International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064

Experimental Investigation on Flexural Behavior of High Strength Concrete Beam By Using STAAD Pro.Concrete Model

N. Sivakumar[1], R. Manikandan[2]

[1]Assistant Professor, Department of Civil Engineering, Jay Shriram Group of Institutions, Tirupur-638660, TamilNadu, India

[2]UG Student Department of Civil Engineering, Jay Shriram Group of Institutions, Tirupur-638660, TamilNadu, India

Abstract: ***In order to evaluate whether high strength concrete with recycled aggregate can be applied for concrete structures, flexural loading tests of reinforced recycled concrete members are to be carried out. The results of this test programme to study the use of recycled coarse aggregate in high strength 40 N/mm² concrete are to be described. The recycled coarse aggregates are mainly produced from various concrete members of a building structure. The high strength concrete by using different percentage of recycled aggregates is testing in this project. Also finite element modelling and analysis of beams are also going to be performed. The aim for this ongoing project is to determine the flexural strength characteristic of recycled aggregates for application in high strength structural concrete, which will give a better understanding on the properties of concrete with recycled aggregates, as an alternative material to coarse aggregate in structural concrete.***

Keywords: High Strength Concrete, Flexural Strength, Recycled Aggregates, Finite Element Analysis, Linear structural analysis.

1. Introduction

In India out of 48 million tones of solid waste generated Construction and Demolition (C&D) waste makes up to 25% annually. Rapid economic growth leading to urbanization and industrialization is generating waste, which is adversely effecting the environment. Estimated waste generation during construction is 40 kg/m^2 to 60 kg/m^2. Similarly, waste generation during renovation and repair work is estimated to be 40 kg/m^2 to 50 kg/m^2. The highest contribution to waste generation comes from the demolition of buildings. Demolition of permanent and semi-permanent buildings, on average generates between 300 kg/m^2 and 500 kg/m^2 of waste, respectively. Projections for building material requirement of the housing sector indicate a shortage of aggregates to the extent of about 55,000 million cu.m. An additional 750 million cu.m. Aggregates would be required for achieving the targets of the road sector. Recycling of aggregate material from construction and demolition waste may reduce the demand-supply gap in both these sectors. However, almost all of the concrete waste that is recycled is used for pavement base or back filling for retaining walls, which does not necessarily require high performance compared with structural concrete. Such limited use of concrete waste is attributable to not only the unclear quality of the original concrete but also low and scattered quality due to high porosity and impurity. From the viewpoint of promoting resource saving, energy saving and environmental preservation, it is essential to study how waste concrete can be used effectively as a structural material.

1.1 High Strength Concrete

The definition of high strength changes over the years as concrete strength used in the field increases. For instance, concrete produced with compressive strength of 30 MPa was regarded as high strength in the 1950's. Gradually, concretes with compressive strength of 40-50 MPa in the 1960's, 60 MPa in the 1970's, and 100 MPa and beyond in the 1980's have evolved and used in practical structures. With the recent advancements in concrete technology and the availability of various types of minerals and chemical admixtures and very powerful super plasticizers, concrete with a compressive strength up to 200 Mpa is possible. As per Indian Standard Recommendations any concrete possesses a 28 day compressive strength more than 35 Mpa is termed as high strength concrete. But elsewhere in the international forum the high strength label is applied to concrete having strength 40 Mpa or above.

1.2 Recycled Aggregates

Recycled aggregates are aggregates derived from the processing of materials previously used in a product and/or in construction. Examples include recycled concrete from construction and demolition waste material (C&D), reclaimed aggregate from asphalt pavement and scrap tyres.

1.3 Types of Recycled Aggregates

(a) Recycled Concrete Aggregate (RCA)

Coarse recycled concrete aggregate (RCA) is produced by crushing sound clean demolition waste of at least 95% by weight of concrete, and having a total contaminant level typically lower than 1% of the bulk mass. Other materials that may be present in RCA are gravel, crushed stone, hydraulic-cement concrete or a combination thereof deemed suitable for premix concrete production. In Australia, RCA has been the most common construction and demolition waste used in concrete production both as coarse and fine aggregate. About five million tones of recycled concrete and masonry are available in Australian markets principally in Melbourne and Sydney, of which 500,000 tones is RCA.

(b)Recycled Concrete and Masonry (RCM)
Coarse recycled concrete and masonry (RCM) is graded aggregates produced from sorted and clean waste concrete and masonry typically for road sub base applications. The material may contain small quantities of brick, gravel, crushed rock or other forms of stony material as blended material. Fine recycled aggregate may also be referred to as crushed concrete fines.

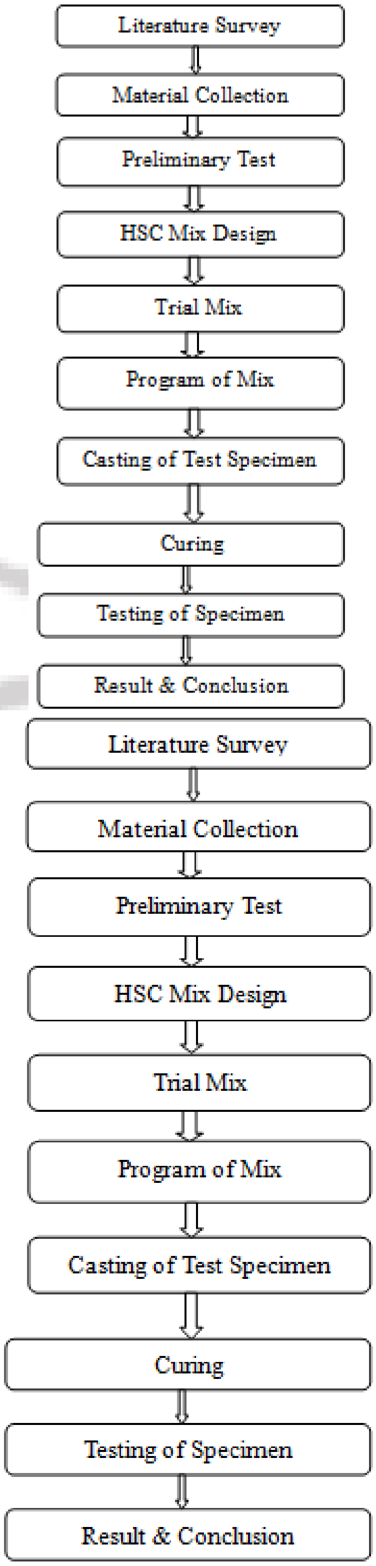
(c)Reclaimed Aggregate (RA)
Aggregate can be reclaimed from concrete returned to a batching plant by separating the aggregates from the water-cement slurry using one of a number of alternative technologies, most of which are based on washing the material with water. Aggregates are screened for later use and the water may be reclaimed, depending on the technology adopted. As an alternative method for reclaiming aggregates from the returned concrete in fresh state, a process of allowing it to harden for a short period, after which it is crushed for use as aggregate in new mixes, has been examined. Reclaimed aggregate is relatively clean and has a combined grading of both coarse and fine aggregate. Like any graded aggregate it must be handled in such a way as to avoid segregation. The physical and mechanical properties of reclaimed aggregate reflect those of the original aggregates used except for their combined grading.

Reclaimed Asphalt Pavement (RAP)
Reclaimed asphalt pavement (RAP) is a reuse of old asphalt concretes as the aggregate base for new asphaltic concrete. The possible use of RAP and RCA as a substitute for roller compacted concrete (RCC) in flexible pavement has been evaluated through laboratory and field trials22. This type of material has been used in several RTA projects including the M7 Motorway. A new brick/RAP blended material for use as a select sub-grade material has proven to have superior properties to conventional material such as sandstone.

Reclaimed Asphalt Aggregate (RAA)
A new reprocessing method has been developed in Japan24 to produce reclaimed coarse aggregate and recycled asphalt granules from waste asphalt concrete and concrete dust. There is no reported use of this process in Australia. Concrete with reclaimed asphalt aggregate achieved about 55%, 65% and 105% of the compressive, tensile and bending strengths respectively of concrete with new aggregate.

Scrap Tyres: The possible use of scraps tyres in the form of tyre chips and crumb rubber aggregate. There is a US Patent on a crumb rubber-reinforced concrete, and research, conducted on concrete with tyre chips and crumb rubber aggregate. Another development is in the use of finely ground scrap or crumb rubber in asphalt. There are three manufacturing methods. In Wet process where the crumb rubber is added to the hot mix asphalt during the manufacturing process using special mixing equipment.In Dry process, the crumb rubber is added to the aggregate prior to the addition of the asphalt concrete.In Terminal blend process, where the rubber is added to the asphalt concrete at the bitumen refinery.

2. Methodology



3. Theoretical investigation

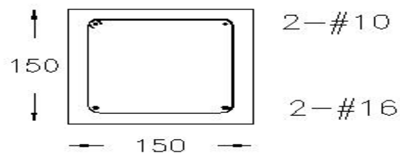


Figure 1: Cross section of beam

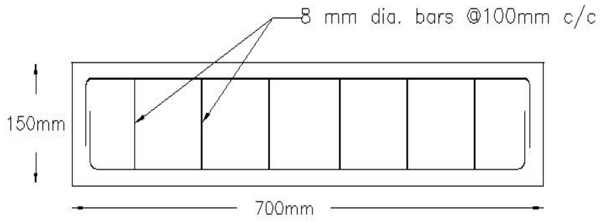


Figure 2: Longitudinal section of beam

3.1 Mix design

IS Method of Design for M_{40} Concrete

Data:
Compressive Strength required = 40 N/mm^2
Max size of Aggregate = 20 mm
Specific Gravity of cement = 3.15
Specific Gravity of Fine aggregate = 2.6
Specific Gravity of Coarse aggregate = 2.7
Aggregate Type: Crushed

Table 1: Quantities of ingredients of M_{40} concrete

Cement	*W/C*	*Water*	*Sand*	*Aggregate*
561	0.33	180	404.3	1259.5
1		0.32	0.72	2.24

Units' kg/m^3

4. Experimental Investigation

4.1 Slump test on fresh concrete

Table 2

Sr. No.	*Percentage of R.C.A*	*Slump (mm)*
1.	0	82
2.	10	81
3.	20	78
4.	30	78
5.	40	75
6.	50	74

4.2 Compressive Strength of Concrete Cubes

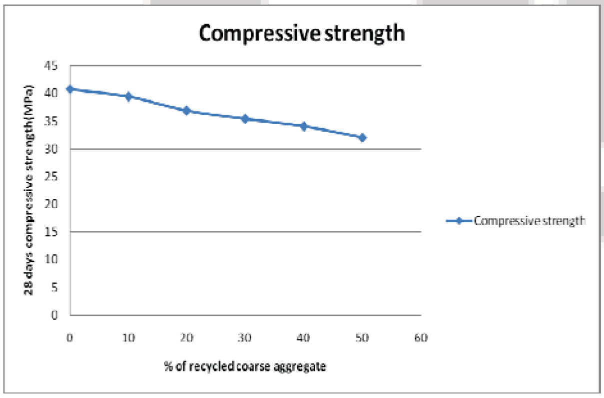


Figure 3: Compressive strength of various proportions

Table 3: Percentage of compressive strength remained and dropped

Sr. No.	% of R.C.A	Remained of compressive strength (%)	Dropped of compressive strength (%)
1.	0	100	0
2.	10	96.7	3.3
3.	20	90.5	9.5
4.	30	86.9	13.1
5.	40	83.6	16.4
6.	50	78.6	21.4

4.3 Flexural Strength of Reinforced Concrete Beams

In this test, a reinforced concrete beam was subjected to flexure using symmetrical two point loading until failure occurs. As the load point was placed at 1/3rd of the span, the test was also called as third point loading test. The theoretical maximum tensile stress reached in the bottom fiber of the test beam is called modulus of rupture. The bearing surfaces of the supporting and loading rollers were wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they were to make contact with the rollers. The specimen was then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 20cm apart. The axis of the specimen is carefully aligned with the axis of the loading device. The load is applied without shock and increasing continuously at a rate such that the extreme fiber stress increases at approximately 0.7kg/cm^2/min. the load was increased until the specimen fails, and the maximum load applied to the specimen during the test was recorded.

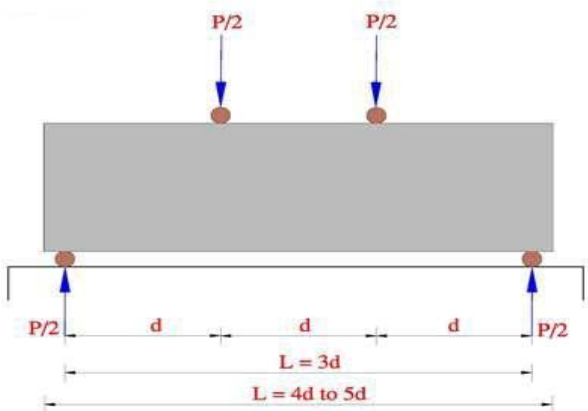


Figure 4: Two Point Loading

The crack pattern of a beam is shown in Fig 5 and the crack had occurred slightly near to the support of the beam. Results of flexural test are shown in figure 6.

Figure 5: Crack Pattern of beam obtained in two points loading

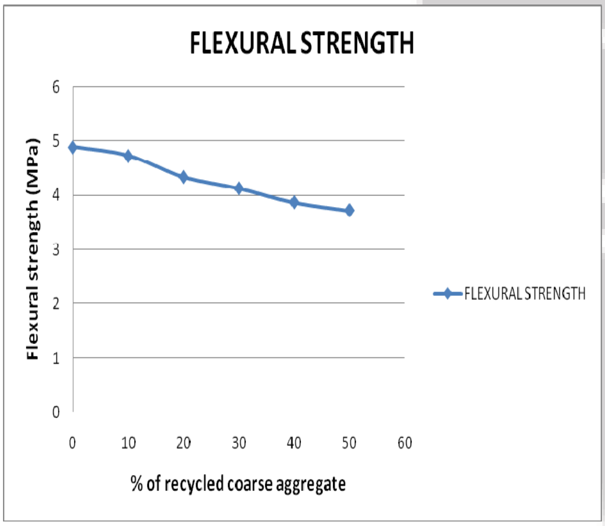


Figure 6: Flexural strength of various proportions

As per IS 456: 2000 cl.6.2.2 the flexural strength is $0.7\sqrt{f_{ck}}$. From the obtained results, it is clear that the batches with 0% and 10% RCA have met the target strength. The flexural strength for other batches is found to be slightly less than the required value. The results show that the flexural strength reduces as the % of recycled coarse aggregate increases.

Table 4 Percentage of flexural strength remained and dropped

Sr.No.	% of R.C.A	Remained of Flexural strength (%)	Dropped of Flexural strength (%)
1.	0	100	0
2.	10	96.7	3.3
3.	20	88.8	11.2
4.	30	84.5	15.5
5.	40	79.1	20.9
6.	50	76.1	23.9

5. Results and Discussion

5.1 Load – Deflection Curves

The graph has been plotted between the applied load and corresponding deflection occurred in the specimen. In the graph the deflection lies in the X-axis and the applied load is in Y-axis.

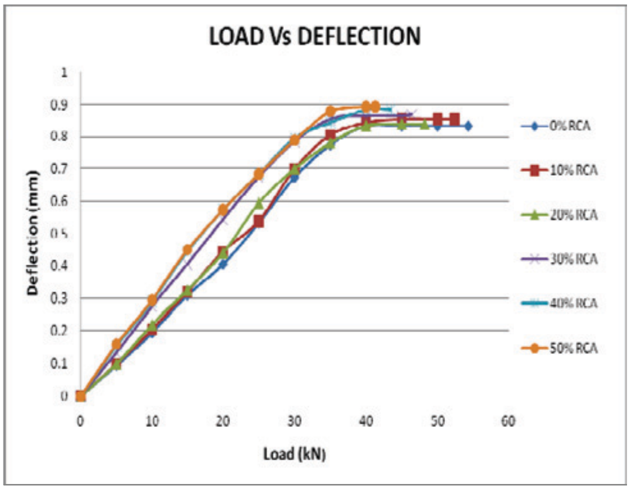


Figure 7: Load Vs Average Deflection Graph

5.2 Moment – Curvature Curves

The graph has been plotted between the bending moment and corresponding curvature values. In the graph the curvature lies in the X-axis and the bending moment is in Y-axis.

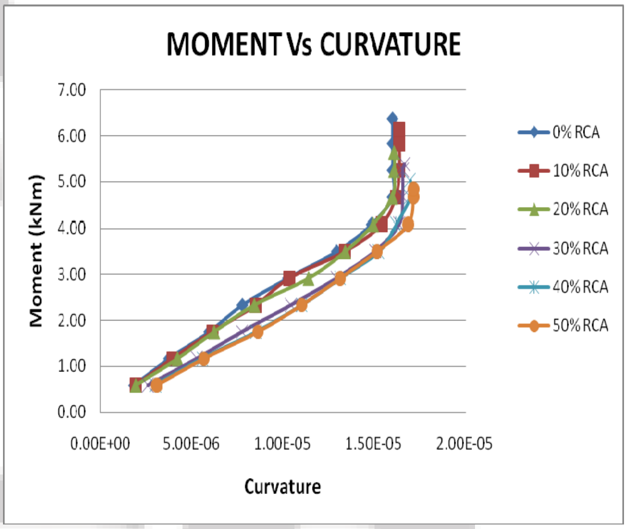


Figure 8: Moment Vs Curvature Graph

6. Finite Element Modeling of Beam

6.1 Nonlinearities in Concrete

The behavior of concrete and reinforced concrete cannot be modeled properly by linear elastic behavior. Recognizing this, the design of R.C.C. structures has gradually shifted over the years from the elastic working stress design to the more rational ultimate strength design. The nonlinearities can be geometric as well as material. Both of these become very important at higher level of deformation.

6.2 Modeling Using STAAD

This analysis and design software proved to be worth its mettle and handled all the various challenges that had to be solved during the course of project work. The software is released by Research Engineers International, California, U.S.A. It has an intuitive, user-friendly GUI, visualization tools, powerful analysis and design facilities and seamless integration to several other modeling and design software products. The software has provisions to allow us to specify the entire structure as a collection of its various elements. Thus, it allows us to discretize the structure. The software has an extremely friendly GUI that makes modeling easy and accurate. For static, dynamic, or pushover analysis of bridges, containment structures, embedded structures (tunnels and culverts), pipe racks, steel, concrete, aluminium or timber buildings, transmission towers, stadiums or any other simple or complex structure, STAAD Pro 2007 has been the choice of design professionals around the world for their specific analysis needs. It provides a comprehensive and integrated finite element analysis and design solution, including a state-of-the-art user interface, visualization tools and international design codes. It is capable of analyzing any structure exposed to a dynamic response, soil-structure interaction, or wind, earthquake and moving loads.Once when the overall geometry of the structure has been specified, the section properties of individual member elements are specified. Thereafter, loading on the members are specified. Following this, the support conditions relevant to the structure are specified as well. The input to the software can easily be inspected and modified with the help of STAAD editor. Thereafter, the analysis can be performed. The analysis yields us the parameters required for performing the structural design of the structure. The required values can directly be read from the STAAD output file. The software also allows us to perform design as per specifications in various international codes of practice.

6.3 Modeling of Beam

A beam of size 150 mm x 150 mm x 750 mm was modeled using STAAD and properties of concrete like Modulus of elasticity (2.1×10^4 N/mm^2) and Poisson's ratio (0.15) were given. Supports are simply supported at a distance of 25 mm from either ends of the beam. Model is shown in fig 9.

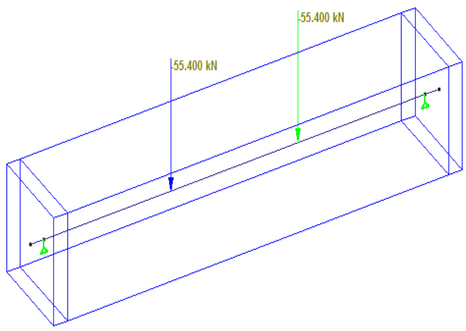


Figure 9: Loading of the beam

6.4 STAAD.Pro Results

Maximum values of Shear Force and Bending Moments obtained after the analysis are given below;

Table 5: Maximum Shear Force and Bending Moment

Beam	Length (mm)	Load combination	Maximum	Max. Fy (kN)	Max. Mz (kNm)
1	700	1.Dead Load	Max. -ve	-0.186	-0.03
			Max. +ve	0.186	0.03
		2.Live Load	Max. -ve	-55.40	-12.92
			Max. +ve	55.40	12.92
		3.Combined Load	Max. -ve	-55.586	-12.96
			Max. +ve	55.586	12.96

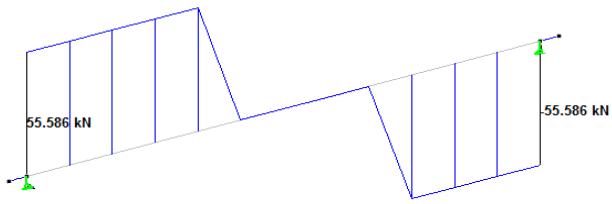


Figure 10: Shear Force diagram

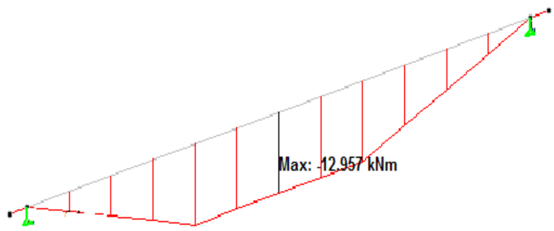


Figure 11: Bending Moment diagram

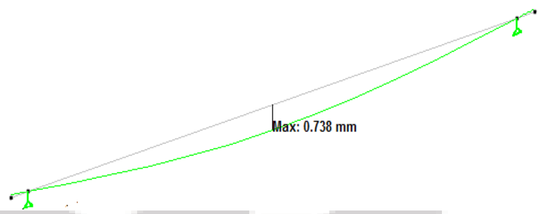


Figure 12: Section Displacement Diagram

By using models we can find the Shear Forces, Bending Moments in the beam and also the deformations for different load combinations. This is very useful in the structural design and calculating reinforcement in beams like longitudinal, transverse and side face reinforcement etc.

7. Conclusion

The flexural behavior of concrete beams with different percentage replacements of Recycled coarse aggregates was studied and the following conclusions were made.

- Recycled Coarse Aggregate replacement (up to 30%) in concrete has shown good improvement in Flexural

Strength.

- Compressive strength was found to be decreasing as the percentage of RCA is increased.
- Recycled Coarse Aggregate can be replaced effectively in high strength concrete without large changes in its strength properties.

8. Scope of Studies

Further testing and studies on the recycled aggregate concrete is highly recommended to indicate the strength characteristics of recycled aggregates for application in high strength concrete. Below are some of the recommendations for further studies:

- Although by decreasing the water/cement ratio, recycled aggregate can achieve high strength concrete. But the workability will be very low. Therefore, it is recommended that adding admixtures such as super plasticizer into the mixing so that the workability will be improved.
- More investigations and laboratory tests should be done on the strength characteristics of recycled aggregate. It is recommended that testing can be done on concrete slabs, beams and walls. Some mechanical properties such as creeping and abrasion were also recommended.
- More trials with different particle sizes of recycled aggregate and percentage of replacement of recycled aggregate are recommended to get different outcomes and higher strength characteristics in the recycled aggregate concrete.

References

[1] "Use of recycled concrete aggregate in making concrete – an overview", *34th Conference on OUR WORLD IN CONCRETE & STRUCTURES: 16 – 18 August 2009, Singapore*

[2] "An experimental study on recycled concrete using high quality recycled coarse aggregate", *Mem.Fac.Eng/ Osaka city university/Vol.44/pp. 37-44, 2003*

[3] "Effect on recycled aggregate on concrete properties", *International Journal of Earth Sciences and Engineering, Volume 04, No 06, 2011*

[4] "Strength of concrete incorporating aggregates recycled from demolition waste", *ARPN Journal of Engineering and Applied Sciences, VOL. 5, NO. 5, MAY 2010*

[5] "Considerations in producing high strength concrete", *Journal of Civil Engineering (IEB), 37 (1) /2009*

[6] "Use of recycled concrete aggregates in high strength concrete", *Materials and Structures/Vol:33/pp.574-580/November 2000*

[7] "Reinforced high-strength concrete beams in flexure", *ACI Structural Journal/Title no. 102-S47, May-June 2005*

[8] "Flexural behavior of reinforced recycled concrete beams", *Journal of Advanced Concrete Technology/Vol.5/No.1/43-61/Feb 2007*

[9] IS: 456 – 2000 (Fourth Revision) Indian Standard Plain and Reinforced Concrete Code of Practice

[10] IS: 383-1970 (Second Revision), Specifications for Coarse and Fine Aggregates from Natural Resources for Concrete

[11] M.S Shetty "Concrete Technology", Theory and practice, S Chand 2011

Author Profile

N. Sivakumar received the B.E. degree in Civil Engineering from TamilNadu College of Engineering Coimbatore in 2006. M.E. degree in Structural Engineering from College of Engineering Guindy Campus in 2010, Anna University Chennai. He has qualified in GATE 2008 held on February 10, 2008. (Percentile Score: 84.84) He has more than 4 years of experience in Structural Consultancy, Construction and Academic experience also. He is an active member in some technical bodies like ISTE, LBS; He has published 4 articles in reputed journals and presented 3 papers in International conferences and 2 papers in national conferences. He now works as Assistant Professor in Department of Civil Engineering at Jay Shriram Group of Institutions.

R. Manikandan is still doing B.E., Civil Engineering final year student of Jay Shriram Group of Institutions. He has presented 1 papers in International conferences and 2 papers in national conferences.