INTERNATIONAL RESEARCH JOURNAL IN ADVANCED ENGINEERING AND TECHNOLOGY (IRJAET) E - ISSN: 2454-4752 P - ISSN : 2454-4744
VOL 4 ISSUE 3 (2018) PAGES 3754 – 3767
RECEIVED : 05.04.2018 PUBLISHED : 08.05.2018

May 08, 2018

Experimental Investigation on Concrete with Replacement Using Domestic Waste Plastic Fibers and Admixture

R.Karikalan[1], Mr.N.Selvakumar[2]

PG Student, Department of Civil Engineering, Global Institute of Engineering and Technology, Vellore, Tamilnadu[1]
Assistant Professor, Department of Civil Engineering, Global Institute of Engineering and Technology, Vellore, Tamilnadu[2]

Abstract:
Construction and demolition waste (C&D) constitutes a major portion of total solid waste production in the world, and for the present most of it is dumped in landfills or left as it is in open ground, which leads to environmental pollution. In this paper we are trying to replace the natural Aggregate with Recycled aggregate in concrete production along with domestic waste plastic fibers. The combination of recycled construction and demolition waste and plastic fibers creates an unusual fiber reinforced concrete; new composite material, which offers a wide field of possible use in construction industry. In this paper we are going to analyze the compressive strength and flexural strength of this Recycled aggregate fiber reinforced concrete. The different percentages of waste plastic fiber reinforced concrete used in the experimentation are 0%, 5%, 10% and 15%, 20% (by volume fraction) with an aspect ratio of 50. The results are compared with the plastic fiber concrete produced from conventional aggregates.
Keywords: Fiber concrete, recycled aggregate, waste plastic fibers, strength and workability characteristics

1. INDTRODUCTION

The recycled aggregate concrete with plastic fibers is not commonly used in Construction industry non-a-days, but in future it is unavoidable because the problems arisen in disposing the material of dismantled building. Construction and demolition waste construction a major portion of total solid production in the world, and for the present most of it is dumped in landfill or left as it is in open ground, which lead to environmental pollution. In this paper we are trying to replace the natural Aggregate with recycled aggregate in concrete production along with domestic waste plastic fibers. The combination of recycled construction and demolition waste and plastic fibers creates an unusual fiber reinforced concrete, new composite material, which offers a wide field of possible use in construction industry Recycled concrete aggregate is obtained mainly by crushing and processing concrete element that have been previously used in construction, where the masonry content is limited to not more than 5 percent

2. RECYCLED CONCRETE AGGREGAE:

Aggregate resulting from the processing of inorganic material previously used in construction and principally comprising crushed concrete washed and graded for use as aggregate in the production of further concrete.

A. PRODUCTION OF RECYCLED CONCRETE AGGREGATES:

The total quantum of waste from construction industry is estimated to be 12 to 14.7 million tons per annum out of which 7-8 million ton are concrete and brick waste. According to findings of survey,70% of the responded have given the reason for not adopting recycled of waste from construction. Recycled aggregate is produced as a result of crushing. Graded inorganic particles processed from the have been used in construction. These material resulted from destruction of building, roads ,bridges and some time even from catastrophes, such as ware and earthquake.

This material is broken into large piece and transported to the processing plant. It must be clean, free of contaminants like steel reinforcement bars, wood and soil then it passes through three main phase crushing, sizing and blending.

The processes of recycling of construction and demolition waste are similar to those producing natural aggregate both have the same equipments crushed screens, removal impurities and transportation facilities.

B. APPLICATION OF RCA :

Nowadays, the application of recycled aggregate in construction areas is wide. The applications are different from country to country

1) Aggregate Base Course, or the untreated aggregate used as foundation for roadways pavement, is the underlying layer which forms a structural foundation for paving

2) Ready Mixed Concrete - It is used for residential slab and foundation walk and curb residential street; commercial slab and foundation concrete paving per aggregate approval.

3) Pipe Bedding: Recycled concrete can serve as a stable bed or firm foundation in which to lay underground utilities.

4) Paving Blocks; Recycled aggregate have been used as paving blocks in some countries.

5) Building Block: recycled aggregate has been used as building block

FIBERS:

In conventional concrete, micro-cracks develop before structure is loaded because of drying shrinkage and other causes of volume change. When the structure is loaded, the micro cracks open up and propagate because of development of such micro-cracks, results in inelastic deformation in concrete. Fiber reinforced concrete is cementing concrete reinforced mixture with more or less randomly distributed small fibers. In the FRC, a number of small fibers are dispersed and distributed randomly in the concrete at the time of mixing, and thus improve concrete properties in all direction the fibers help to transfer load to the internal micro cracks.FRC is cement based composite material that has been developed in recent years. It has been successfully used in construction with its excellent flexural-tensile strength, resistance and resistance to plastic shrinkage cracking of mortar. These fibers have many benefits. Steel fibers can improve the structural strength to reduce in the heavy steel reinforcement requirement. Freeze thaw resistance of the concrete is improved .durability of the concrete is improved to reduced in the cracks widths. Polypropylene and nylon fibers are used to improve the impact resistance.

INTERNATIONAL RESEARCH JOURNAL IN ADVANCED ENGINEERING AND TECHNOLOGY (IRJAET) E - ISSN: 2454-4752 P - ISSN : 2454-4744
VOL 4 ISSUE 3 (2018) PAGES 3754 – 3767
RECEIVED : 05.04.2018 PUBLISHED : 08.05.2018

C. IMPOTANCE OF PLASTIC FIBER:

The problem of disposing and managing solid waste materials in all countries has become one of the major environmental, economical and social issues. A complete waste management system including source reduction, reuse recycling, land-filling, and incineration needs to be implemented to control the increasing waste disposal problems. Typically a plastic is not recycled into the same type of plastic products made from recycled plastics are often not recyclable.

The purpose of this project is to evaluate the possibility of using granulated plastic waste materials to partially substitute for the fine aggregate in concrete composites. The polyethylene bottle which can easily be obtained from the environment with almost no cost is shredded and added into ordinary concrete to examine the strength behavior of various specimens.

D. SCOPE:

The rabid construction activity and growing demand for house in our country has led to short fall of traditional building materials. Rapid infrastructural development has led to generation of lrge quantities of construction and wastes, which possess major problem of disposal. in this paper we are trying to replace the natural aggregate with recycled aggregate in concrete production along with domestic waste plastic fibers. The combination of recycled construction and demolition waste and plastic fibers creates an unusual fiber reinforced concrete: new composite material, which offers a wide field of possible use in construction industry.

E. OBJECTIVES:

The objective of our project is

1. To find out the physical properties of cement.
2. To find out the physical and mechanical properties of fine aggregate.
3. To find out the physical and mechanical properties of coarse aggregate
4. To find out the mechanical properties of the recycled aggregate concrete
5. To design a proper mix of concrete of standard M20.

EXPERIMENTAL PROCEDURE Recycled concrete is obtained mainly by crushing and processing concrete elements that have been previously used in construction, where the masonry contents is limited to not more than 5 percent. Recycled concrete aggregate are therefore not the same as recovered aggregate, which are obtained by washing the cement paste out of fresh concrete returning the aggregate to the aggregate stock pile.

There are two main aspects, which require close attention before considering use of recycled aggregate in structural concrete.

I. Interior physical properties, for example, lower density and higher water absorption compared with natural aggregate. These are attributable to the adhesion of cement-sand paste from the parent concrete, which cannot be removed completely even with the advanced processes in practice.
II. Likelihood of problem inherited from the parent concrete, caused by internal chemical reactions.

From the different studies regarding the use of recycled as raw material for new concrete, It has been reported that the properties of concrete prepared with recycled concrete aggregate (RCA) could vary widely depending upon the source of the recycled aggregate, age of concrete at time of demolition, etc . The recycled

Aggregate known to have higher water absorption due to the residual mortar attached to it. It has also been found that concrete made with recycled aggregate leads to a reaction in the compressive strength of the concrete and the replacement ratio strongly affects other properties of the new concrete.

F.RECYCLED COARSE AGGREGATE:

Recycled aggregate were collected from demolished concrete slabs, beams and columns. The aggregates used in the experimentation were 20mm passing and Retained in 10mm sieve and tested as per IS: 383-2386 (I, II and III) the Aggregate test performed and the observation is as follows.

F. Test on Fresh Concrete:

Slump Test:

This test is to determine the workability of the cement concrete to be used. The mix is prepared and placed in a clean mould and tamped and the top of the cone is leveled off. Then the mould is lifted up vertically and the nature of slump is analyzed to get the workability of the given cement concrete sample As per IS 456 Code

H.Fibers:

The waste plastic fibers were obtained by collecting domestic waste plastics from waste plastic pots, buckets, cans, drums and untensils . Then melting and extruding into fiber. The waste plastic fibers obtained were all recycled plastics. The fibers were cut from steel wire cutter and it is labour oriented. The thickness of waste plastic fibers was 1mm to and its length was kept 5mm to25mm and these fibers were straight. The different volume fraction of fibers and suitable aspect ratio were selected and use in this investigation.

Fig. Fibers

INTERNATIONAL RESEARCH JOURNAL IN ADVANCED ENGINEERING AND TECHNOLOGY (IRJAET) E - ISSN: 2454-4752 P - ISSN : 2454-4744
VOL 4 ISSUE 3 (2018) PAGES 3754 – 3767
RECEIVED : 05.04.2018 PUBLISHED : 08.05.2018
May 08, 2018

I.MIX DESIGN**:**

Design mix for M20 grade of concrete as per IS 10262-2009

Design data

Grade of concrete = M20
Maximum nominal size of aggregate = 20 mm
Characteristic strength fck = 20 Mpa
Type of cement = OPC 53 grade
Standard deviation =5
Target mean strength = Fck+ 1.65 σ
= 20+ 1.65x5
= 28.25 Mpa

Material properties

Specific gravity of coarse aggregate = 2.81
Specific gravity of fine aggregate = 2.50
Specific gravity of cement = 3.15
Specific gravity of water = 1.00
Water absorption

i) Coarse aggregate = 0.92
ii) Fine aggregate =1.20

Mix design

Slump value = 70 mm
Water cement ratio = 0.50
(from IS 10262-1982 for M20 grade)
Percentage of total fine aggregate = 30%
Select water content for 20 mm aggregate= 186 kg/m^3
Hence the volume of cement content = 186/0.50
= 372kg/m^3
Percentage of chemical admixture = 20%
Volume of all aggregate =1-(0.11+0.140+0.006)
= 0.743
Volume of fine aggregate = ex volume of fine aggregate x specific gravity of fine aggregate
= 0.743x 0.30 x 2.50
Volume of fine aggregate = 520.24 kg/m^3
Volume of coarse aggregate = ex volume of C.A x specific gravity of C.A
=1257.98 kg/m^3

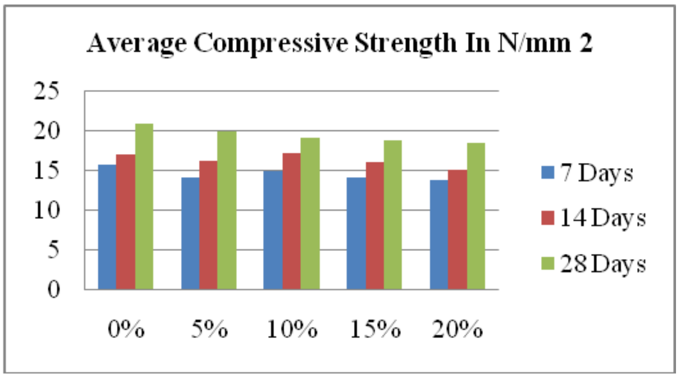
INTERNATIONAL RESEARCH JOURNAL IN ADVANCED ENGINEERING AND TECHNOLOGY (IRJAET) E - ISSN: 2454-4752 P - ISSN : 2454-4744
VOL 4 ISSUE 3 (2018) PAGES 3754 – 3767
RECEIVED : 05.04.2018 PUBLISHED : 08.05.2018
May 08, 2018

3. COMPARISION B/W RCA AND NCA

J. TEST ON COMPRESSIVE STRENGTH:

Sl. No.	Mix	Average Compressive Strength In N/mm ^{2}		
		7 Days	14 Days	28 Days
1	0%	15.70	17.10	21.00
2	5%	14.10	16.25	20.00
3	10%	15.00	17.15	19.15
4	15%	14.15	16.15	18.90
5	20%	13.75	15.10	18.50

Fig.1 COMPRESSIVE STRENGTH

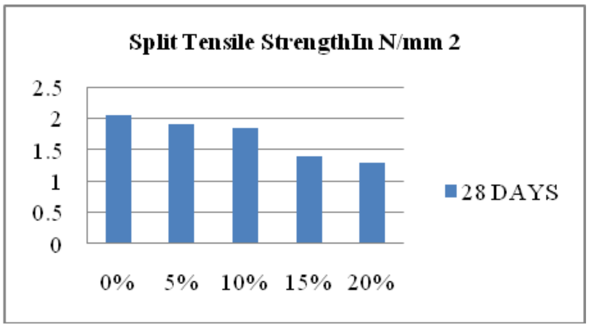


K.TEST ON SPLIT TENSILE STRENGTH:

Sl.No	Mix	Split Tensile StrengthIn N/mm ^{2}
1	0%	2.05
2	5%	1.90
3	10%	1.85

INTERNATIONAL RESEARCH JOURNAL IN ADVANCED ENGINEERING AND TECHNOLOGY (IRJAET) E - ISSN: 2454-4752 P - ISSN : 2454-4744
VOL 4 ISSUE 3 (2018) PAGES 3754 – 3767
RECEIVED : 05.04.2018 PUBLISHED : 08.05.2018

4	15%	1.40
5	20%	1.30



L. TEST ON FLEXURAL STRENGTH:

Sl.No	Mix	Flexural Strength In N/mm ^{2}
1	0%	2.15
2	5%	2.00
3	10%	1.95
4	15%	1.35
5	20%	1.25

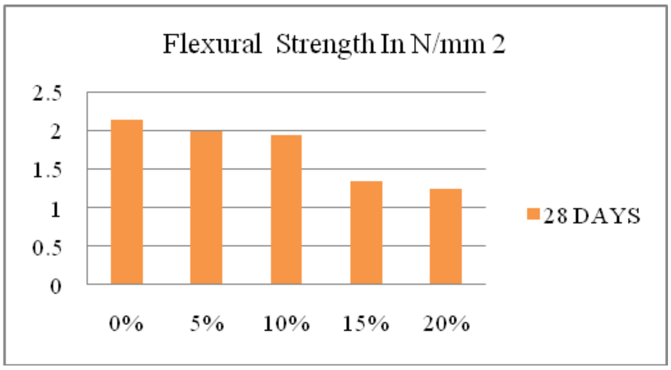


Fig.9 FLEXURAL STRENGTH AT 28 DAYS

M. BEAMS

GENERAL SHAPES

Some of the issues to consider when choosing which type of beam to use come down to preference. If the beam will be exposed or built out, the shape may make a difference in its appearance. But structurally both square and rectangular beams are appropriate in most applications. The biggest difference between the two is the load each can carry according to its dimensions and mass. In general a rectangular beam can carry a greater load with a narrower width than a square beam. For example, a 2’’x8’’ solid fir beam can carry out 1900 pounds per foot span. A 4’’x4’’ beam can only carry about 1000pounds for the same span. So basically for the same mass a rectangular beam can carry a greater load. Now the actual load ratings vary with species of wood, solid vs. laminated lumber, and other factors, so be sure to verify the capacity of any beam before installation.

N. ADVANTAGES AND DISADVANTAGES

The advantages and disadvantages of one type over the other really come down to your application. A square beam may take up more width, but have a shorter profile than a rectangular beam. This could change the appearance of a wall by making it taller or shorter, so could affect the proportions of the house from the exterior, or affect the spacing needed for plumbing, ductwork, etc. if your beams are exposed inside the house their shape could have an impact on the aesthetic; Rectangular beams are often consistent with more contemporary designs

Efficiency**:** For the same cross sectional area (volume of the beam per length) subjected to the same loading conditions, the beam deflects less.

STRESS IN BEAMS : Internally beams experience compressive, tensile and shear stresses as a result of the loads applied to them. Typically under gravity loads the original length of the beam is slightly reduced to enclose a smaller radius arc at the top of the beam, resulting in compression while the same original beam length at the bottom of the beam is slightly stretched to enclose a larger radius arc, and so is under tension. The same original length of the middle of the beam, generally halfway between the top and bottom, is the same as the radial arc of bending, and so it is under neither compression nor tension and defines the neutral axis. Above the supports the beam is exposed to shear stress

O. BEND TEST

Bend tests deform the test material at the midpoint causing a concave surface or a bend to form without the occurrence of fracture and are typically performed to determine the ductility or resistance to fracture of that material. Unlike in a flexure test the goal is not to load the material until failure but rather to deform the sample into a specific shape. The test sample is loaded in a way that creates a concave surface at the midpoint with a specified radius of curvature according to the standard in relation to which the test is performed. Bending tests are as popular as tensile test, compression test and fatigue tests. Bend testing a material allows for the determination of that materials ductility, bend strength, fracture strength and resistance to fracture.

INTERNATIONAL RESEARCH JOURNAL IN ADVANCED ENGINEERING AND TECHNOLOGY (IRJAET) E - ISSN: 2454-4752 P - ISSN : 2454-4744
VOL 4 ISSUE 3 (2018) PAGES 3754 – 3767
RECEIVED : 05.04.2018 PUBLISHED : 08.05.2018

P. FLEXURE TEST

The three point bending flexural test provides values for the modulus of elasticity in bending, flexural stress, flexural strain and the flexural stress-strain response of the material. The main advantage of a three point flexural test is the ease of the specimen preparation and testing.

Fig.10 Flexural strength test

DESIGN OF BEAM

Beams carry load primarily by bending action. In the limit state method, these members are first designed for strength and durability and their performance is then checked with regard to other limit states f serviceability e.g. Deflection and cracking. As per IS 456: 2000

ULTIMATE STRENGTH OF RC BEAMS
(LIMIT STATE OF COLLAPSE BY FLEXURE) ASSUMPTIONS

The following are the assumptions of the design of flexural members by employing limit state of collapse

Plane sections normal to the axis remain plane after bending

This assumption ensures that the cross section of the member does not warp due to the loads applied. It further means that the strain at any point on the cross section is directly proportional to its distance from the neutral axis.

The maximum strain in concrete at the outer most compression fibre is taken as 0.0035 in bending

This is clearly defined limiting strain of concrete in bending compression beyond which the concrete will be taken as reaching the state of collapse. It is very clear that the specified limiting strain of 0.0035 does not depend on the strength of concrete.

The acceptable stress strain curve of concrete is assumed to be parabolic

The maximum compressive stress strain curve in the structure is obtained by reducing the values of the top parabolic curve (fig.21 of IS 456:2000) in two stages. First, dividing by 1.5 due to size effect and secondly, again dividing by 1.5 considering the partial safety factor of the material.

The tensile strength of concrete is neglected as the section is assumed to be cracked up to the neutral axis.

BEAM DESIGN

Dimensions

Breadth = 150mm

Depth = 230 mm

d' = 25 mm

Length = 1.829 m

a) Stress

Fck = 20N/mm^2

Fy=415 N/mm^2

Load factor 1.5 for dead load and live load

b) Cross sectional dimension

Refer cl 23.2.1 of IS 456 adopt a span / depth ratio is 20.

Effective depth =d= (Span/20)=1829/20=91.25mm

Adopt

d=200mm

D=230mm

b=150mm

L=1.829m

c) Load

Self weight =0.15x0.23x25=0.8625 kN/m

Dead load for slab=0.15x1x25=3.75kN/m

Live load= 5 kN/m

Total Load W = 9.61kN/m

Design ultimate load(w_u) = 9.61x1.5=14.415kN/m

d) Ultimate Moments and shear forces

UltimateMoment Mu = $0.125w_ul^2$

$= 0.125 \times 14.415 \times 1.829^2$

Mu =6.0kN.m

Vu=0.5WuxL=0.5x14.415x1.829

Vu=13.1 kN

e) Tensile reinforcement

$M_{u1} = 0.138f_{ck}bd^2$

$= 0.138 \times 20 \times 150 \times 200^2$

= 16.56kN.m

Since Mu <Mul section is under reinforced

Mu=0.87x fy x Ast (d-Ast x fy)/bfck

6x10e6=0.87x415xAst (200-Astx415)/150x20

AstRequired=90 mm2

Ast Min= 0.85bd/fy
Ast Min=0.85x150x200/415
Ast Min=61mm2
Provide 2 no 10mm dia (Ast=157mm2)

f) Check for shear stress

τ_v= Vu/bd
τ_v= 13.1x1000/150x200=0.436
Pt= 100 Ast/bd=100x157/150x200=0.523
τ_c=0.49
$\tau_v < \tau_c$
Hence provide nominal reinforcement. Using 8mm dia 2 legged stirrups

S_v=Asv 0.87 fy/0.4b=2x50x0.87x415/0.4x150=601.75mm
S <0.75d (0.75x200)=150mm
Adopt spacing of stirrups 150mm

Fig Beam reinforcement

Fig Beam casting

Q. FLEXURAL VERSUS TENSILE STRENGTH

The flexural strength would be the same as the tensile strength if the material were homogeneous. In fact, most materials have small or large defects in them which act to concentrate the stresses locally, effectively causing a localized weakness. When a material is bent only the extreme fibers are at the largest stress so, if those fibers are free from defects, the flexural strength will be controlled by the strength of those intact 'fibers'. However, if the same material was subjected to only tensile forces then all the fibers in the material are at the same stress and failure will initiate when the weakest fiber reaches its limiting tensile stress. Therefore, it is common for flexural strengths to be higher than tensile strengths for the same material. Conversely, a homogeneous material with defects only on its surfaces (e.g., due to scratches) might have a higher tensile strength than flexural strength.

FLEXURAL STRENGTH TEST (IS 516:2004)

REFERENCE STANDARDS

IS 516 : 2004 – Methods of tests for strength of concrete

R. EQUIPMENT & APPARATUS

- Beam mould of size 15 x 15x 70 cm (when size of aggregate is less than 38 mm) or of size 10 x 10 x 50 cm (when size of aggregate is less than 19 mm). Here the rectangular beam mould size is 15x22x120 cm.
- Flexural test machine– The bed of the testing machine shall be provided with two steel plates, on which the specimen is to be supported and these plates shall be 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 plates 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 plates.

PROCEDURE

1. Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire cross section of the beam mould and throughout the depth of each layer.
2. Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
3. Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes.
4. The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.
5. The load shall be applied 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.

CRACKING MOMENT

The load at which the first crack was observed was calculated as the cracking moment. As the tensile reinforcement is increased the cracking moment also increases. The theoretical cracking moment was calculated as per the IS: 456-2000 recommendations and compared with the experimental values for the varying tensile reinforcement. All the beams were failed in flexural mode, as the load increases the flexure cracks initiates in the pure bending zone and the first cracks appears almost in the mid span. As the load increases, existing cracks propagated and new cracks developed along the span. The cracks at the mid-span opened widely near failure, the beams deflected significantly, thus indicating that the tensile steel must have yielded at failure. Crack width is an important factor from the durability point of view and cracks formed were < 0.3mm conforming to the IS: 456-2000. The cracks formed propagated towards the compression zone from the tension zone and the observations were made.

Fig.12 Crack pattern

DEFLECTION

The deflection of the beam were measured at an interval of 2kN at the mid span and 1/3rd span from both the sides of support till the failure of the beams.

CONCLUSION

In this study, the aggregate have been used with the addition of plastic fibers and tested their material properties and strength. Where the fiber proportion mixes of 5%,10%,15% and 20% have been chosen with uniform size of 20mm coarse recycled aggregate. Cube were casting and tested at the end of 7th day, and 28th day .it can be concluded that higher strength of waste plastic fibers concrete using recycled aggregate and conventional aggregates can be obtained with 1% admixture oil .the strength properties of waste plastic fibers concrete produced from conventional aggregate and workability of waste plastic fiber concrete produced from recycled aggregate is slightly lower than the waste plastic fiber concrete produced from conventional aggregate. Plastic fibers alter the energy absorption properties of the composite significantly. And addition of fiber decreases the brittleness of the concrete.

ACKNOWLEDGMENT

I acknowledge with deep sense of gratitude to chairperson Mr.V.RAMAPRASAD and Mrs.HEMAPRASAD, , Global Institute Of Engineering & Technology for their permission to undertake project work successfully.I express my gratitude and sincere thanks to my Principal Mr.K.SIVAKUMAR, M.E., Global Institute Of Engineering & Technology for being the source of great inspiration to us.At the very outset I would like to extend my gratitude to Prof. A.S.VIJAY VIKRAM, M.E, Head of the Department of Civil Engineering, Global Institute Of Engineering & Technology for giving me encouragement for completing this project work.I express my sincere thanks to our PG-Coordinator, Mr. JAYASEELAN,M.E Assistant Professor, Department of Civil Engineering, Global Institute Of Engineering & Technology, for his support and for all his help in the completion of the course of work. I extend my gratitude and my heartfelt thanks to all the staff members of Civil Engineering Department who extend their kind co-operation by means of valuable suggestion and timely help during the course of this work.

I also have immense pleasure in thanking my parent and friends for their whole hearted support. I also thank all the persons who influenced me in carrying out the project work.

REFERENCES

1. Bhogayata, A and N.K.Arora,2010 use of post- consumer plastic waste in concrete structural engineering digest,
2. Kandasamy,R and R.Murugan,2011 fiber reinforced concrete using domestic waste plastic as fibers
3. Concrete technology-M.S Shetty
4. IS 516-1959 (used for flexural strength determination)
5. IS 383-1970 and 2386 (I, II and III) (used for checking properties of recycled aggregate and grade of fine aggregate)
6. IS 456-2006, (selection of w/c ratio)
7. IS 10262:2009 (conforming to grade of cement)
8. B.w.jo, S.K. Park, J.Ch. Park, ”mechanical properties of polymer concrete made with recycled PET and recycled concrete aggregate”, cement & concrete composite 22(2008) 2281-2291
9. Raj Prasad (2006) ‘Experimental studies on behavior of R.C beams and columns with treated recycled aggregate concrete’
10. Raj Kumar B, Vijay kalimuthu B, Raj Kumar R, Santha Kumar A.S (2005) ‘Proportioning of recycled aggregate concrete’ the Indian concrete journal, oct, pp46-5