shu, X. (2005),Experimental Study on Properties of Portland Cement Concrete Containing Recycled Asphalt Pavements. Innovations for Concrete Pavement: Technology Transfer for the Next Generation (pp. 485-499). Colorado Springs: International Society for Concrete Pavements.

[5] Hossiney, N. J. (2008), Evaluation of Concrete Containing RAP for use in Concrete Pavement,Civil Engineering, Gainesville: University of Florida.

[6] Concrete Technology (Theory and Practices) by M.S. SHETTY. S.Chand& Company Pvt.LtdPublications.

[7] Highway Engineering by S.K.Khanna and C.E.G.Justo, Nem Chand & Bros, Roorkee,U.K.,India (Ninth Edition 2011).

[8] Principles and Practices of Highway Engineering – by Dr. L R Kadyali, Dr. N B Lal. [9] IRC: 15-2011, Standard Specifications and code of practice for Construction ofConcrete Roads, 4 thRevision, Indian Roads Congress, New Delhi.

[10] IRC: 44-2011, Guidelines for cement concrete mix design for pavements, IndianRoads Congress, New Delhi.

[11] IS: 10262-2009, Indian Standard CONCRETE MIX PROPORTIONING –GUIDELINE (First Revision)