Section A-Research paper
ISSN 2063-5346

High Strength Self-Compacting Concrete Reinforced Beams with Steel and GFRP Bars: Performance of Fly-ash and GGBS-based Materials

Balachandu koya[1], M. Sureshkumar[2]

[1]Research Scholar, Department of Civil & Structural Engineering, SCSVMV, Enathur, Tamil Nadu – 631 561, India, Email: bala.c923@gmail.com

[2]Department of Civil & Structural Engineering, SCSVMV, Enathur, Tamil Nadu – 631 561, India, Email: sureshgis@kanchiuniv.ac.in

Abstract:

By eliminating the need for further compaction from the outside, High strength self-compacting concrete (HSSCC) is a unique kind of concrete with improved Workability. The incorporation of Supplementary Cementitious Materials (SCMs) into HSSCC manufacturing is widely regarded as crucial for economic, technological, and ecological reasons. For this reason, GGBS and Fly-ash is an innovative, potentially useful mineral admixture based on slag that may be used as an SCM. Reinforcing concrete buildings in harsher settings may benefit from using Glass Fibre Reinforced Polymers (GFRP) rebars as an alternative to steel rebars. The purpose of this research is to conduct the first investigation of its kind into the flexural behaviour of steel and GFRP-reinforced GGBS and Fly-ash based SCC beams. The effects of reinforcement and HSSCC mix proportions on concrete and reinforcement's bearing capacity, ultimate deflection, cracking, and energy absorption were investigated. Notable results showed that steel-reinforced beams broke under flexure, whereas GFRP beams broke brittlely.

Key words: High Strength Self-Compacting Concrete (HSSCC), GGBS,Flyash, Beam test, Glass Fibre Reinforced Polymer (GFRP) rebar, Load-Crack width, Ultimate load was energy absorption.

1. Introduction:

The development of self-compacting concrete, sometimes referred to as SCC (Domone 2006, 2007; Su and Miao 2003), is widely regarded as being among the most important breakthroughs that have taken place in more recent times. SCC has the ability to run hrough any gaps in the reinforcement and into any corners of the mould when the procedure is being poured (Dinakar, 2012). This is because SCC does not need vibration or compaction during the manufacturing process. According to the findings of the investigation that Okamura and Ouchi carried out in 2003, it is conceivable for it to be broken down using nothing more than its own weight. When SCC is used in industrial settings, the lack of compacting work results in reduced placement costs, shorter construction durations, and greater productivity (Dinakar, 2012). This is due to the fact that SCC does not need labour to compact the material. In place of cement, supplemental cementitious materials (SCMs) were used throughout the manufacturing process of SCC (Vivek et al., 2017). Some examples of these SCMs are marble powder, fly ash, silica fume, metakaolin, and ground granulated blast furnace slag. According to Sagar and Sivakumar (2020), the use of supplementary cementitious materials (SCMs) in the manufacturing of concrete, either as a partial or entire substitute for cement, is one of the most important and significant technological advancements in the industry. In this sense, symmetric key cryptography (SCC) employs a greater number of secret key modules (SCMs) in binary, ternary, and quaternary configurations than does cryptography based on binary, ternary, and quaternary cyphers. Utilising SCMs results in economic, ecological, and functional advantages that are all advantageous, all without sacrificing the product's longevity.

One of these SCMs is called Alccofine, and it is a novel micro-fine mineral admixture that is based on slag. Slag is the primary component of this particular admixture. Despite the fact that it is highly reactive and includes a substantial quantity of glass, the presence of this low-calcium silicate material does not in any way cause damage to the surrounding ecosystem. According to a number of different sources (Balamuralikrishnan and Saravanan, 2019; Parveen et al., 2018; Saloni et al., 2020; Sharma et al., 2016), this GGBS material is believed to be the product of considerable processing and to comprise ultra-fine particles. These claims have been made by a number of different researchers. The researchers Abraham et al. (2019), Balamuralikrishnan and Saravanan (2019), Kavitha and Kala (2016, 2020), Kavyateja et al. (2020), Narender et al. (2018, 2020), Sagar and Sivakumar (2020), and Upadhyay and Jamnu (2014) have all conducted studies in which cement is replaced by an alccofine maximum of 25% with additional SCMs in normal concrete and SCC. Prithiviraj and Saravanan (2020) conducted a series of experiments in which they replaced alccofine in SCC at several percentages ranging from 10% to 60%. They found that the optimal percentage was 30%, which did not need the inclusion of any other SCMs. Beams were constructed for the purpose of this study by mixing steel and fiber-reinforced polymer (FRP) reinforcements in proportions that were determined by the work of Prithiviraj and Saravanan (2020).

According to Golafshani et al. (2014), the use of fiber-reinforced polymer, which is also known as FRP, as reinforcement in reinforced concrete (RC) structures is on the rise. RC stands for reinforced concrete. This is as a result of the promise that FRP has as an innovative and contemporary building material that has the ability to take over the construction industry. According to Golafshani et al. (2014), the popularity of FRP bars may be related to their greatly enhanced mechanical performance, low weight, and acceptable durability in severe conditions. Additionally, these characteristics may have contributed to their widespread adoption. Pavements composed of deicing salt-treated concrete; constructions created in or near salt water (for example, marine barriers or undersea projects); wastewater; and other surfaces with comparable characteristics are all examples of salt-sensitive surfaces. Previous studies (Alsayed 1998; Ascione et al., 2010; Hassan et al., 2019; Kalpana, 2011; Mazaheripour et al., 2016; Roja et al., 2014) have shown that fibreglass reinforced plastic (FRP) is a good alternative to steel in the applications that have been outlined above. Because of the unbroken nature of the components that make it up.

Even though FRP bars are one of a kind owing to the features they have, not a lot of research has been done on the flexural behaviour of GFRP bars in HSSCC. This is despite the fact that there has been a lot of research done on the unique properties of FRP bars. In particular, the flexural behaviour of GGBS and Fly-ash based SCC with GFRP has not been examined in any of the previous research that have been carried out. GFRP is an example of glass fibre reinforced plastic. In this study, we provide the findings of an experimental investigation into the flexural performance of conventional steel and sand-coated GFRP bars embedded in traditional HSSCC, GGBS, and Fly-ash-based HSSCC while being subjected to static monotonic stress. The bars were tested under conditions in which they were subjected to the stress in a constant manner. The use of static monotonic testing allowed for the collection of data pertaining to the load, the fracture width, and the energy absorption. graphics that depict the connection between load and crack width and the relationship between load and energy absorption have been published. These graphics can be found in the article.

2. Experimental investigation

2.1 Test Specimens

For the purpose of this investigation, fifteen beams were constructed and subjected to a load applied from two different points. Every one of the beams was 3000 mm in length and included a cross-section that measured 150 mm by 300 mm. Beams were halved utilising GGBS and fly ash as a substitute in the HSSCC, and reinforcement was also replaced. Beams 1 through 3 are built out of a normal HSSCC combination with Steel, whilst Beams 4 through 15 are set out using varying percentages of GGBS and flyash-based HSSCC is reinforced with GFRP bars (GFRP, 20% GFRP, 20% FA, 20% FA+GGBS), each measuring 16 millimetres in diameter, at the tension and compression face of the structure. The longitudinal reinforcements in beams 1 to 15 are contained by steel stirrups with a diameter of 8 millimetres that are separated at 150 millimetres center-to-center. Beams are needed. In Table 1, the beam specs are provided.

Table 1: Beam details

MIX	Beam ID	Longitudinal Bars dia (mm)		Stirrups
		Top	Bottom	
HSSCC M60	Steel-M60	2# 16	2#16	8mm @ 150 c/c
HSSCC M60	GFRP-M60	2# 16	2#16	8mm @ 150 c/c
HSSCC (Flyash, GGBS) M60	GFRP-M60 (GGBS, FA)	2# 16	2#16	8mm @ 150 c/c

2.2 Material properties

Ordinary Portland Cement (OPC) 53 grade was utilised in accordance with IS 12269-1987 for beam preparation. It was measured to have a specific gravity of 3.15. In lieu of cement with a specific gravity of 2.4 and 2.62, the pozzolanic material Flyash and GGBS is used as per IS 3812:2013 & IS 12089-1987. River sand, which is readily accessible, was employed as the fine aggregate, and its specific gravity of 2.56 and fineness modulus of 2.96 validate Zone II per IS: 383-1970. According to IS: 383-1970, coarse aggregates consist of crushed angular aggregates with a size that passes a 20mm screen but is held by a 4.75mm sieve. These aggregates have a specific gravity of 2.6. The chemical admixture utilised is a locally available super plasticizer HI-FORZA 864, which is Sulphonated Naphthalene based IS 9103-1999. The laboratory tap water used to make the concrete was free of chemicals and other contaminants, therefore it was utilised to make the samples. Table 2 lists the mechanical parameters of the steel grade Fe550 (TMT bars) that was utilised to make the main bars and stirrups.

Table 2: Mechanical properties of rebars

Rebar	Tensile Strength (N/mm^2)	Yield Strength (N/mm^2)	% of Elongation
Steel	716	597	17.50
GFRP	467.57	432.75	5

2.2.1 GROUND GRANULATED BLAST-FURNACE SLAG (GGBS)

Ground-granulated blast furnace slag, or GGBS for short, originated in iron blast furnaces. It was retrieved from JSW Cement in Hyderabad, Telangana, India.

2.2.2 Fly-ash

The low calcium Fly Ash (FA) comes from the Vijayawada Thermal Power Stations (VTPP) in the Indian state of Andhra-Pradesh. The physical properties of the fly ash are characterised by testing in accordance with IS 3812:2013. A molecular study of fly ash revealed that silicon dioxide and aluminium oxide made up the bulk of the material.

2.2.3 GFRP Bars

The characteristics of GFRP bars are somewhat varied. Neither the procedure nor its components are the same. The mechanical characteristics of GFRP bars are tabulated in Table 2. To provide a strong connection between the GFRP and the concrete, surface treatment of a plain GFRP bar is required. The present study thus involves coating the simple smooth bars with epoxy glue and then covering the surface with dry sand via rolling the bars.

2.2.4 Reinforcement's Framework

The concrete beams' top and bottom reinforcing bars each measured 16 millimetres in diameter before casting. Binding wires were used to adequately secure the positions of the 8 mm dia. stirrup bars, and the primary reinforcement bars and hanger bars. Reinforcement architecture is shown in Figure 1.

Figure 1. Reinforcement Details

2.3 Mix design:

In the laboratory, fresh qualities such as flowability (flow table), filling ability (V-funnel), and passing ability (L-box) are evaluated in accordance with the recommendations provided by EFNARC. The results of these evaluations are then compared to the recommendations provided by EFNARC (EFNARC 2005). The characteristics of HSSCC

ISSN 2063-5346

both when it was fresh & hardened was studied earler . The suggested amounts of HSSCC-Steel, HSSCC-GFRP and HSSCC beams of 20% GGBS –GFRP, 20% Flyash- GFRP, (10%GGBS+ 10%Fly Ash)- GFRP, (5%GGBS+5% Fly Ash)- GFRP in the mix have a typical compressive strength of 63.22 and 68.97 N/mm2 respectively.

2.4 Test Specimen:

Before the beam specimen was installed into the loading frame, the length of the beams was measured and then divided into three portions using the notation L/3. After that, the grid patterns are created in the flexural zone of the beam so that the size of the fracture may be measured. Adjustments were made to the location of the supports (hinged and roller) in the loading frame after the length of the beam specimen was determined. After that, the beam is positioned within the loading frame where it will remain. In order to establish the capacity of the beams that were just simply supported, a two-point loading condition was used (Figure 2). The planned beams have steel and GFRP bars placed below them for further reinforcement. The load was progressively added with the assistance of a hydraulic jack with a capacity of 500 kN, and the load was transmitted to the beam specimen with the assistance of a steel spreader in the form of an I-section. In order to determine the amount of strain deviation that occurs during loading, two surface strain gauges, one linear and one lateral, each with a gauge length of 5 millimetres were attached to the concrete surface of each beam and linked to the strain indicator. In addition, Demac gauge pellets are fastened to the surface of the concrete so that a human may physically measure the surface concrete strain. Linear Variable Differential Transformer (LVDT) was used in order to examine the deflection that occurred in the middle of the span. With the assistance of a Demec gauge, the surface strain of the concrete is evaluated and analysed. The load was gradually increased by the hydraulic jack at intervals of 5 kN, and the progress was monitored by a load cell. At each load increment, many observations were recorded, including deflections, strains on the concrete surface, stresses on the rebar, and fissures on the beam's face. The initial fracture load, the final crack load, failure type, load-bearing capability, and other parameters were carefully monitored and recorded throughout the process.

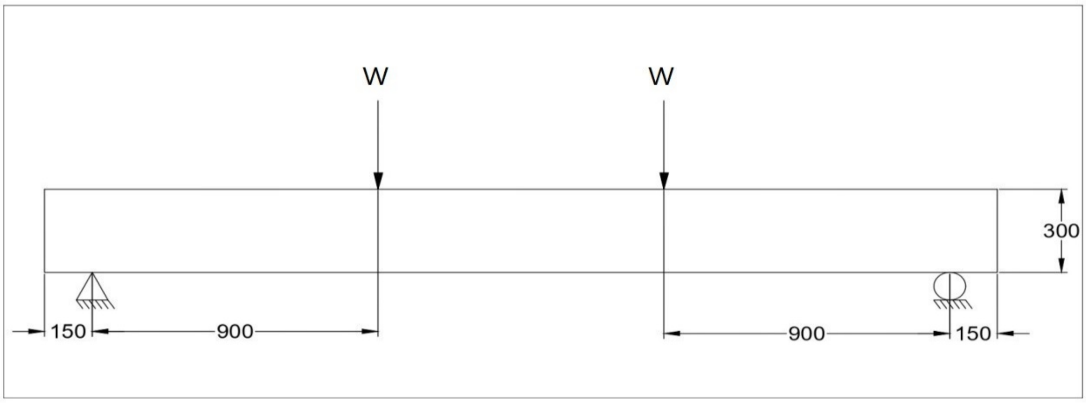

Figure 2: Test specimen

3. Results and Discussion

The performance of the GFRP and steel-reinforced concrete beams was evaluated using a number of different metrics, including Ultimate deflection, Ultimate load, first crack load deflection, Yield load, yield deflection and Energy absorption. This section includes the average consequence for each group, as well as the average values for the ultimate load; refer to Table 3 for further information.

Table 3: Readings at Ultimate Load

Beam Designation	Type of FRP	First Crack Load (KN)	First Crack Deflection (mm)	Yield Load (KN)	Yield Deflection (mm)	Ultimate Load (KN)	Ultimate Deflection (KN)	Energy Absorption at Yield load (Nm)
RCC	STEEL	20.01	0.8	140	19.5	155.05	27.66	229.24495
GFRP	GFRP	16	1	130	35	133	40	260.76
20% FA	GFRP	10	1.2	110	32	127.83	41.33	288.43183
20% GGBS	GFRP	15	0.85	131	36	131.16	41.6	476.8295
20% (FA+ GGBS)	GFRP	17	1.35	115	35	125.04	41	296.76801

3.1 Load Bearing Capacity

When compared to traditional HSSCC Steel (RCC) beams, the ultimate load-bearing capability of the GGBS & Fly-ash based HSSCC GFRP (GFRP, 20% GGBS, 20% FA, 20% FA+) beams is considerably equivalent to that of the conventional beams. When it comes to rebars, the performance of steel reinforcement is noticeably higher than that of GFRP rebars. In comparison to steel-reinforced beams, GFRP reinforced HSSCC GFRP (GFRP, 20% GGBS, 20% FA, 20% FA+) beams had an ultimate load that was about 15% to 20% less, respectively, than steel-reinforced beams shown in Figure 3. The ultimate load-bearing capacity of GFRP beams and steel reinforced beams designed in accordance with ACI 440.1R-06 and ACI 318.10 standards is compared in Table 3. It's possible that the qualities of the rebars are to blame for this turn of events.

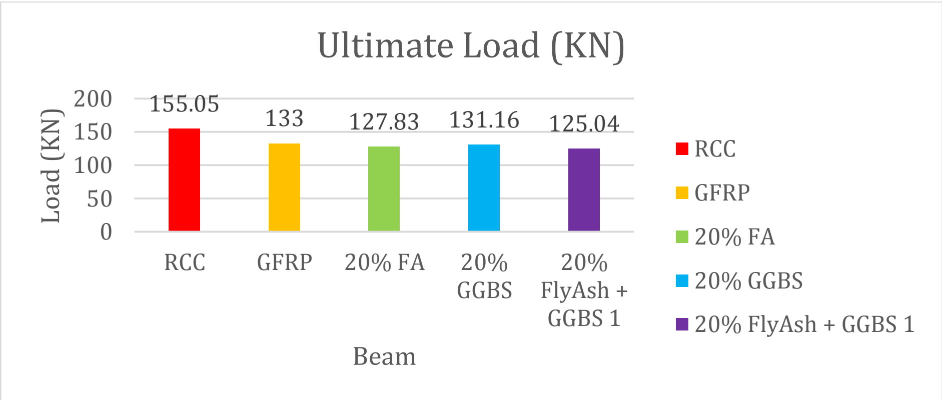

Figure 3: Ultimate load VS HSSCC Beams with different replacement of admixture

3.2 Ultimate load vs Ultimate Deflection

The ultimate load-ultimate deflection behaviour of the HSSCC beams is shown graphically in Figure 4, which shows the behaviour of the beams with five various mix proportions and reinforcements, respectively. The beams are stiff and free of cracks before the weight is applied. The beam experiences deformation along with the development of fractures in the tension zone whenever there is an increase in the load that is being applied. The continued application of load causes the creation of new cracks as well as the widening of any existing fractures in the material. Based on the observation made during the test, the behaviour of the steel-reinforced beams during their ultimate deflection is highly parallel up to the service loads, which is indicative of the beam's stiffness. When subjected to different loading situations, the GFRP-reinforced beams exhibited the same behaviour as one another. At the very end of the process, it was discovered that the rate of load increment that causes beams to bend is most important in determining how quickly they bend. Beams reinforced with glass fibre reinforced plastic exhibited a partly linear elastic behaviour up to the point of failure, while beams reinforced with steel exhibited a nonlinear elastic behaviour. When it came to deflection, the GFRP bars that were embedded in the HSSCC M60 mix performed much better than the steel bars that were inserted in the RCC mix. Beams that were reinforced with GFRP did not perform as well as beams that were reinforced with steel. Figure 3 depicts the ultimate load, whereas Table 3 details the yield load at the point where the first fracture appeared. In addition, a profile of the ultimate deflection of steel and GFRP reinforced HSSCC beams under ultimate load was created so that it could be understood. Figure 4 displays the ultimate load- ultimate deflection profile.

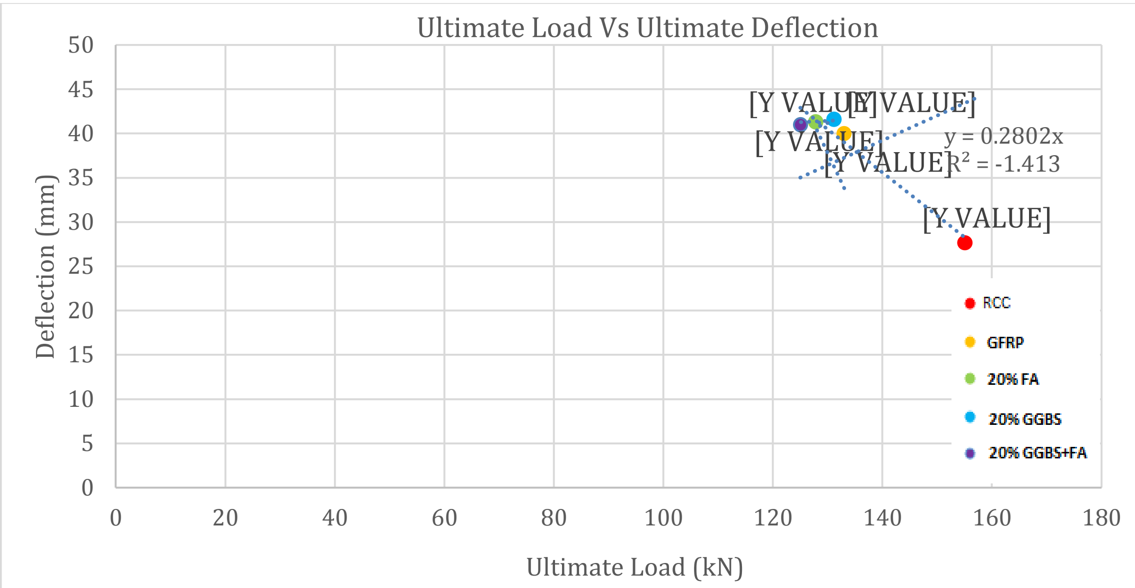

Figure 4: Ultimate Load vs. Ultimate Deflection of HSSCC Beam

3.3 First Crack load vs First Crack Deflection

Figure 5 is a graphical representation of the First crack load vs First crack deflection behaviour of the HSSCC beams. This figure depicts the behaviour of the beams with five different mix proportions and reinforcements, including steel-reinforced beams RCC and GFRP reinforced HSSCC GFRP (GFRP, 20% GGBS, 20% FA, 20% FA+GGBS) beams. Before the weight is placed, the beams have sufficient rigidity and do not include any fractures. Anytime there is a rise in the load that is being applied, the beam suffers deformation in addition to the development of cracks in the tension zone. This occurs anytime the load is increased. As a result of the observations that happened during the test, the first crack load in relation to the first fracture deflection was recorded. It was discovered that the initial crack deflection is smaller in RCC beams when compared to GFRP beams. Additionally, the traditional RCC Beam has successfully accepted a higher first crack load than GFRP beams. In contrast to steel-reinforced beams, GFRP reinforced HSSCC GFRP (GFRP, 20% GGBS, 20% FA, 20% FA+) beams had a First crack load that was about 20%, 50%, 25% and 15% lower; conversely, the First crack deflection was 25%, 50%, 6.25%, and 69% higher. The first crack load-first fracture deflection profile is shown in Figure 5.

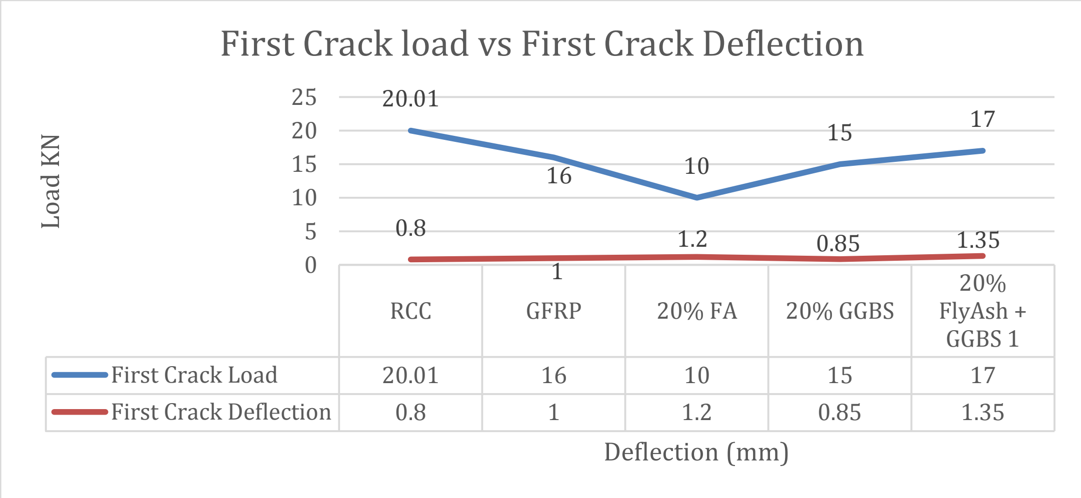

Figure 5: First Crack Load vs. First Crack Deflection of HSSCC Beams

3.4 Yield load vs Energy Absorption

Figure 6 shows a graphical illustration of the behaviour of the HSSCC beams in terms of their yield load and energy absorption. Because of the observations that were made while the test was being carried out, the yield load in proportion to the amount of energy that was absorbed was recorded. It has been shown that the energy absorbed by RCC beams is much lower when compared to the energy absorbed by GFRP beams. In addition to this, conventional RCC beams have been shown to effectively take a yield load that is greater than that of GFRP beams. In comparison to steel-reinforced beams, GFRP reinforced HSSCC GFRP (GFRP, 20% GGBS, 20% FA, 20% FA+) beams had a yield load that was about 7.14%, 6.4%, 21.42%, and 17.85% lower; on the other hand, the Energy absorption was 13.53%, 108%, 26%, and 29.25% greater.

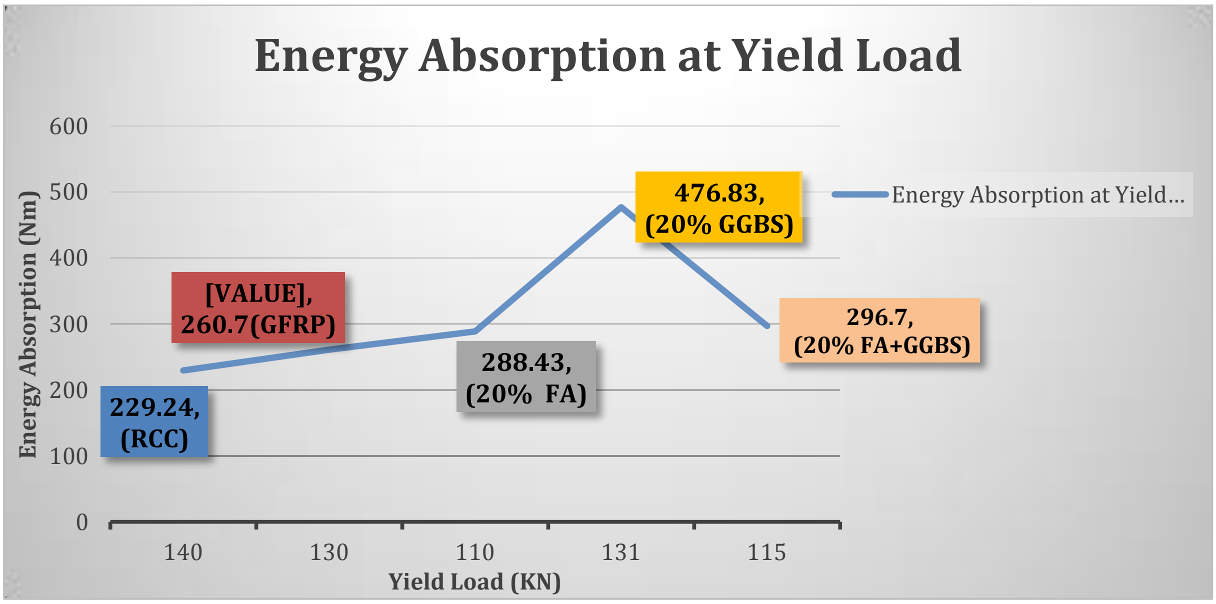

Figure 6: Yield vs. Energy Absorption of HSSCC Beams

4. Conclusion:

The goal of this study was to explore the flexural behaviour of HSSCC steel and HSSCC GFRP reinforced beams (GFRP, 20% GGBS, 20% FA, and 20% FA+GGBS) when they were exposed to static stress. According to the collected data, each and every HSSCC beam had a nonlinear link up to the point when it broke down. When flexure is applied to beams reinforced with steel, the beams break; however, when flexure is applied to beams reinforced with GFRP, it generates brittle failure in the concrete and rupture in the reinforcement. A partially linear elastic behaviour led to the failure of this GFRP component, which was used in the construction. There is not a perceptible growth in the load-bearing capacity of beams in conjunction with the increase in the strength of the concrete. Steel has a far bigger influence on the flexural load-bearing capacity and deflection of beams when compared to GFRP reinforcements. Steel also has the advantage of being much more durable. A decrease in the stiffness of the GFRP rebar led to wider fracture widths developing in the beams, which was the outcome of the beams. However, the early fracture stress will not have any impact on the GFRP bars because of the fact that they are non-corrosive by the environment surrounding them; as a consequence, the limitation of the first crack load may be loosened somewhat. In terms of ultimate load, ultimate deflection, and first crack load, the HSSCC-reinforced beams produced with steel, GFRP, and 20% GGBS do not differ from one another by a great lot from one another. Steel has the highest ultimate load, while GFRP have the highest ultimate deflection. Due to the constraints of serviceability standards, the use of GFRP rebars can only be implemented in a limited number of structures. More study on the acceptability of GFRP bars in the construction industry is now being carried out all over the world.

5. References

1. In 2019Abraham, Ranjan, Neelakantan, and Ramesh Babu. 2019. Self-Compacting Concrete with Alccofine and Glass Fiber. International Journal of Engineering and Advanced Technology, 9(1S3), 188-91.
2. ACI Committee 440.1R-06. 2006. Guide for the Design and Construction of Concrete Reinforced with FRP Bars. American Concrete Institute, 44.
3. Alsayed, Saleh Hamed. 1998. Flexural Behaviour of Concrete Beams Reinforced with GFRP Bars. Cement and Concrete Composites, 20, 1-11.
4. Ascione, L., G. Mancusi, and S. Spadea. 2010. Flexural Behaviour of Concrete Beams Reinforced with GFRP Bars. Strain, 46(5), 460-69.
5. Balamuralikrishnan, R. and Saravanan, J., 2019. Effect of Alccofine and GGBS Addition on the Durability of Concrete. Civil Engineering Journal, 5(6), 1273-1288.
6. Dinakar, Pasla. 2012. Design of Self-Compacting Concrete with Fly Ash. Magazine of Concrete Research, 64(5), 401-10.
7. Domone, P. L. 2006. Self-Compacting Concrete, An Analysis of 11 Years of Case Studies. Cement and Concrete Composites, 28(2), 197-208.
8. Domone, P. L. 2007. A Review of the Hardened Mechanical Properties of Self-Compacting Concrete. Cement and Concrete Composites, 29(1), 1-12.
9. EFNARC. 2005. The European Guidelines for Self Compacting Concrete, 63.
10. Golafshani, E.M., Rahai, A. and Sebt, M.H., 2014. Bond behavior of steel and GFRP bars in self-compacting concrete. Construction and Building Materials, 61, 230-240.
11. Hassan, A., Khairallah, F., Mamdouh, H. and Kamal, M., 2019. Structural behaviour of self-compacting concrete

12. columns reinforced by steel and glass fibre-reinforced polymer rebars under eccentric loads. Engineering Structures, 188, 717-728.
13. Kalpana, V. G., and Subramanian, K., 2011. Behavior of Concrete Beams Reinforced with GFRP BARS. Journal of Reinforced Plastics and Composites, 30(23), 1915-22.
14. Kavitha, S., and Kala, T. F., 2016. Evaluation of Strength Behavior of Self-Compacting Concrete Using Alccofine and GGBS as Partial Replacement of Cement. Indian Journal of Science and Technology, 9(22), 1-5.
15. Kavyateja, B. V., Jawahar, J. G., and Sashidhar, C., 2020. Effectiveness of Alccofine and Fly Ash on Mechanical
16. Properties of Ternary Blended Self Compacting Concrete. Materials Today, Proceedings.
17. Mazaheripour, H., Barros, J. A. O., Soltanzadeh, F., and Sena-cruz, J., 2016. Deflection and Cracking Behavior of SFRSCC Beams Reinforced with Hybrid Prestressed GFRP and Steel Reinforcements. Engineering Structures, 125, 546-65.
18. Narender Reddy, A., and T. Meena., 2018. A Study on Compressive Behavior of Ternary Blended Concrete Incorporating Alccofine. Materials Today, Proceedings, 5(5), 11356-63.
19. Okamura, H., and Ouchi, M., 2003. Self-Compacting Concrete. Journal of Advanced Concrete Technology, 1(1), 5-15.
20. Parveen, D. S., Junaid, M.T., Jindal, B.B. and Mehta, A., 2018. Mechanical and microstructural properties of fly ash based geopolymer concrete incorporating alccofine at ambient curing. Construction and building materials, 180, 298-307.
21. Prithiviraj, C., and Saravanan, J., 2020. Influence of W/B Ratio and Chemical Admixture on Fresh and Hardened Properties of Self Compacting Concrete Using Alccofine. Journal of Xidian University, 14(5), 4906-15.
22. Roja, Y. S., Gandhi, P., Pukazhendhi, D.M., and Elangovan, R., 2014. Studies on Flexural Behaviour of Concrete
23. Beams Reinforced with GFRP Bars. in International Conference on Emerging Trends in Science,Engineering and Technology - ICETSET-2014.
24. Sagar, B., and Sivakumar, M. V. N., 2020. An Experimental and Analytical Study on Alccofine Based High Strength Concrete. International Journal of Engineering, 33(4), 530-38.
25. Singh, A. and Sandhu, V., 2020. Effects of alccofine and curing conditions on properties of low calcium fly ashbased geopolymer concrete. Materials Today, Proceedings, 32, pp.620-625.
26. Sharma, D., Sharma, S. and Goyal, A., 2016. Utilization of Waste Foundry Slag and Alccofine for Developing High Strength Concrete. International Journal of Electrochemical Science, 11(4), 3190-3205.
27. Su, N., and Miao, B., 2003. A New Method for the Mix Design of Medium Strength Flowing Concrete with Low Cement Content. Cement and Concrete Composites i, 215-22.
28. Upadhyay, S., and Jamnu, 2014. Effect on Compressive Strength of High Performance Concrete Incorporating Alccofine and Fly Ash. Journal of International Academic Research for Multidisciplinary, 2(2), 125-30.
29. Vivek, S. S., Narayanan, R. S., Dhinakaran, G., 2017. Comparative Study on Flexural Behaviour of RCC Beam and SCC Ternary Beams with Mineral Admixtures. Construction and Building Materials, 152, 57-64