ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

A STUDY ON STRENGTH PROPERTIES OF FLY-ASH BASED GEOPOLYMER CONCRETE USING GGBS

Dr. M.V. Rama Raju[*1], Sri. E Maheshwar Reddy[2] & Sri. K. Nikhil[3]
[*1]Professor, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology (Autonomous) (CBIT), Gandipet, Hyderabad-500075, India
[2]Assistant Professor, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology (Autonomous) (CBIT), Gandipet, Hyderabad-500075, India
[3]Master of Engineering student, Department of Civil Engineering, Chaitanya Bharathi Institute of Technology (Autonomous) (CBIT), Gandipet, Hyderabad-500075, India

ABSTRACT

Concrete is one of the most widely used construction material all over the globe. Portland cement production is a major contributor to carbon dioxide emissions caused to global warming, many efforts are being made in order to reduce the use of portland cement in concrete. The world is facing the challenge of global warming and climate changes due to carbon dioxide greenhouse gases and increment of carbon foot print. To minimise the effect of global warming, the geopolymer technology could help in reducing the carbondioxide emissions. Introducing geopolymer materials not only will help in environmental issues but also for reduction of carbon dioxide emission caused by the 80 % to 90 % arise due to production of cement. The absence of cement in geopolymer mixtures is a gifted property and many researchers believe that the geopolymer concrete will be the future concrete. In this paper, the efforts were made to study the different strength properties of geo-polymer concrete with different percentage replacement of Ground Granulated Blast Furnace Slag (GGBS) and Fly-Ash and also to evaluate the optimum mix proportion of geo-polymer concrete with fly-ash replaced in various percentages by GGBS.

Keywords: *Geopolymer concrete, sodium silicate, sodium hydroxide, fly ash, compressive strength, split tensile strength, and flexural strength.*

I. INTRODUCTION

Ground Granulated Blast Furnace Slag (GGBS) and Fly-Ash:

Cement production contributes significant amount of greenhouse gas, because the production of one ton of portland cement also releases about one tone of CO_2 gas in to the atmosphere. In such cases alternatively utilization of supplementary cementation materials is well accepted and these materials replace the by weight of cement without sacrificing the original properties of concrete.

Ground granulated blast furnace slag is obtained by quenching molten iron slag (a by-product of iron and steel making)from a blast furnace in water (or) steam to produce a glassy, granulated product that is then dried and ground into a fine powder. The met kaolin (MK) or calcined kaolin, other type of pozzolan, produced by calcination has the capacity to replace silica fume as an alternative material. In overall view of the global sustainable development, it is imperative that supplementary cementing materials should be used to replace large proportions of cement in the construction industry.

Blast furnace slag is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500ºC to 1600ºC. The molten slag has a composition of 30% to 40% silicon dioxide (SiO_2) and approximately 40% CaO, which is close to the chemical composition of Portland cement. After molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues, is then rapidly water- quenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS).

Fly-ash is used as a supplementary cementitious material (SCM) in the production of Portland cement concrete. A supplementary cementitious material, when used in conjunction with Portland cement, contributes to the properties of the hardened concrete through hydraulic or pozzolanic activity, or both. As such, supplementary cementitious materials include both pozzolanos and hydraulic materials. Pozzolanos that are commonly used in concrete include fly ash, silica fume.

Optimum amount of fly ash that can be used in a concrete mixture which will maximize the technical, environmental, and economic benefits of fly ash use without significantly impacting the rate of construction or imparting the long term performance of the finished product is a challenging task for civil engineers. The optimum amount of fly ash will be a function of wide range of parameters and must be determined on a case-by-case basis.

Table: 1 Dosage levels of fly ash

Level of Fly Ash Classification % by mass of total cementitious material	**Classification**
<15	Low
15-30	Moderate
30-50	High
>50	Very High

II. LITERATURE REVIEW

P. Ganapati Naidu, A.S.S.N. Prasad, S. Adiseshu, P.V.V. Satayanarayana made an attempt to study the strength properties of geopolymer concrete using low calcium fly-ash replacing with slag in 5 different percentages. Higher concentrations of G.G.B.S (slag) result in higher compressive strength of geopolymer concrete. 90%of compressive strength was achieved in 14 days. *S. Sundar Kumar, J. Vasugi, P.S. Ambily and B. H. Bharatkumar* summarized that the development of low concentration alkali activator geopolymer concrete mixes and tests were conducted to determine the mechanical properties like compressive, split Tensile and flexural strengths. The experimental results from *Behzad Nematollahi and Jay Sanjayan* indicated that the effect of different SPs on the workability and strength of fly ash based geopolymer directly depends on the type of activator and the super plasticizer (SP). Using 8M NAOH solution as the activator, naphthalene based SP was effective. *Deb Partha Sarathi, Nath Pradip and Kumar Sarker Prabir* investigated by adding 0% to 20% of GGBS to total binder, significant increase in strength and decrease in workability was observed. The addition of GGBS enhanced setting of the concrete at ambient temperature. The strength gain observed slow down after the age of 28 days and continues to increase at a slower rate until 180 days. The effect of mixture variables on the development of tensile strength was similar to that on the development of compressive strength.*K. Parthiban and K. Saravana Raja Mohan*reported that the various proportions of GGBS (0%-100%) on fly-ash based GPC, the effect of the amount of Alkaline Activated Solution (AAS)in the mixture of GPC on their compressive strength is tested under ambient temperature conditions.

III. EXPERIMENTAL INVESTIGATION

Materials Used: GGBS, Fly-Ash, Fine Aggregate (River Sand), Coarse Aggregate (20mm), Sodium Hydroxide, Sodium Silicate and SP Conplast 430. GGBS is waste material produced by industry, used as binder material to way towards the waste utilization. Commercially available ground granulated blast furnace slag (GGBS) of JSW, was used along with Fly Ash as a binder in this experiment as confined to IS 12089:1987**.**

RESEARCHERID
THOMSON REUTERS
[Babu, 6(6): June 2019]
DOI- 10.5281/zenodo.3275813
ISSN 2348 – 8034
Impact Factor- 5.070

Table 2: Properties of GGBS

Parameter	Colour	Bulk Density	Fineness	Odour	Appearance	Specific Gravity	Particle Size
Property	Pale white	1150-1250 kg/m^3	350-400 kg/m^3	Odourless	Fine	2.61	20 micron-mean

Table 3: Chemical Properties of GGBS

Sample	Sio_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	P_2O_5	TiO_2	LOI
GGBS (%)	37.8	8.00	0.51	39.70	10.80	0.38	0.74	0.20	0.02	0.55	0.21

Table 4: Properties of Fly Ash

Parameter	Colour	Bulk Density	Fineness	Odour	Appearance	Specific Gravity	Particle Size
Property	Grey	540-860 kg/m^3	320 kg/m^3	odourless	Fine	2.44	35 micro-mean

Table 5: Chemical Properties of Fly Ash

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	P_2O_5	TiO_2	LOI
Fly Ash (%)	55.70	25.74	8.98	3.90	0.74	0.41	1.49	0.66	0.05	1.09	1.57

Table 6: Properties of Fine Aggregate

S. No.	Characteristics	Result
1	Zone	2
2	Specific gravity	2.046
3	Fineness modulus	3.19

Table 7: Sieve Analysis of Fine Aggregate

Sieve No.	Weight retained (Grams)	Percentage retained	Percentage passing	Cumulative weight retained (Grams)
10mm	0	0	100	0
4.75mm	628	20.93	79.07	20.93
2.36mm	260	8.67	70.4	29.6
1.18mm	416	13.87	56.53	43.47
600	207	6.9	49.63	50.37
300	852	28.4	21.23	78.73
150	540	18	3.23	96.77

ISSN 2348 – 8034
Impact Factor- 5.070

Pan	97			
Total	3000			∑C = 319.91

Total weight taken = 3000 grams
Fineness modulus of fine aggregate = ∑C /100 = 319.91/100
FM = 3.19

Table 8: Properties of Coarse Aggregate

S. No.	Characteristics	Result
1	Aggregate type	Crushed stone
2	Maximum size of aggregate	20
3	Specific gravity	2.71
4	Fineness modulus	1.945

Table 9: Sieve Analysis of Coarse Aggregate

Sieve No.	Weight retained(Kg)	% Weight retained	% Weight passing	Cumulative % weight
40 mm	0	0	100	0
20 mm	0.745	7.45	92.55	7.45
10 mm	8.150	81.5	11.05	88.95
4.75 mm	0.921	9.21	1.84	98.16
Pan	0.163			
Total	10			**∑C= 194.56**

Fineness modulus of 20 mm aggregate = 194.56/100
FM = 1.945

Table 10: Characteristics of Sodium Hydroxide

Molar Mass	Appearance	Specific Gravity	Melting Point	Boiling Point	Amount of heat liberated(dissolved in water)
40gm/mol	White solid	1.13	318°C	1390^{O}C	266 cal/gm

Table 11: Characteristics of Sodium Silicate

Specific Gravity	Colour	Na_2O	SiO_2	Weight of Solids	Water	Weight Ratio
1.53	Slight Grey to Yellow	14.70%	29.40%	44.10%	55.90%	2.5

IV. MIX DESIGN CALCULATIONS

Mix design method developed by *B. V. Rangan*for the design of GPC mixes, are followed in both preliminary and main study.

Design step for preliminary study are as follow:

- The density of GPC is assumed as 2400 kg/m^3.
- As per IS code mass of combined aggregate varies from 70-80% in concrete. In this study 78% mass of GPC is taken as combined aggregates.
- Two type of aggregate are used in this work, fine aggregate and coarse aggregate.
- In trial fine aggregate was taken as 30% of total aggregate and coarse aggregate combination of 20mm was taken as 70% of total aggregate.
- AAS to base material ratio analogous to water cement ratio can vary from 0.3 to 0.5. From literature review maximum strength has come at 0.4 or 0.45, so for pilot study two mixes are prepared by taking AAS to binder ratio 0.4 and 0.45.
- Ratio of SS to SH is kept constant 2.5.

V. MIX DESIGN (GRADE-40)

- Unit weight of concrete = 2400 Kg/m^3
- Total mass of combined aggregates assumed = 78% of 2400 = 1872 Kg/m^3
- Mass of fine aggregate (Coarse sand) = 30% of 1872 = 561.6 Kg/m^3
- Mass of coarse aggregates = 1872-561.6 = 1310.4 Kg/m^3
- Mass of source material (Fly Ash) and alkaline liquid = 2400-1872 = 528 Kg/m^3
- Alkaline liquid to source material ratio = 0.40
- Mass of Source material (Fly Ash) = 528/ (1.40) = 377.143 Kg/m^3
- Mass of alkaline liquid = 150.857 Kg/m^3
- Na_2SiO_3/NaOH = 2.5
- Mass of NaOH solution = 150.857/3.5 = 43.102 kg/m^3
- Mass of Sodium silicate solution = 150.857-43.102 = 107.755 Kg/m^3

Table 12: Design Data

DESIGN DATA	Kg/m^3
Fly Ash	377.14
Coarse Aggregate	1310.4
Fine Aggregate	561.6
Sodium Hydroxide(NAOH)	43.10
Sodium Silicate(NA_2SIO_3)	107.75
Conplast SP (430)	10.6

Table 13: Percentage Replacement of Fly-Ash & GGBS

MIX ID	FLY-ASH	G.G.B.S
1	100	0
2	85	15
3	75	25

4	65	35
5	55	45

Table 14: Mix Design Proportions (Kg/m^3) (G-40)

MIX ID	FLY-ASH	GGBS	C.A	F.A	NAOH	NA_2SIO_3	SP (430)
M-1	377.14	0	1310.4	561.6	43.10	107.75	10.6
M-2	320.56	56.571	1310.4	561.6	43.10	107.75	10.6
M-3	282.86	94.28	1310.4	561.6	43.10	107.75	10.6
M-4	245.15	131.99	1310.4	561.6	43.10	107.75	10.6
M-5	207.43	169.71	1310.4	561.6	43.10	107.75	10.6

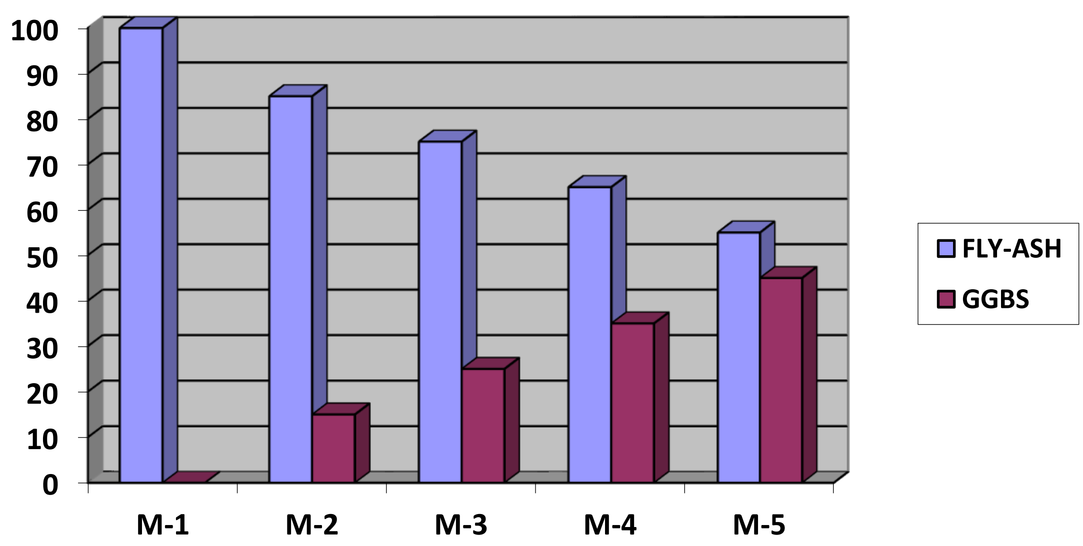

Fig. 1: Percentage Replacement of Fly-Ash & GGBS

VI. OBSERVATIONS

The results of concrete test specimens for 5 different mixes are presented in tabular forms and the comparison between the results is presented in the form of chart. All the values are the average of three trials in each case in testing program of this study.

Table 15: Compressive Strength Values

MIX ID	7 Days (N/mm^2)	28 Days (N/mm^2)
M-1	14.21	18.48

[Babu, 6(6): June 2019] ISSN 2348 – 8034
DOI- 10.5281/zenodo.3275813 Impact Factor- 5.070

M-2	44.81	50.95
M-3	47.86	53.03
M-4	51.12	68.37
M-5	54.56	76.7

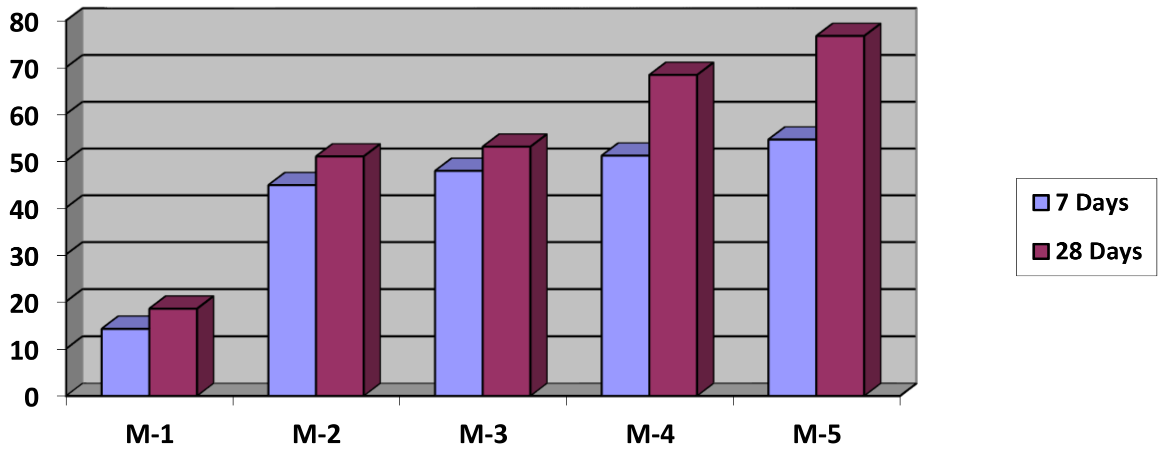

Fig. 2: Showing Compressive Strength Variation

Table 16: Split Tensile Strength Values

MIX ID	7 Days (N/mm^2)	28 Days (N/mm^2)
M-1	-	-
M-2	1.23	2.01
M-3	1.51	2.23
M-4	2.06	3.02
M-5	2.27	3.28

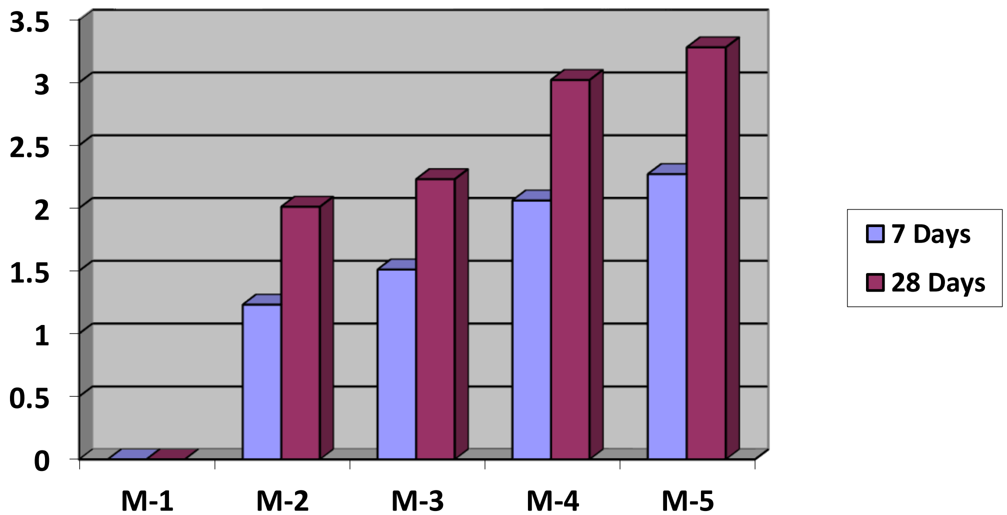

Fig. 3: Showing Split Tensile Strength Variation

ISSN 2348 – 8034
Impact Factor- 5.070

Table 17: Flexural Strength Values

MIX ID	7 Days (N/mm^2)	28 Days (N/mm^2)
M-1	2.71	3.73
M-2	3.11	4.38
M-3	3.45	4.93
M-4	4.43	6.4
M-5	5.58	8.13

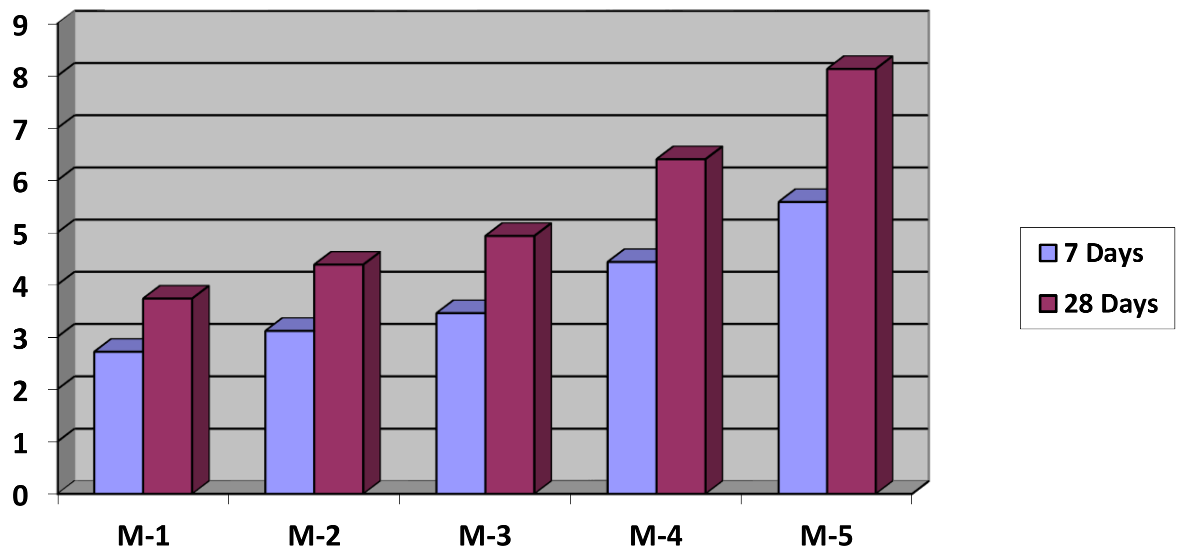

Fig. 4: Showing Flexural Strength Variation

1. In Mix-1 it is observed that amount with 100% fly-ash the 7 days average compressive strength is 14.21 & it is 50% less than the codal value. Similarly, for 28 days the average compressive strength values obtained about 55% less than codal value.
2. In Mix-1 we are using only fly-ash as a binding material. It is observed that Fly-ash doesn't have strength.
3. In Mix-2 with 85% Fly-ash & 15% GGBS it is observed that the 7days average compressive strength is 44.81 & it is 60% more than the codal value. Similarly, for28 days the average compressive strength values obtained more than 27% than codal value.
4. In Mix-3 with 75% Fly-ash & 25% GGBS it is observed that the 7 days average compressive strength is 47.86 & it is 70% more than codal value. Similarly, for 28 days the average compressive strength values obtained more than 33% than codal value.
5. In Mix-4 with 65% Fly-ash &35% GGBS it is observed that the 7days averagecompressive strength is 51.12 & it is more than 80% of codal value. Similarly, for 28 days the average compressive strength value obtained more than 70% than codal value.
6. In Mix-5 with 55% Fly-ash & 45% GGBS it is observed that the 7 days average compressive strength is 54.56& it is more than 90% than codal value. Similarly for 28 days the average compressive strength value obtained more than 88% than codal value.

VII. CONCLUSIONS

1. As percentage of replacement of GGBS increased in geopolymer concrete, it is observed that workability is decreased.

2. The strength of Geopolymer concrete increased with increase in percentage of GGBS in a mix.
3. It can be observed that the compressive strength of Geopolymer concrete increased with replacement of Fly-Ash by GGBS upto 45% in Geopolymer concrete with 10 molarity.
4. Among all the mixes, the mix with the combination of 55% fly ash, 45% GGBS is taken as optimal mix, as it obtained highest strength properties to other combinations.

REFERENCES

1. *Behzad Nematollahi, and Jay Sanjayan- Effect of different super plasticizers and activator combinations on workability and strength of fly ash based geopolymer, Materials and Design 57 (2014) 667–672*
2. *P. Ganapati Naidu, A.S.S.N. Prasad, S. Adiseshu, P.V.V. Satayanarayana - A Study on Strength Properties of Geopolymer Concrete with Addition of G.G.B.S, International Journal of Engineering Research and Development, Volume 2, Issue 4 (july 2012) PP. 19-28*
3. *S. SundarKumar,J. Vasugi, P.S.Ambily and B.H. Bharatkumar-Development and Determination of Mechanical Properties of Fly Ash And Slag Blended Geo Polymer Concrete" International Journal of Scientific & Engineering Research, (2013),Volume 4, Issue 8.*
4. *K. Parthiban and K. Saravana Raja Mohan, "Effect of Sodium Hydroxide Concentration and Alkaline Ratio on the Compressive Strength of Slag Based Geopolymer Concrete. International Journal of ChemTech Research 2014; 6(4): 2446-50.*
5. *Deb Partha Sarathi,Nath Pradip and Kumar SarkerPrabir "The effects of ground granulated blast-furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature" (May 2014), Materials and Design 62.*
6. *B. V. Rangan, "Mix design and production of fly ash based geopolymer concrete", Indian Concrete Journal, V. 82 (5), 2008, pp. 7 – 15*
7. *Indian standard code of practice, Method of sampling and analysis of concrete IS: 11991959, Reaffirmed 2004, BIS New Delhi, India.*
8. *Indian standard code of practice, Methods of Test for strength of concrete, IS: 516-1959, Reaffirmed 2004, BIS New Delhi, India.*
9. *Indian standard code of practice, splitting tensile strength of concrete- method of test IS: 5816-1999, Reaffirmed 2004, BIS New Delhi, India.*