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EXPERIMENTAL AND ANALYTICAL ANALYSIS OF FLEXURAL BEHAVIOUR OF SELF COMPACTING CONCRETE WITH GGBS

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Abstract — *Ground granulated blast furnace slag (GGBS), due to its pozzolanic nature, could be a great asset for the modern construction needs, because slag concretes can be of high performance, if appropriately designed. The use of GGBS as a cementitious material as well as fine filler is being increasingly advocated for the production of High Performance Concrete (HPC), Roller Compacted Concrete (RCC) and Self-Compacting Concrete (SCC), etc. However, for obtaining the required high performance in any of these concrete composites, slag should be properly proportioned so that the resulting concrete would satisfy both the strength and performance criteria requirements of the structure. The present paper is an effort towards presenting a mix design methodology for the design of GGBS concretes based on the efficiency concept. The methodology will be successfully verified through a proper experimental investigation and the GGBS concretes were evaluated for their strength characteristics. The results will indicate that the proposed method is for proportioning mixes with maximum possible replacement of cement by GGBS for achieving strength.*

Keywords—*HPC, GGBS, SCC, Tensile Strength, Compressive strength, Flexural strength.*

I. INTRODUCTION

SCC is now an emerging technique in the field of concrete technology. SCC is an innovative idea to tackle the problem of concreting through dense reinforcement. SCC is unique, because of its properties, like fill ability, flow ability, pump ability, and make production of concrete more industrialized. The use of cementitious fines like GGBS makes the concrete economical. It becomes necessary to develop a compaction free production system thereby reducing the overall cost of the project, improve the quality of the work, and providing safety in the work environment. SCC possesses high flow ability, resistance to segregation, passing ability which enables the concrete to fill in through the dense reinforcement. In addition to the properties of fresh concrete, SCC should also possess the properties of hardened concrete, in order to ensure the hardened concrete properties. The use of SCC will lead to a more industrialized production, reduce the technical costs of in situ cast concrete constructions, improve quality, durability, pump ability and reliability of concrete structures and eliminate some of the potential for human error. It will replace manual compaction of fresh concrete with a modern semi-automatic placing technology and in that way improve health and safety in and around the construction site. SCC must have a great filling ability, a high segregation resistance during and after placing the concrete and a great filling ability through dense reinforcement and around other obstacles such as recesses and embedded items.

A. Self Compacting Concrete

Self-compacting concrete (SCC) represents one of the most significant advances in concrete technology for decades. Inadequate homogeneity of the cast concrete due to poor compaction or segregation may drastically lower the performance of mature concrete in-situ. SCC has been developed to ensure adequate compaction and facilitate placement of concrete in structures with congested reinforcement and in restricted areas. Self-compacting concrete (SCC) is a special concrete that can settle into the heavily reinforced, deep and narrow sections by its own weight, and can consolidate itself without necessitating internal or external vibration, and at the same time maintaining its stability without leading to segregation and bleeding. SCC was developed first in Japan in the late 1980s to be mainly used for highly congested reinforced structures in seismic regions (Bouzoubaa and Lachemi, 2001). As the durability of concrete structures became an important issue in Japan, an adequate compaction by skilled labors was required to obtain durable concrete structures. This requirement led to the development of SCC and its development was first reported in 1989 (Okamura and Ouchi, 1999).

Two general types of SCC can be obtained:

- one with a small reduction in the coarse aggregates, containing a VMA and
- one with a significant reduction in the coarse aggregates without any VMA

To produce SCC, the major work involves designing an appropriate mix proportion and evaluating the properties of the concrete thus obtained. In practice, SCC in its fresh state shows high fluidity, self-compacting ability and segregation resistance, all of which contribute to reducing the risk of honey combing of concrete. With these good properties, the SCC produced can greatly improve the reliability and durability of the reinforced concrete structures.

B. Ground Granulated Blast Furnace Slag (Ggbs)

Granulated Blast Furnace Slag (GGBS) 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, granular product is then dried and ground into a fine powder. In India we produce about 8 million tones of blast furnace slag. Dumping of these was a very big problem itself. But nowadays we are using this product every effectively in concrete. In contrast to the stony grey of concrete made with Portland cement the near white colour of GGBS cement permits architects to achieve a lighter colour for exposed fair-faced concrete finishes at no extra cost. To achieve a lighter colour finish, GGBS is usually specified at between 20% to 60% replacement levels, although levels as high as 85% can be used. GGBS cement also produces a smoother, more defect free surface, due to the fineness of the GGBS particles. Dirt does not adhere to GGBS concrete as easily as concrete made with Portland cement, reducing maintenance costs. GGBS cement prevents the occurrence of efflorescence, the staining of concrete surfaces by calcium carbonate deposits. Due to its much lower lime content and lower permeability, GGBS is effective in preventing efflorescence when used at replacement levels of 20% to 60%. Concrete containing GGBS cement has a higher ultimate strength than concrete made with Portland cement. It has a higher portion of the strength- enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime which does not contribute to concrete strength.

C. Study Of Literatures

1. In general SCC is achieved based on the three proportion using admixtures which are filling ability, pouring ability, segregation resistance.
2. Typical corrosion resistant concrete can be produced by using GGBFS mineral admixture at the ratio of 25%.
3. Partial replacement of cement with GGBS by 30% has given more strength and durability.
4. This research work focuses on strength characteristics, it is concluded that the curing age and type are important and corrosion resistant concrete can be produced by using GGBFS mineral admixture at the ratio of 30%.
5. The compressive strength, flexural strength and split tensile strength of M20 grade concrete increase when the replacement of cement with ceramic powder 30% and the replacement of fine aggregate with GGBS upto 40% replaces and further replacement of fine aggregate with GGBS decreases the compressive strength.

II. METHODOLOGY

The concrete mix was made as dry with PPC and fine aggregate (River Sand). The materials were properly mixed in the dry condition and different volume of GGBS were taken in terms of weight with respect to the weight of concrete as 20%, 40% and 60%. The water cement ratio of 0.5 was used to prepare the concrete mix. Totally 7 number of specimens were casted and cured for 28 days. After the curing period the specimens were subjected to testing using the flexural strength to find the loading capacity of the specimen with respect to the deflection of beam. To analyze the beam using STAAD-PRO software.

III. EXPERIMENTAL PROGRAM

A. Materials

1. Cement

Cement is one of the binding material of concrete used as a proportion for casting of beam specimen. Portland Pozzolanic Cement of ACC plus 53 grade was used. Specific gravity - 3.15, Initial setting time - 35 minutes, Final setting time - 585 minutes.

2. Fine Aggregate

Locally available river sand was used as fine aggregate which passes through 4.75mm. The specific gravity of the fine aggregate is 2.67. The fineness modulus of aggregate was 2.62.

3. GGBS

Cement is one of the binding material of concrete used as a proportion for casting of beam specimen.. Specific gravity - 3.45, Initial setting time -50 minutes, Final setting time - 625 minutes.

B. Testing Procedure

Concrete beam specimen of size 1200mm x 150mm x 120mm was casted in the mix proportion of 1:1.56:2.92. The beams were tested after curing of 28 days for determining the Flexural strength.

IV. RESULTS

A. Experimental Results

TABLE.1 COMPRESSIVE STRENGTH RESULT

CUBE	GGBS (%)	LOAD (KN)	COPRESSIVE STRENGTH(N/mm^2)	AVERAGE
1	0	933	41.5	38.125 N/mm^2
2	20	888.75	43.8	
3	40	877.5	43	
4	60	843.75	42.7	

TABLE.2 SPLIT TENSILE STRENGTH RESULT

CYLINDER	GGBS %	LOAD (KN)	SPLIT TENSILE STRENGTH (N/mm^2)	AVERAGE
1	0	204.178	2.89	2.935 N/mm^2
2	20	213.363	3.02	
3	40	207.004	2.93	
4	60	204.88	2.9	

TABLE.3 FLEXURAL STRENGTH RESULT

Beam Designation	Materal Types	Deflection	Ultimate Load (KN)	Ultimate Moment (KNm)	Stiffness (KN/m)	Flexural Strength N/m^2
1	GGBS (0%)	14	21	7.13	6.29	4.725
2	GGBS (20%)	12	25	7.26	6.71	11.11
3	GGBS (40%)	12.7	23.5	7.53	7.66	10.4
4	GGBS (60%)	13.8	22.7	8.06	8.89	10.08
5	SCC – 1	11.6	26.5	7.72	7.84	11.7
6	SCC - 2	10.5	28	7.59	7.48	12

B. Experimental Results of Load and Deflection Graphs

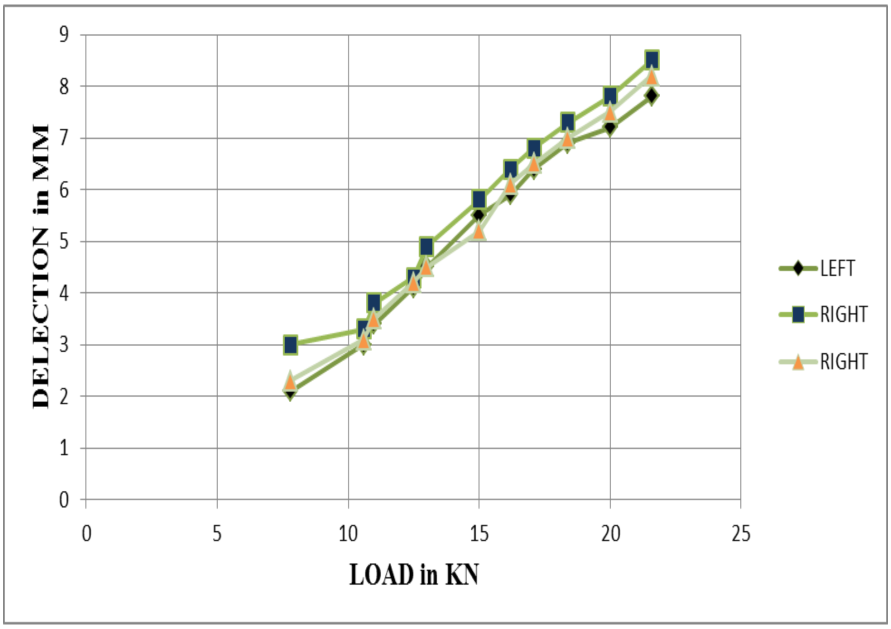


Fig.1 Load Vs Deflection of GGBS @ 0% deflection curve

Fig.2 Load Vs Deflection of GGBS @ 20% deflection curve

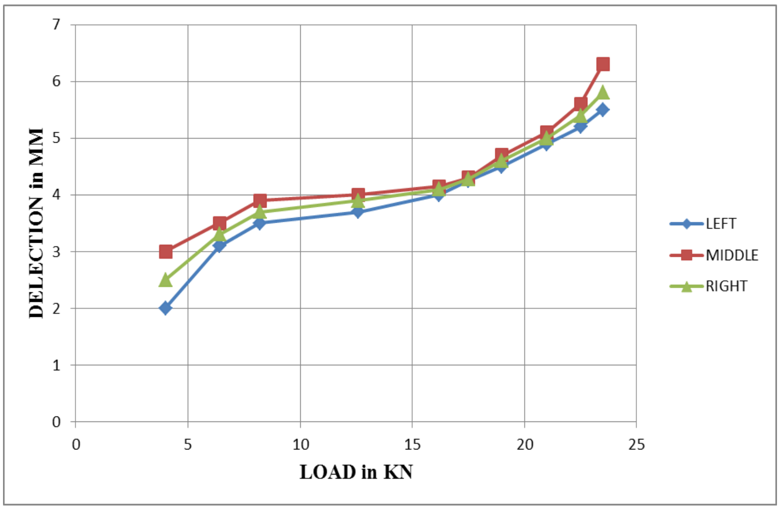


Fig.3 Load Vs Deflection of GGBS @ 40% deflection curve

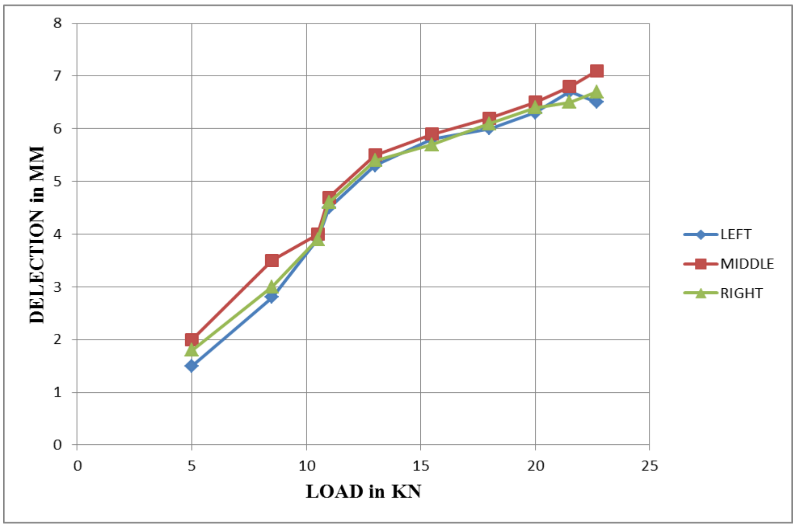


Fig.4 Load Vs Deflection of GGBS @ 60% deflection curve

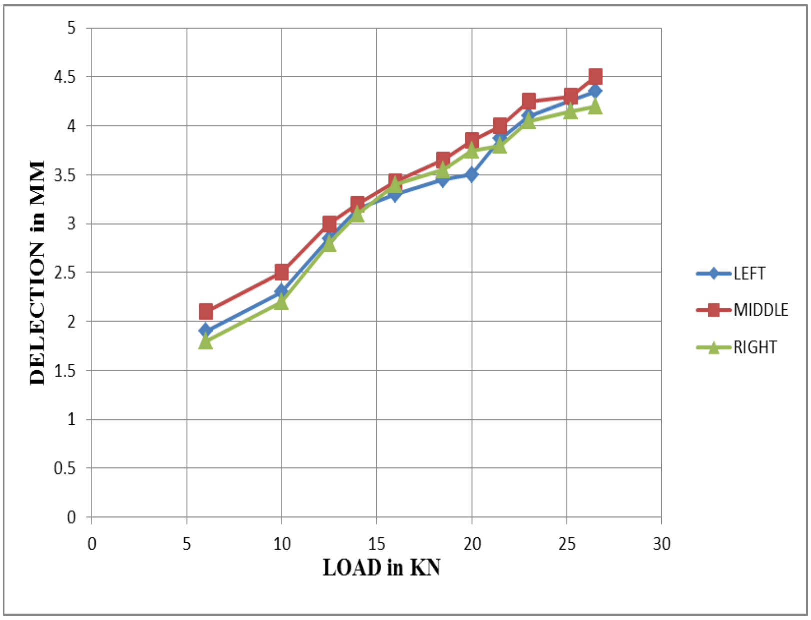


Fig.5 Load Vs Deflection of SCC - 1 deflection curve

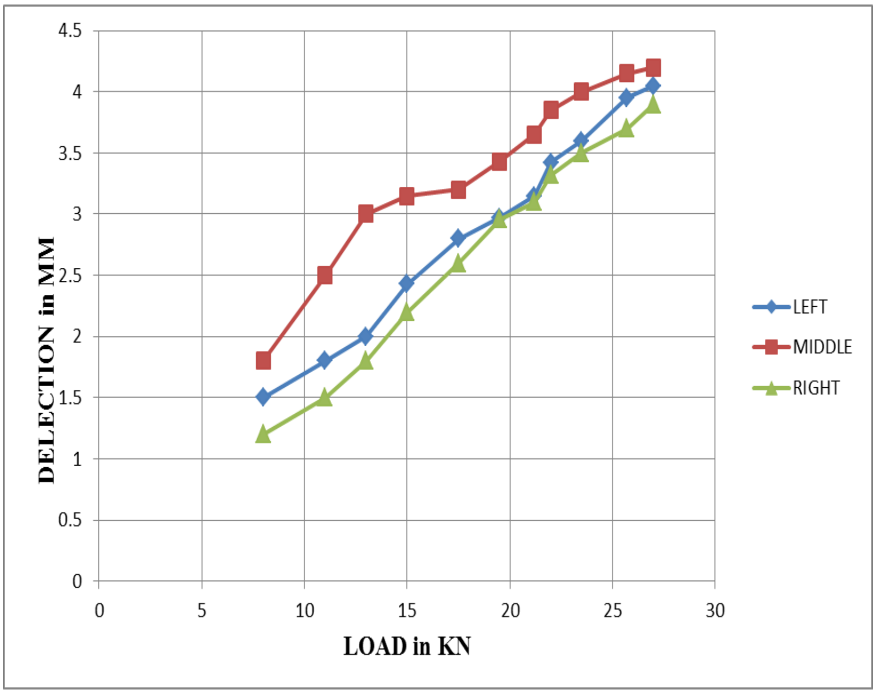
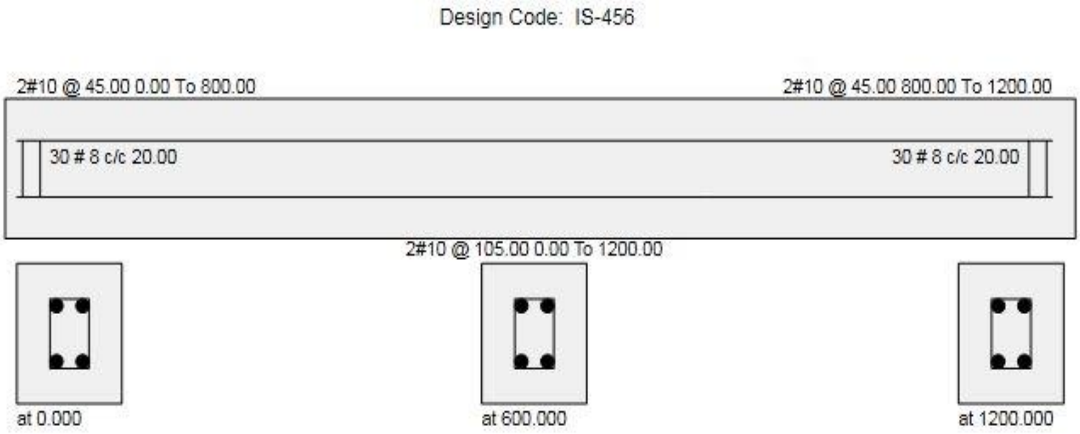


Fig.6 Load Vs Deflection of SCC - 2 deflection curve

C. Experimental set up of instrument in load alied for beam

D. ANALYSIS and Design of Beam Using STAAD-PRO Result

- Analysis the beam using staad -pro software.
- To compare the result for deflection of conventional beam result to analytical method result. But, analytical method is very low deflection and load is same strength carried.



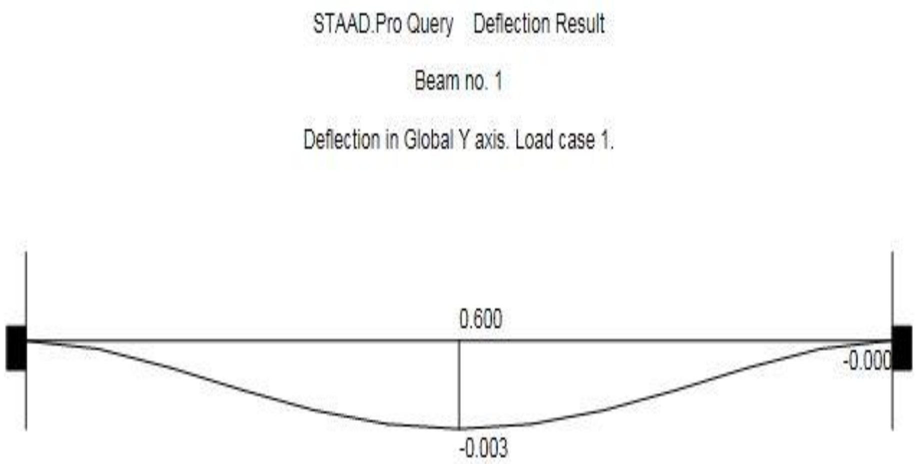


Fig.7 Deflection of Beam

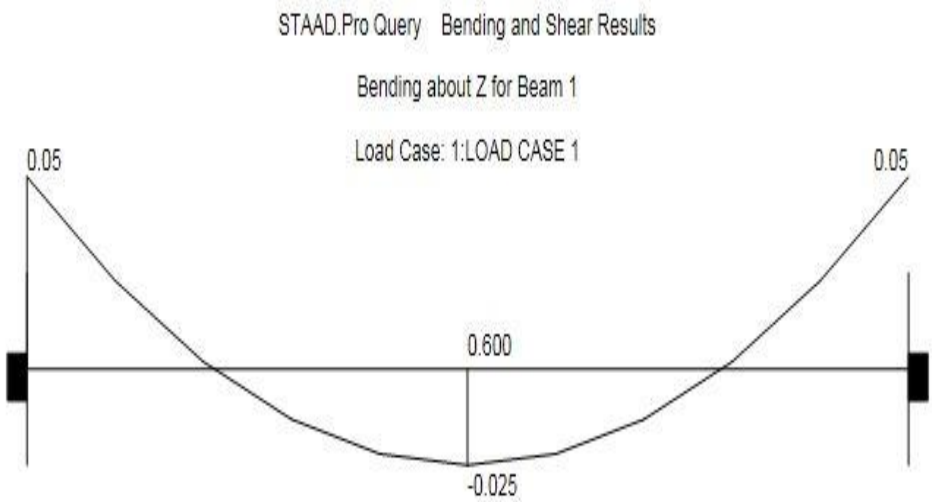


Fig.8 Shear Bending of beam

Beam Displacement Detail

Displacements shown in italic indicate the presence of an offset

Beam	L/C	d (m)	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
1	1:LOAD CASE	0.000	0.000	0.000	0.000	0.000
		0.120	-0.000	-0.001	0.000	0.001
		0.240	-0.000	-0.003	0.000	0.003
		0.360	-0.000	-0.006	0.000	0.006
		0.480	-0.000	-0.008	0.000	0.008
		0.600	-0.000	-0.009	0.000	0.009
		0.720	-0.000	-0.010	0.000	0.010
		0.840	-0.000	-0.009	0.000	0.009
		0.960	-0.000	-0.007	0.000	0.007
		1.080	-0.000	-0.004	0.000	0.004
		1.200	0.000	0.000	0.000	0.000
	2:LOAD CASE	0.000	0.000	0.000	0.000	0.000
		0.120	-0.000	-0.017	0.000	0.017
		0.240	-0.000	-0.055	0.000	0.055
		0.360	-0.000	-0.100	0.000	0.100
		0.480	-0.000	-0.142	0.000	0.142

Beam Maximum Moments

Distances to maxima are given from beam end A.

Beam	Node A	Length (m)	L/C		d (m)	Max My (kNm)	d (m)	Max Mz (kNm)
1	1	1.200	1:LOAD CASE	Max -ve	0.000	0.000	0.000	0.113
				Max +ve	0.000	0.000	0.700	-0.064
			2:LOAD CASE	Max -ve	0.000	0.000	0.000	1.801
				Max +ve	0.000	0.000	0.700	-1.245

Beam Maximum Shear Forces

Distances to maxima are given from beam end A.

Beam	Node A	Length (m)	L/C		d (m)	Max Fz (kN)	d (m)	Max Fy (kN)
1	1	1.200	1:LOAD CASE	Max -ve	0.000	0.000	0.000	0.476
				Max +ve	0.000	0.000	1.200	-0.287
			2:LOAD CASE	Max -ve	0.000	0.000	0.000	5.701
				Max +ve	0.000	0.000	0.800	-2.699

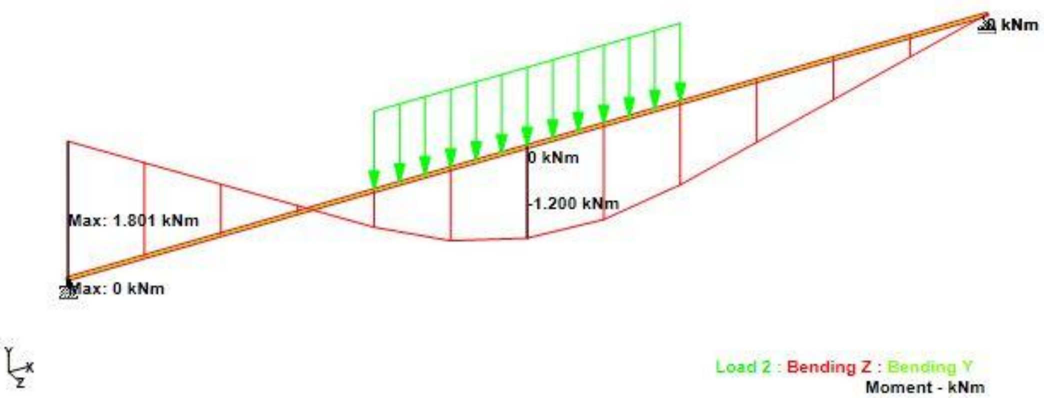


Fig.9 Bending Moment diagram

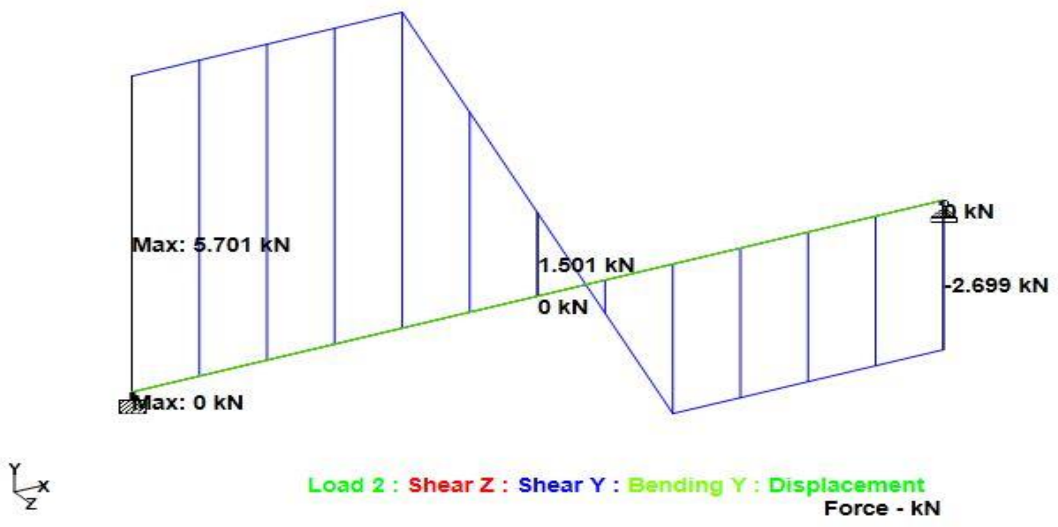


Fig.9 Shear Force in Diagram

IV. CONCLUSIONS

- SCC mixes can be made using GGBS as an alternative to coarse aggregate without sacrificing the strength.
- GGBS can be effectively used as replacement of coarse aggregate up to 20% by weight without any decrease in strength after that the results showed a gradual decrease in strength.
- With the increase of GGBS replacement level up to 40% the Slump flow and L-box Passing ability of the SCC mixtures with GGBS increased.
- SCC-1 mix containing compared to 20% in GGBS attained an increase in the compressive strength to 12.38% when compared with compressive strength of normal concrete at 28 days.
- SCC-2 mix containing compared to 20% in GGBS attained an increase in the ultimate moment to 13.04% when compared to normal concrete.
- Flexural strength of coventional beam result is normally to analytical method compare to strength is same but deflection very low deflection is carried.

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