International Journal of Scientific Research and Engineering Development-– Volume 5 Issue 3, May-June 2022

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE OF CONCRETE WITH PARTIAL REPLACEMENT OF FINE AGGREGATE BY IRON SCALE

P.Gayathiri,* S.Ravi Shankar**

*(Structural Engineering, PRIST UNIVERSITY, MADURAI CAMPUS, THANJAVUR
Email: gaya2000k@gmail.com)

** (Department of Civil Engineering, PRIST UNIVERSITY, MADURAI CAMPUS, THANJAVUR)

--************************----------------------------------

Abstract:

This experimental investigation involves the comparative study of the properties of concrete subjected to partial replacement of fine aggregate by using iron scale with conventional concrete. The study involves six different mixes consisting of different replacement levels S2(10%), S3(20%), S4(30%), S5(40%), S6(50%) & S7(60%) of iron scale replacement of fine aggregate (M Sand) of which compared with conventional concrete(S1). This study investigates for fresh concrete properties such as slump cone test and hardened concrete properties such as compressive strength test for cubes, splitting tensile test for cylinders and flexural strength test for beams. These properties are compared with conventional concrete with an aim of finding the optimum partial replacement level of fine aggregate with iron scale.

Keywords — **M-Sand, Iron scale, fresh and hardened concrete properties.**

--************************----------------------------------

I. INTRODUCTION

Crushed stone and gravel are most commonly used as a coarse aggregate in concrete, while natural sand or river sand and manufactured sand as a fine aggregate in concrete. The fine aggregate and coarse aggregates generally occupy 60% to 75% of the concrete volume and therefore, strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. It is therefore, important to obtain right type and good quality aggregate at site, because the aggregate form the main matrix of concrete. The global concrete industry required 8 to 12 billion metric tons of natural aggregates annually.

Conventional aggregates (fine or coarse) are mined from the earth, either dug out of pits or blasted out of quarries. This process has many significant environmental impacts. The need to mitigate these environmental stresses to make construction sustainable and to reduce rising costs of construction has necessitated research into the use of alternative cheap materials, more importantly, locally available ones which can replace conventional ones in concrete production. Here, an attempt is made by utilizing iron scale as suitable substitutes for fine aggregates in concrete and to study the behaviour and performance of concrete.

Iron scale is an industrial waste material. During the heating of steel in the reheating furnace, hot steel surfaces react with the in-furnace oxidizing atmosphere resulting in the formation of an iron oxides layer. This is known as iron scale. The material is shown in the fig.1.

fig.1 Iron scale

II. OBJECTIVES

Different objectives of this study are given below:

- To compare the workability of concrete mixes incorporating iron scale as partial replacement of manufactured sand with control concrete mix.
- To compare the compressive strength, splitting tensile strength and flexural strength of concrete mixes incorporating iron scale as partial replacement of manufactured sand with control concrete mix.
- To find out the optimum percent replacement of manufactured sand with iron scale so as to give acceptable workability and hardened properties.

III. SCOPE

- To utilize the waste materials that causes pollution and environmental problems.
- To check whether the use of iron scale improves the performance of concrete.

Properties	Values for experimentally
Fineness	9.8%
Normal consistency	32%
Initial setting	95 min
Final setting time	270 min
Specific gravity	2.9

IV. PROPERTIES OF CEMENT

Portland Pozzolona Cement of TNPL brand of 43 grade confirming to IS: 1489- 1991 part 1 was used in the present study. The properties of cement are shown in Table I.

TABLE: I
PROPERTIES OF CEMENT

V. PROPERTIES OF IRON SCALE

The Iron scales are analysed for different proportions of iron scale with manufactured sand and the values are Table II

TABLE II
DIFFERENT PROPORTION OF IRON SCALE PROPERTIES

Parameter of Iron scale	10%	20%	30%	40%	50%	60%
Fineness modulus	2.97	2.94	2.73	2.7	2.62	2.45
Specific gravity	2.69	2.67	2.68	2.75	3.08	3.21

VI. MIX RATIO

TABLE III MIX RATIO

Cement	Fine aggregate	Coarse aggregate	W/ C
1	1.35	2.64	0.44

VII. RESULT AND DISCUSSION

The test results on fresh concrete and hardened concrete such as slump test, compressive strength, Split tensile strength and flexural strength obtained from the experimental study are discussed below.

A. SLUMP CONE TEST

The targeted slump have been analyses as per the IS code IS 1199–1959. Table IV and Fig 2 shows the variation of slump value of concrete using iron scale. From the graph it is observed that in concrete, percentage of iron scale increases, it decreases the workability.

TABLE IV VALUES OF SLUMP CONE TEST

Mix designation	% of Iron scale	Initial slump	Final slump	Slump value	Workability
S1	0	300	227	73	Medium
S2	10	300	232	68	Medium
S3	20	300	238	62	Medium
S4	30	300	243	57	Medium
S5	40	300	252	48	Low
S6	50	300	258	42	Low
S7	60	300	263	37	Low

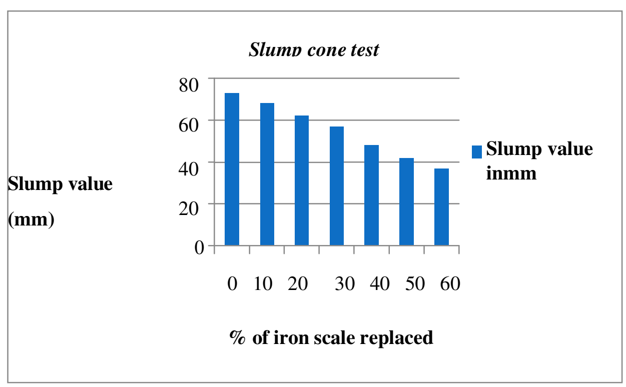

Fig 2 Variations of slump value

B. COMPRESSIVE STRENGTH TEST

The Compressive tests are carried out on CTM after curing with water for 28 days. Table V represents the values of compressive strength for different proportion of iron scale Fig.3 shows the compressive strength variations. The compressive strength goes on increasing for 10%, 20%, and 30% but goes on decreasing for 40%, 50% and 60% compare to conventional concrete. The

Designation	Iron scale (%)	Compressive strength of individual specimens (N/mm²)			Compressive strength (N/mm²)
		1	2	3	
S1	0	38.22	39.11	37.78	38.37
S2	10	38.67	39.56	40.44	39.56
S3	20	40.00	41.78	41.56	41.11
S4	30	43.11	44.44	43.56	43.7
S5	40	37.33	36.44	36.89	36.88
S6	50	36.00	34.67	34.22	34.96
S7	60	28.89	25.78	27.11	27.26

result shows that 30% replacement is desirable and economical replacement of iron scale as compare to fine aggregate. Also 10%, 20% and 30% replacement increases the strength as compare to conventional concrete.

TABLE V COMPRESSIVE STRENGTH OF CONCRETE AT 28 DAYS

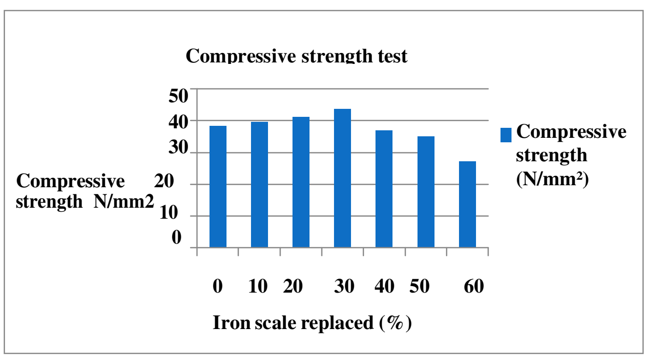

Fig 3 Compressive strength variations

C. SPLIT TENSILE STRENGTH TEST

The Split tensile tests are carried out on CTM after curing with water for 28 days. Table VI represents the values of split tensile strength for different proportion of iron scale and Fig.4 shows the split tensile strength variations. The split tensile strength goes on increasing for 10%, 20%, 30% and 40% but goes on decreasing for 50% and 60% compare to conventional concrete. The result shows that 30% replacement is desirable and economical replacement of iron scale as compare to fine aggregate.

TABLE VI
SPLIT TENSILE STRENGTH OF CONCRETE AT 28 DAYS

Designation	Iron scale (%)	Split tensile strength (N/mm^2)
S1	0	2.48
S2	10	2.69
S3	20	3.04
S4	30	3.19
S5	40	2.83
S6	50	2.41
S7	60	2.34

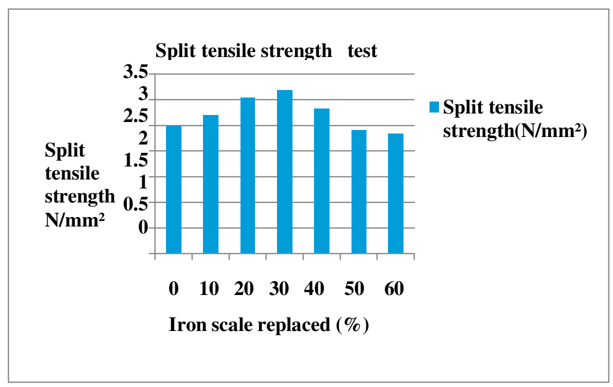

Fig 4 Split tensile strength variations

D. FLEXURAL STRENGTH TEST

The flexural strength test results show that the specimen S4 has higher flexural strength when compared with other specimens. The specimen S2, S3, S5 & S6 also has a high strength when compared with conventional concrete but S7 is lower than the conventional concrete. Table VII represents the values of deflections for different proportion of iron scale and Table VIII shows the flexural strength at 28 days.

TABLE VII TEST RESULTS ON BEAMS

Designation	Ultimate Load (kN)	Ultimate Deflection(mm)		First crack load (kN)	First load mid span deflection (mm)
		L/2	L/3		
S1	32.038	10.728	7.048	10.79	1.826
S2	40.67	24.062	23.734	10.624	2.773
S3	44.82	21.783	17.166	11.62	2.946
S4	48.472	17.754	17.243	12.948	1.808
S5	42.164	22.235	18.016	13.446	1.936
S6	36.52	24.368	21.306	10.96	2.441
S7	28.552	20.966	19.448	12.616	2.358

TABLE VIII FLEXURAL STRENGTH OF CONCRETE AT 28 DAYS

Designation	Iron scale (%)	Flexural strength (N/mm^2)
S1	0	24.21
S2	10	30.73
S3	20	33.87
S4	30	36.63
S5	40	31.86
S6	50	27.59
S7	60	21.59

E. LOAD – DEFLECTION BEHAVIOUR OF RC BEAMS

The load vs maximum deflection of the beam is a major criterion in determining the flexural performance of reinforced concrete beam.

1. CONVENTIONAL CONCRETE – S1

The load deflection data of the conventional beams is shown in fig 5. Here the reinforced beam failed in bending zone. After the first crack load of 10.79KN with the deflection of 1.826mm then the reinforcements started yielding and more number of cracks has formed in bending zone extended towards the point loads with increment in loads. Then the beam takes an ultimate load of 32.038 KN with 10.728mm mid span deflection after that it has been failed.

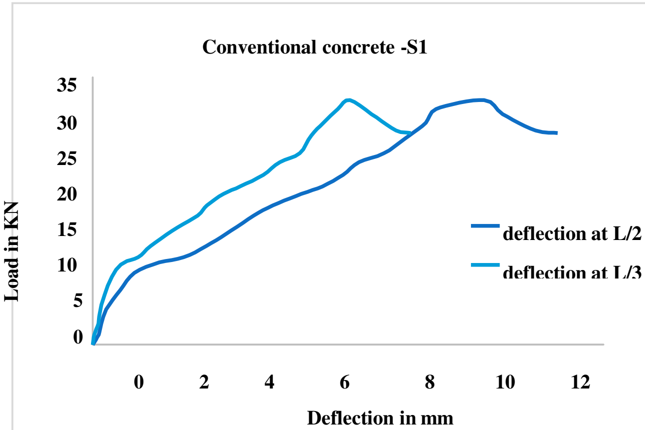

Fig 5 Load vs Deflection of S1

2. 10% IRON SCALE REPLACED – S2

Here the reinforced beam failed in bending zone. After the first crack load of 10.62KN with the deflection of 2.773mm then the reinforcements started yielding with increment in loads. Then the beam takes an ultimate load of 40.67KN with 24.062mm mid span deflection after that it has been failed. The comparison is made between S1 & S2 as shown in fig 6.

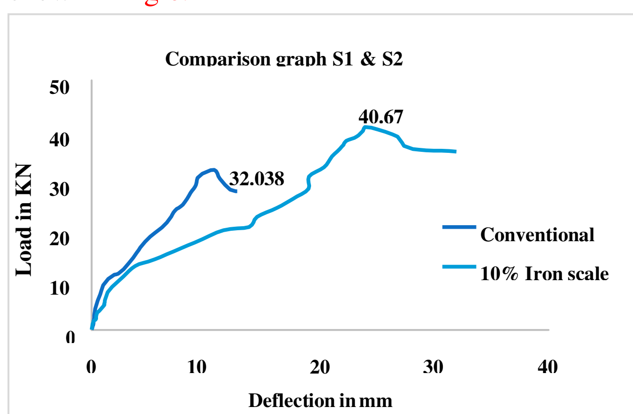

Fig 6 Load vs Deflection of S1 & S2

3. 20% IRON SCALE REPLACED – S3

Here the reinforced beam failed in bending zone. After the first crack load of 11.62 KN with the deflection of 2.946 mm then the reinforcements started yielding and a number of cracks has formed in bending zone extended towards the point loads with increment in loads. Then the beam takes an ultimate load of 44.82 KN with 21.783 mm mid span deflection after that it has been failed. The comparison is made between S1 and S3 as shown in fig 7

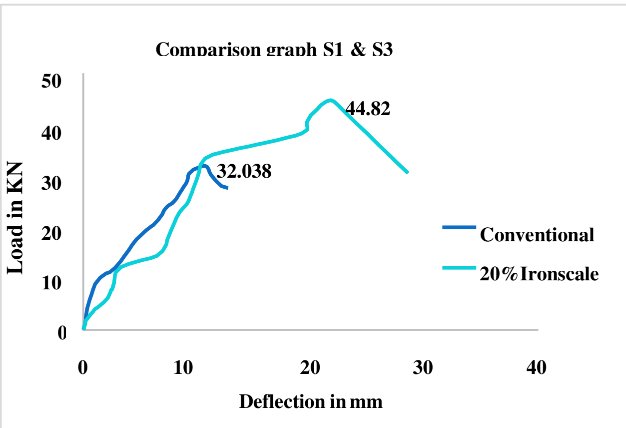

Fig 7 Load vs Deflection of S1 & S3

4. 30% IRON SCALE REPLACED – S4

Here the reinforced beam failed in bending zone. After the first crack load of 12.948 KN with the deflection of 1.808 mm then the reinforcements started yielding with increment in loads. Then the beam takes an ultimate load of 48.472 KN with 17.754 mm mid span deflection after that it has been failed. The comparison is made between S1 & S4 as shown in fig 8.

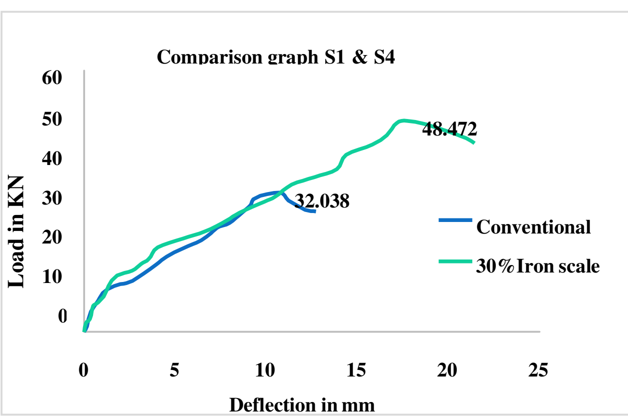

Fig 8 Load vs Deflection of S1 & S4

5. 40% IRON SCALE REPLACED – S5

Here the reinforced beam failed in bending zone. After the first crack load of 13.446 KN with the deflection of 1.936 mm then the reinforcements started yielding and a number of cracks has formed in bending zone extended towards the point loads with increment in loads. Then the beam takes an ultimate load of 42.164 KN with 22.235 mm mid span deflection after that it has been failed. The comparison is made between S1 & S5 as shown in fig 9.

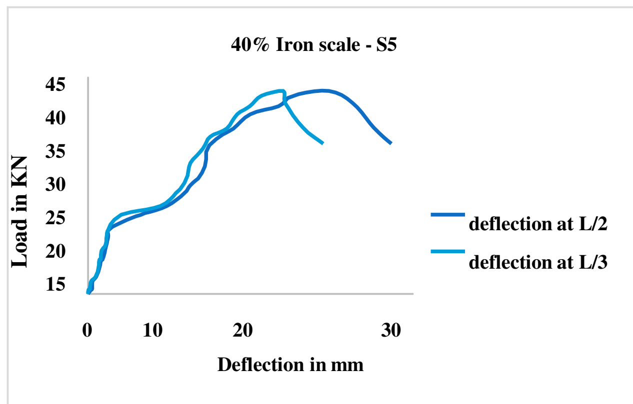

Fig 9 Load vs Deflection of S1 & S5

6. 50% IRON SCALE REPLACED – S6

. Here the reinforced beam failed in bending zone. After the first crack load of 10.96 KN with the deflection of 2.441 mm then the reinforcements started yielding and a number of cracks has formed in bending zone extended towards the point loads with increment in loads. Then the beam takes an ultimate load of 36.52 KN with 24.368 mm mid span deflection after that it has been failed. The comparison is made between S1 & S6 as shown in fig 10.

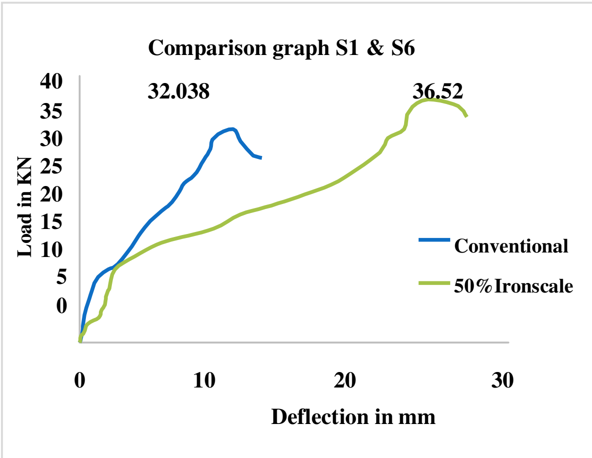

Fig 10 Load vs Deflection of S1 & S6

7. 60% IRON SCALE REPLACED – S7

Here the reinforced beam failed in bending zone. After the first crack load of 12.616 KN with the deflection of 2.358 mm then the reinforcements started yielding and a number of cracks has formed in bending zone extended towards the point loads with increment in loads. Then the beam takes an ultimate load of 28.552 KN with 20.966 mm mid span deflection after that it has been failed. The comparison is made between S1 & S7 as shown in fig 11.

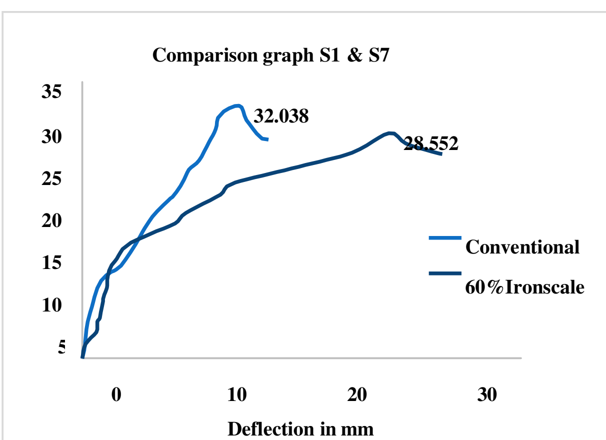

Fig 11 Load vs Deflection of S1 & S7

8. COMPARATIVE FLEXURAL TEST RESULTS

The comparative flexural test results of specimens S1, S2, S3, S4, S5, S6 and S7 as shown in fig 12.

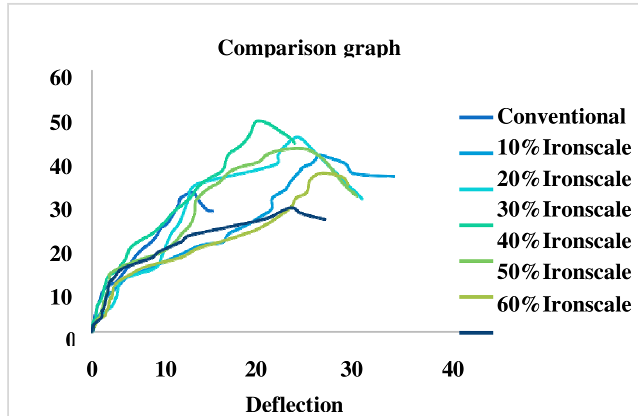

Fig 12 Load vs Deflection curve

F. DISPLACEMENT DUCTILITY

Ductility is the property which allows the structure to undergo large deformation without losing its strength. Ductility is the most important factor to evaluate the seismic behaviour of the RC beam.

TABLE VIII DUCTILITY INDEX

S. No	Designation	Yield load mid span deflection (Δy in mm)	Ultimate load mid span deflection load (Δuin mm)	Ductility index $\mu = \Delta u / \Delta y$	% increase in Ductility index	Ductility ratio
1	S1	2.498	10.728	4.295	-	-
2	S2	3.824	24.062	6.292	46.5	1.46
3	S3	3.918	21.783	5.56	29.45	1.28
4	S4	2.649	17.754	6.702	56.04	1.56
5	S5	3.622	22.235	6.138	42.91	1.42
6	S6	3.844	24.368	6.339	47.59	1.47
7	S7	4.64	20.966	4.518	5.19	1.05

The table VIII shows the ductility index of different specimens among those S4 shows higher ductility index and higher ductility ratio compared to that of other specimens. The entire specimen shows higher ductility index to that of conventional concrete S1

G. STIFFNESS

Stiffness may be defined as the load required to causing unit deflection. The stiffness values of S1, S2, S3, S4, S5, S6 and S7 specimens at first crack load and ultimate load are given in the Table IX and X.

TABLE IX STIFFNESS FOR FIRST CRACK LOAD

S. No	Designation	First crack load (KN)	First crack load mid span deflection (mm)	Stiffness (KN/ mm)
1	S1	10.79	1.826	5.91
2	S2	10.624	2.773	3.83
3	S3	11.62	2.946	3.94
4	S4	12.948	1.808	7.16
5	S5	13.446	1.936	6.95
6	S6	10.96	2.441	4.49
7	S7	12.616	2.358	5.35

The Table IX shows that the stiffness at first crack load here S4 shows higher stiffness in first crack load. Then the S5 shows higher stiffness in first crack load next to that S4 compared to that of S1 then the S2 shows the least stiffness to that of all specimens.

TABLE X STIFFNESS FOR ULTIMATE LOAD

S. No	Designation	Ultimate load (KN)	Ultimate load mid span deflection (mm)	Stiffness (KN/ mm)
1	S1	32.038	10.728	2.986
2	S2	40.67	24.062	1.69
3	S3	44.82	21.783	2.058
4	S4	48.472	17.754	2.73
5	S5	42.164	22.235	1.896
6	S6	36.52	24.368	1.498
7	S7	28.552	20.966	1.362

The Table X shows that the stiffness at ultimate load here S1 shows higher stiffness in ultimate load. Then the S4 shows higher stiffness in ultimate load next to that S1. S7 shows the least stiffness to that of all specimens.

VIII. CONCLUSION:

The present experimental investigation was conducted to study the suitability of iron scale as a partial replacement of manufactured sand in concrete. Workability, compressive strength, splitting tensile strength and flexural strength of concrete were tested by replacing manufactured sand with iron scale at different varying percentages in concrete. Test results indicate that iron scale, an industrial by-product, is a suitable substitute of manufactured sand in concrete.

- The workability of concrete decreases with increase in percentage of iron scale.
- Compressive strength of concrete was increased with inclusion of iron scale as partial replacement of manufactured sand. Concrete mix with 30% fine aggregate replacement level had maximum compressive strength at all other proportions. The value of compressive strength is 43.7 N/mm2.
- Splitting tensile strength of concrete was increased with inclusion of iron scale as partial replacement of manufactured sand. Concrete mix with 30% fine aggregate replacement level had maximum splitting tensile strength at all other proportions. The value of splitting tensile strength is 3.19 N/mm2.
- Flexural strength of concrete was increased with inclusion of iron scale as partial replacement of manufactured sand. Concrete mix with 30% fine aggregate replacement level had maximum flexural strength at all other proportions. The value of ultimate load is 48.472 kN and corresponding mid span deflection of the beam specimen is 17.754mm.
- The stiffness at ultimate load at S1 is higher stiffness in ultimate load (i.e.,) 2.986 kN/mm. Then the S4 is higher stiffness in ultimate load next to S1. S7 shows the least stiffness to that of all specimens.

REFERENCES

[1] A M Neville, *fourth edition [2009]"properties of concrete"*, published by Pearson education.

[2] Anil Singh et.al *''Study of partial replacement of fine aggregate by iron slag''* International Journal Advanced Research ISSN 2320-5407-10.21474/IJAR01/1159 (July 2016).

[3] Anupam Singhal, Dipendu Bhumia, BartikPandel, "*Effect of Sand Replacement by Mill Scale on the Properties of Concrete",* International Journal of Engineering Technology Science and Research, Volume 2, Special Issue, March 2015, PP 60-67

[4] BIS 10262:2019, *Concrete mix proportioning* ─ Guidelines, Bureau of Indian Standards, New Delhi

[5] BIS 1199:1959, *Methods of sampling and analysis of concrete*, Bureau of Indian Standards, New Delhi

[6] BIS 456:2000, *Plain and reinforced concrete* ─ Code of practice, Bureau of Indian Standards, New Delhi

[7] BIS 516:1959, *Methods of tests for strength of concrete*, Bureau of Indian Standards, New Delhi

[8] BIS 2386(Part 1):1988, *Methods for test for aggregate: Part 1;* Particle size and shape, Bureau of Indian Standards, New Delhi

[9] BIS 2386(Part 3):1963*, Methods of Test for Aggregates for Concrete – Specific Gravity, Density, Voids, Absorption & Bulking*, Bureau of Indian Standards, New Delhi

[10] BIS 383:1970, *Specification for coarse and fine aggregate for natural sources,* Bureau of Indian Standards, New Delhi

[11] BIS 5816:1999, *Method of test splitting tensile strength of concrete*, Bureau ofIndian Standards, New Delhi

[12] B.Venkatesan & V.J.Lijina.et.al *''Partial replacement of fine aggregate steel slag and coarse aggregate by walnut shell in concrete"* Materials today: proceedings- (2020)

[13] Gambir, M.L., *Concrete Technology",2nd edition* , Tata McGraw Hill Co. Ltd, New Delhi, 1995

[14] Gaurav Desai et al. "*Partial replacement of fine aggregate using steel slag"* International journal of engineering department and research (IJEDR) ISSN: 2321- 9939 Volume 6, Issue 2 (2015)

[15] Kr.Ramsundar, R.Jayanthi ''*Partial Replacement of Fine Aggregate with Iron Slag* " International journal of Innovative Research in Science, Engineering and Research ISSN: 2319 -8753 Volume 7,special issue 5 (April 2018)

[16] Shetty M.S., "*Concrete Technology",4th edition*, ,S.Chandand Company, New Delhi,2005

[17] S.T.Borole et.al "*Replacement of fine aggregate by steel slag"* International journal of innovative research in science and engineering. Vol.No.2, Issue 03 (2016)

