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An Experimental Study on Properties of Ternary Blended Steel Fibre Reinforced Concrete

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Compressive strength; Flexural strength; Modulus of elasticity; GGBS; Nano silica; Hooked End Steel Fibre; Elasticity modulus test; Failure pattern.

Abstract

This research presents the mechanical properties of ternary blended concrete incorporating steel fibres. Cement was replaced by GGBS (Ground Granulated Blast furnace Slag) and Nano Silica. Replacing with GGBS 35% and Nano silica 1% was found to give the optimum combination. Hooked end steel fibres of aspect ratio 75 in different volume fractions of 0.5%, 1%, 1.5%, 2% were added to the ternary blended concrete. Compressive strength test, Flexural strength test, and elasticity modulus test were conducted to study the mechanical properties of ternary blended concrete. The test results show that micro reinforcement concrete with GGBS and Nano silica execute well compared to the control sample. The addition of steel fibres improves the ductility and performance of concrete.

Disciplinary: Civil Engineering & Technology (Construction Material), Sustainability.

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1 Introduction

Concrete is still a popular construction material in the field of infrastructure, with the passage of time concrete has to be used under various exposure conditions. To show the purpose, the properties of concrete need to be tailored to suit specific situations. In view of this demand, many materials have come to replace cement aggregates and steel rebars. In the present days' requirements of durability and ductility are gaining prominence to enhance the durability of concrete micro fillers and nano-fillers have a splay appositive role come into vogue. To improve the ductility of concrete micro reinforcements plays a positive role.

The addition of ten percent Metakaolin and twenty percent GGBS (Ground Granulated Blast-furnace Slag) increases compressive strength by 19-22.8% and tensile strength by 13.5-57.4% (Teja, et al.. 2018). The inclusion of 3% Nano silica and 30% GGBS improved the strength properties of concrete appreciably (Ramachandran et al. 2019). The incorporation of 2% Nano silica with cement improved the compressive strength to 71.85 N/mm^2 and the split tensile strength to 4.3/mm^2 and flexural strength to 5.9 N/mm^2 (Prakash et al., 2019). Mechanical properties of concrete increased notably with the addition of 30% GGBS and 2% Nano silica (Ramesh et al., 2016). The addition of 30% GGBS and 3% Nano Silica influences the compressive strength, split tensile strength, flexural strength and acid resistance notably (Chaitanya et al., 2018). The inclusion of 50% GGBS and 4% Nano Silica improves the flexural strength, compressive strength, bond strength of high strength concrete appreciably (Shah et al., 2011). The split tensile strength increased from 19-98.3% and the modulus of rupture from 28.12% to 126.5% with fibre volume fraction ranging from 0.5-2% (Song et al., 2004). Compressive strength was enhanced by adding 5% micro silica and 15% fly ash to water binder ratios of 0.35, 0.45, and 0.55 (Audianrayana et al., 2013). Replacement of cement 40% with GGBS and steel fibre helped in improving the strength of the concrete substantially compared to control concrete (Joe and Rajesh, 2014). Replacing with GGBS 20% and Nanosilica (NS) 4%yielded an optimum strength compared to other percentage replacements (Nagendra et al., 2016).

The main purpose of this study is to combine GGBS and Nanosilica to make the greatest ternary concrete mix possible. An experimental programme was conducted in detail to achieve the study's target. This research aims to determine the strength of ternary blended concrete with different volume fractions of steel fibres. To find the optimal combination for ternary blended steel fibre reinforced concrete mix, the mechanical properties of all ternary concrete blended mixes were studied and compared to the traditional mix.

This paper's research objective is to decrease the amount of cement used in the concrete mixture. This helps in the reduction of greenhouse emissions in the atmosphere. The utilization of these materials also avoids the disposal and landfill issues that are causing havoc on the environment. It is essential to use these materials as a cost-effective alternative to cement in order to maintain sustainability.

2 Test Programme

2.1 Materials

2.1.1 Cement

OPC 53 grade cement is the preferred building and construction material. The fineness of cement causes an early rise in strength, but at the expense of high hydration heat. Ordinary Portland cement of 53 grade conforming to IS 12269 (2013) was used in this investigation. The specific gravity of cement used was 3.15. Its properties are listed in Table 1

Table 1: Properties of Cement

Colour	Grey
Specific gravity	3.15
Specific surface area	308
Insoluble Residue (%)	1.34
Magnesia content (%)	3.15
Sulphide anhydride (%)	2.62
Loss on ignition (%)	1.27
Chloride content (%)	0.012
Normal Consistency (%)	29
Initial Setting time (minutes)	140
Final Setting time (minutes)	220

2.1.2 Coarse Aggregate

Crushed angular granite of maximum size 20 mm Conforming to IS 383(2016) was used as coarse aggregate. The specific gravity of coarse aggregate used was 2.77

2.1.3 Fine Aggregate

Locally available natural river sand and M-sand combine conforming to zone 3 was used as fine aggregate. The specific gravity of fine aggregate used was 2.67.

2.1.4 GGBS (Ground Granulated Blast-furnace Slag)

GGBS has been widely used in Europe, and increasingly in the United States and Asia for its higher concrete durability, extending the lifespan of structures from fifty to a hundred years.GGBFS is a steel industry waste product that is high in SiO2 and calcium aluminates. Steel mills produce about 12 million tonnes of slag each year.GGBS in (Figure 1) used in this experimental work was purchased from Astraa chemicals, Chennai. Its properties are listed in Table 2.

Figure 1: GGBS.

Table 2: Properties of GGBS

Colour	Off White
Specific gravity	2.85
Specific surface area	390m2/kg
Insoluble Residue (%)	0.49
Magnesia content (%)	7.73
Sulphide sulphur (%)	050
Sulphite content (%)	0.38
Loss on ignition (%)	0.26
Manganese content (%)	0.12
Chloride content (%)	0.009
Glass content (%)	91
Moisture content (%)	0.10

2.1.5 Nano Silica

Nano silica is the most widely used material in cement and concrete to improve performance due to its pozzolanic reactivity and pore-filling effect. Nano Silica in (Figure 2) used in this experimental work was purchased from Astraa chemicals, Chennai. Table 3 lists its properties.

Figure 2: Nano Silica.

Table 3: Properties of Nano Silica

Specific gravity	1.1
Specific surface area	202
PH Value	4.12
Loss on drying (%)	0.47
Loss on ignition (%)	0.66
Sieve Residue	0.02
Tamped Density	44
SiO2 content (%)	99.88
Carbon content (%)	0.06
Chloride content (%)	0.009
Al2O3	0.005
TiO2	0.004
Fe2O3	0.001

2.1.6 Steel Fibre

Quality base steel bar is used to make hooked end steel fibre, which has good mechanical features, including high tensile strength. Stresses may be thoroughly diffused and crack propagation efficiently controlled due to the high strength and uniform distribution of fibres. Hooked end steel fibres (Figure 3) of aspect ratio 75 purchased from stewolls India Pvt Limited, Nagpur were used in this study. The properties of steel fibres are listed in Table 4.

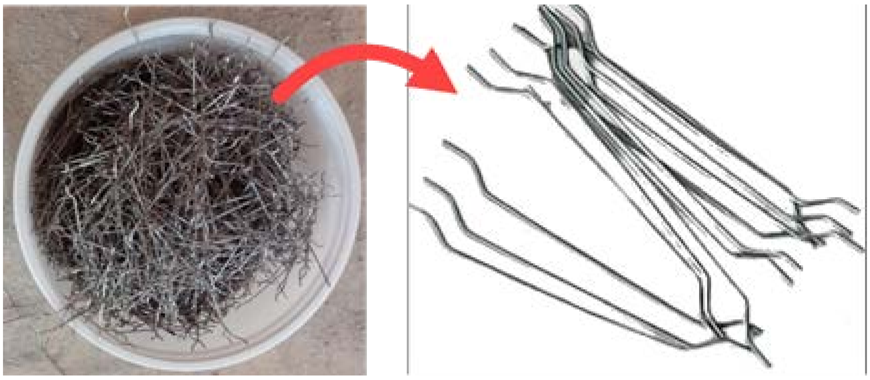

Figure 3: Hooked End Steel Fibres.

Table 4: Properties of Steel Fibres

Length	60mm
Diameter	0.80mm
Aspect ratio	75
Density	7850kg/m3
Elasticity modulus	210 GPa
Tensile strength	1225 MPa

2.1.7 Super Plasticizer

Superplasticizers (SPs), commonly referred to as high-range water reducers are additives used in the production of high-strength concrete. Plasticizers are chemical substances that allow for the manufacturing of concrete with a water content of about 15% less. Water content can be reduced by up to 30% with superplasticizers. These additives are used in small amounts, only a few percent of the total weight of the product. Concrete curing is slowed by plasticizers and superplasticizers. A high range water admixture Conplast 430 (Figure 4) supplied by FOSROC chemicals, Chennai was used in this experimental investigation.

Figure 4: Conplast430

Table 5: Properties of Super Plasticizer

Type	Sulphonated Naphthalene base
Colour	Brown
Specific gravity	1.18

2.1.8 Water

Potable water was used for preparing and curing of the control and beam specimens.

3 Experimental Programme

The experimental programme was split into two stages. In the first stage, cement was replaced by different proportions of GGBS and Nano Silica, the optimum combination of GGBS and Nano Silica was found. In the second stage, the hooked end steel fibres of aspect ratio 75 in different volume fractions (0.5, 1, 1.5, 2) were added to the concrete with the optimum percentage of GGBS and Nano silica. Compressive strength test for cube and cylinder, flexural strength test for prism, Elasticity modulus test for the cylinder was carried out to find the mechanical properties of ternary blended concrete. A water binder ratio of 0.48 was used for all the mixes. Specimen specifications are listed in Table 6.

Table 6: Specimen Specification

Specimen ID	Description
BSS	C0NTROL SPECIMEN
BSS11	35% GGBS+1% NS
BSS12	0.5SF+35% GGBS+1% NS
BSS13	1SF+35% GGBS+1% NS
BSS14	1.5SF+35% GGBS+1% NS
BSS15	2SF+35% GGBS+1% NS

Note:
GGBS – Ground Granulated Blast-Furnace Slag
NS – Nano Silica
SF – Steel Fibres

3.1 Compressive Strength Test

3.1.1 Compressive Strength Test for Cube

Cubes of size 150 X 150 X150mm were used to find the compressive strength of concrete. Control concrete, concrete with GGBS and Nano Silica, ternary blended concrete with different volume fractions of fibre were cast and tested. The tests were carried out as per IS 516:1959(2004 Reaffirmed). The test setup is shown in Figure 5 and the test results are shown in Table 7

Figure 5: Cube Tested in Compressive Testing Machine

Table 7: Compressive Strength test

S.No	Specimen Id	Cube Compressive Strength in MPa
1	BSS	33.33
2	BSS11	35.11
3	BSS12	37.78
4	BSS13	40.89
5	BSS14	45.33
6	BSS15	40.01

3.1.2 Compressive Strength Test for Cylinder

Cylinder specimens of standard size 150 X 300mm were used in this experimental work. Control concrete, concrete with GGBS and Nano Silica, ternary blended concrete with different volume fractions of fibres were cast to find the compressive strength of concrete. The tests were done as per ASTM C39. The test set up shown in Figure 6. The test results are shown in Table 8.

Figure 6: Cylinder Tested in Compressive Testing Machine

Table 8: Compressive test Results of Cylinder

S.No	Specimen Name	Cylinder Compressive Strength in MPa
1	BSS	27.16
2	BSS11	27.73
3	BSS12	30.56
4	BSS13	32.82
5	BSS14	36.78
6	BSS15	32.26

3.2 Flexural Strength Test

Prisms of standard size 100 X 100 X 500mm were used for the flexural strength test. Concrete without supplementary cementitious material, concrete with GGBS and Nano Silica, Ternary blended concrete with different volume fractions of fibres was cast and tested for finding the flexural strength of concrete. The test was performed as per IS 516:1959(2004 Reaffirmed). The test setup is shown in Figure 7. The test results are shown in Table 9.

Figure 7: Test set-up for Flexural strength.

Table 9: Flexural Strength Test Results

S.No	Specimen ID	Flexural Strength in MPa
1	BSS	4
2	BSS11	4.2
3	BSS12	4.6
4	BSS13	5.2
5	BSS14	6
6	BSS15	6.8

3.3 Elasticity Modulus Test

A cylinder specimen of standard size 150 X 300mm was used for the Elasticity modulus test. Control concrete, concrete with GGBS and Nano Silica, ternary blended concrete with different volume fractions of fibres were cast to find the modulus of rupture. The test was done as per IS 516:1959(2004 Reaffirmed). The test results are shown in Table 10.

Table 10: Modulus of Elasticity Test Results

S.No	Specimen ID	Modulus of Elasticity in GPa
1	BSS	28.8
2	BSS11	29.96
3	BSS12	30.64
4	BSS13	31.94
5	BSS14	33.72
6	BSS15	35.9

4 Result and Discussion

4.1 Compressive Strength Results

In comparison to the typical control specimen, concrete prepared with GGBS and Nanosilica had a higher compressive strength. The ternary mixed concrete specimens had an average compressive strength of 35.11 MPa. When compared to control specimens, the cube specimens BSS11 show a rise of 6%. When compared to control specimens, the cylinder specimens BSS11 show a 2.09% increase. Figures 9 and 10 show the compressive strength of ternary blended concrete with and without different steel fibre volume fractions. With the addition of 0.5% and 1% volume fractions of Hooked end steel fibres, compressive strength was increased by 13.33% and 22.68% for cube and 2.09% and 12.5% for cylinder respectively. The compressive strength of concrete with a 1.5% volume fraction of hooked end steel fibres rose significantly, peaking at 45.33 Mpa for the cube and 36.78Mpa for the cylinder. The compressive strength of concrete with a 2% volume fraction of hooked end steel fibres was reduced, As a result, the bond between the fibres and the concrete matrix becomes critical.

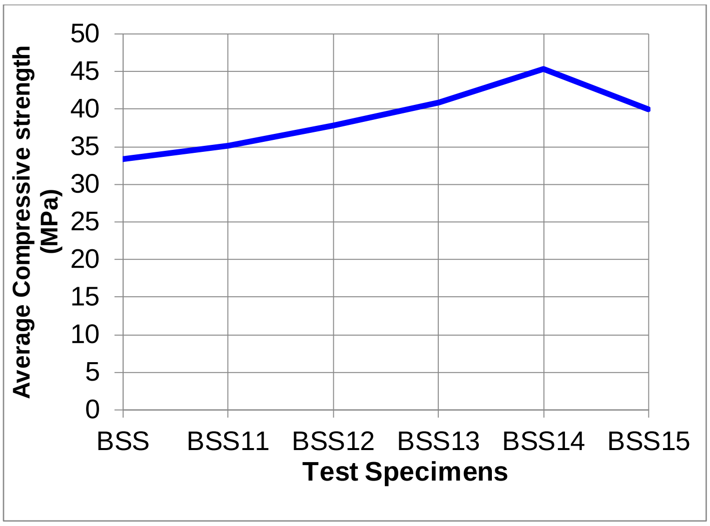

Figure 9: the compressive strength results of the cube.

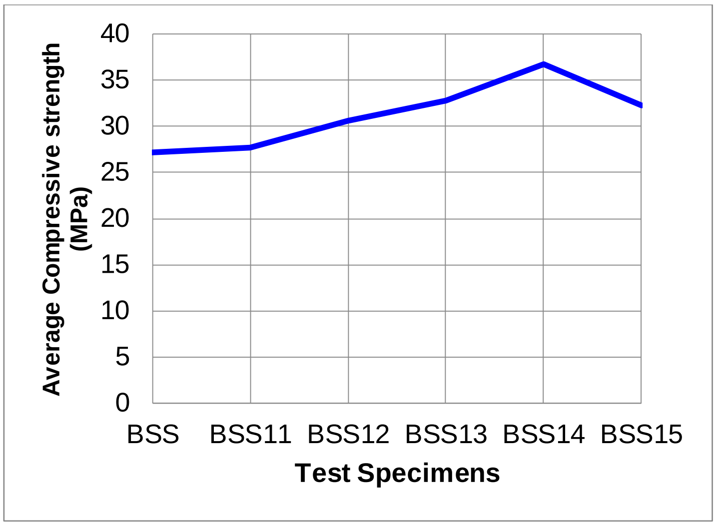

Figure 10: Compressive strength results of the cylinder.

4.1.1 Failure Modes

Figure 11 depicts the failure pattern of Ternary blended fibre reinforced concrete cubes. The fissures were only visible on the surface in the beginning. The initially created fissures spread to the interior regions as axial load increased, accompanied by concrete spall. It's worth noting that cracking and spalling were less severe in the BSS11 comparative control concrete. This may be due to an improved bond between the aggregate and the matrix enhanced by the inclusion of nano-silica and GGBS, as indicated by the different failure patterns seen in the specimens BSS12, BSS13, BSS14 and BSS15. This is due to the internal confinement mechanism formed by the Hooked end steel fibres, which prevented the concrete from cracking and spalling. The volume fractions of hooked end steel fibres have a big impact on the cube specimen failure pattern.

Figure 11: Failure Pattern of Cube specimens.

4.2 Flexural Strength Results

Table 9 presents the results of flexural strength tests for various mixes. Each test value indicates the average of three test specimens. When compared to control specimens, the prism specimens BSS11 exhibit a 5 % increase. With an increase in fibre volume fraction from 0.5% to 2%, the flexural strength increased from 4.2N/mm^2 to 6.8 N/mm^2. Based on the fibre volume fraction used, the rate of increase in flexural strength was 15 % to 70 %. The increase in flexural strength with increasing fibre volume percentage could be due to the fact that the hooked end steel fibres continue to share the load after matrix cracking. The crack propagation was gradual due to gradual fibre debonding during the fracture process. When the fibres pulled out, the final failure occurred due to unstable fracture propagation. Figure 12 illustrates the Rupture modulus of ternary blended hooked end steel fibres reinforced concrete.

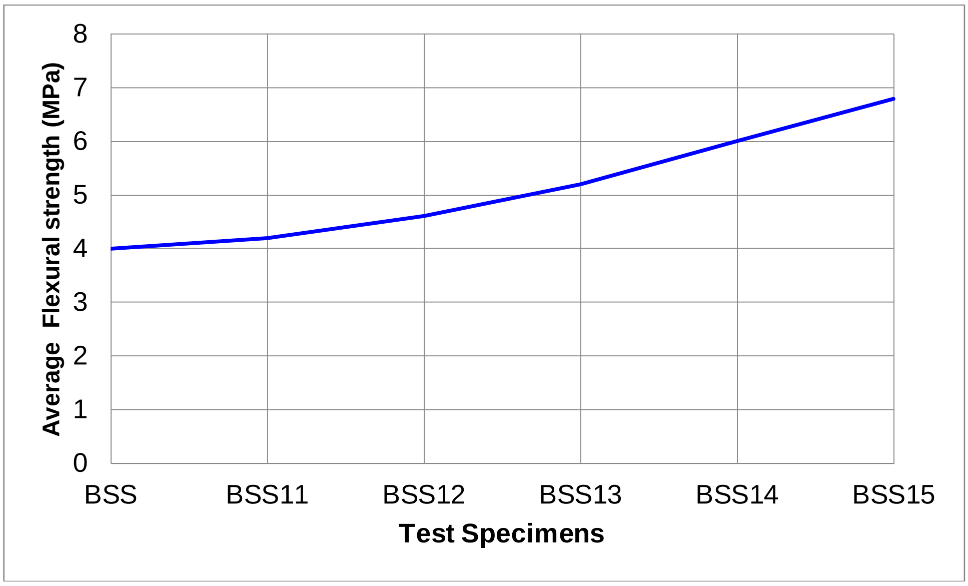

Figure 12: Flexural strength results of prism.

4.2.1 Failure Modes

The prism specimens were tested using a two-point loading method in a standard loading frame. The failure pattern was found to be the same in specimens with and without hooked end steel fibres. The bridging action of the micro-reinforcement would have resulted in an increase in flexural load as fibre volume fractions increased. Figure 13 depicts the failure modes of prism specimens with and without hooked end steel fibres.

Figure 13: Failure pattern of prism specimens.

4.3 Modulus of Elasticity

Each value is the average of three specimens' test results. When compared to the control specimen, the cylinder specimen BSS11 illustrates a 4.07% higher. Table 10 shows the elasticity modulus of ternary blended concrete with different hooked end steel fibre volume fractions. When comparing non-fiber reinforced concrete to fibre reinforced concrete, test results show a 6.38% increase in strength. The elasticity modulus increased when more hooked end steel fibres were added. The addition of 0.5%, 1%, and 1.5% hooked end steel fibres enhances the elasticity modulus by 6.38%, 10.90%, and 17.08% respectively, whereas the addition of 2% hooked end steel fibre increases it by a maximum of 24.65%. The modulus of elasticity increased as the hooked end steel fibre content increased.

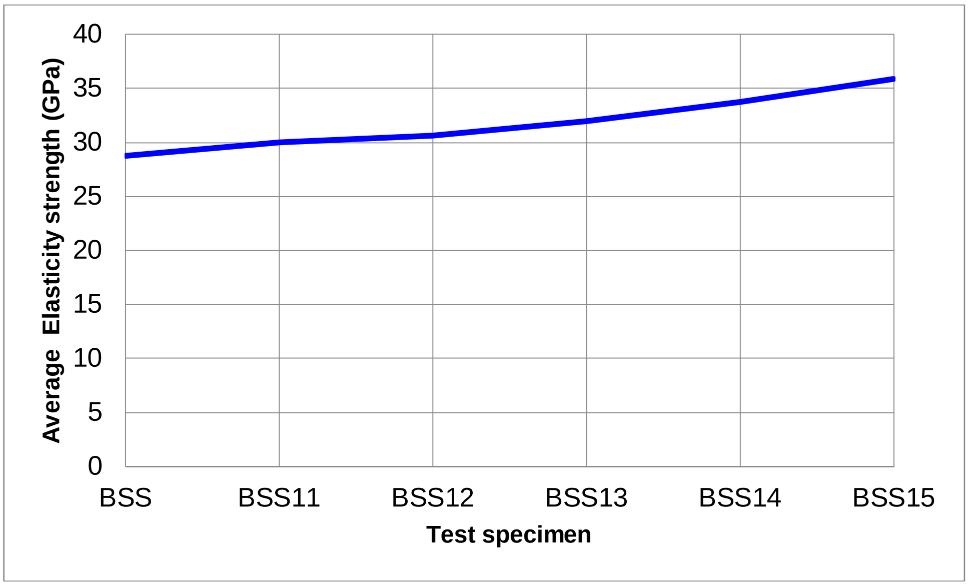

Figure 14: Modulus of elasticity results of cylinder

4.3.1 Failure Modes

Figure 14 shows the modulus of elasticity results. A compression testing machine with a capacity of 1000 kN was used to test the cylinder specimens. During the first phase, a longitudinal crack running the length of the cylinder specimen was discovered. More cracks occurred parallel to the previously created longitudinal crack as compressive load increased. The failure pattern altered differently in the cylinder specimens containing hooked end steel fibres. The formation of crack and travel of crack was slowed down and the density of cracking was found to be more. The inclusion of hooked end steel fibres would have caused an internal mechanism by which the tendency of concrete to crack and spall was minimized. The failure pattern of all the cylinder specimens are shown in Figure 15

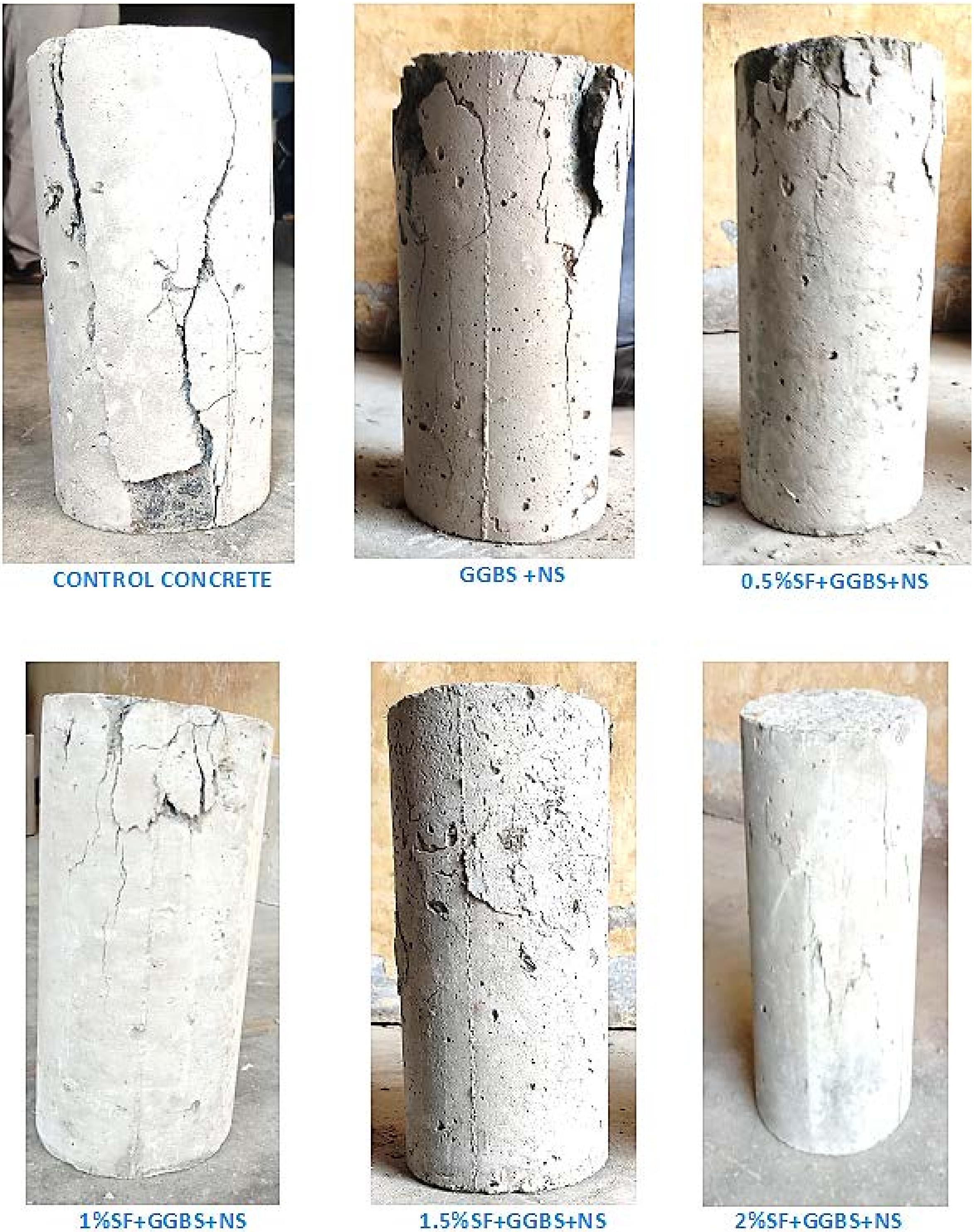

Figure 15: Failure Pattern of Cylinder specimens

5 Conclusion

The effects of GGBS, nanosilica and steel fibres on the mechanical characteristics of concrete have been investigated experimentally. The addition of GGBS and nano-silica to steel fibre reinforced concrete improved a variety of mechanical qualities. In ternary mixed concrete, adding 1% Nano silica and 35% GGBS resulted in a 6% increase in compressive strength, 5% increase in flexural strength, and 4% increase in modulus elasticity.

The incorporation of 2% hooked end steel fibres resulted in a 70% improvement in flexural strength and 24.65% increase in modulus of elasticity. The addition of 1.5% hooked end steel fibres resulted in a maximum gain of 36% in compressive strength.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

7 References

ASTM-C39. (2016). *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*. ASTM International. DOI: 10.1520/C0039_C0039M-16

Audinarayana, D., Sarika, P., Sekar, T. S., Rao, S., Apparao, P. S. G. (2013). Studies on compressive strength of ternary blended concrete at different water binder ratios. *American Journal of Engineering Research*, 2(9), 37-45.

BIS. (2006). *IS 516 (2004 Reaffirmed): Indian Standard Methods of Test for Strength of Concrete*. Bureau of Indian Standards. New Dehli.

BIS. (2013). *IS 12269 (2013): Ordinary Portland Cement,53 Grade - Specification*. Bureau of Indian Standards. New Dehli.

BIS. (2016). *IS 383(2016) Coarse and Fine Aggregate for Concrete — Specification*, Bureau of Indian Standards. New Dehli.

BIS. (2019). *IS 10262(2019) Concrete Mix Proportioning —Guidelines*. Bureau of Indian Standards. New Dehli.

Chaitanya, K. K., Prasanna, V. L., Reddy, N. A. K. (2018). An Experimental study on mechanical properties of concrete with replacement of cement by ggbs along with nano silica. *International Journal of Scientific Research and Review*, 7(7).

Duan, P., Shui, Z., Chen, W., & Shen, C. (2013). Enhancing microstructure and durability of concrete from ground granulated blast furnace slag and metakaolin as cement replacement materials. *Journal of Materials Research and Technology*, *2*(1), 52-59.

Joe, M. A., & Rajesh, A. M. (2014). An experimental investigation on the effect of GGBS & steel fibre in high performance concrete. *International Journal of Computational Engineering Research*, *4*(4).

Kutanaei, S. S., & Choobbasti, A. J. (2016). Experimental study of combined effects of fibers and nanosilica on mechanical properties of cemented sand. *Journal of Materials in Civil Engineering*, *28*(6), 06016001.

Lukowski, P., Salih, A. (2015). Durability of mortars containing ground granulated blast-furnace slag in acid and sulphate environment. *Procedia Engineering*, 108, 47-54.

Nagendra, V., Sashidhar, C., Kumar, S.M.P., Ramana, N.V. (2016). GGBS and nanosilica effect on concrete. *International Journal of Civil Engineering & Technology*, 7(5), 477-484.

Prakash, A., Nagaraju, A.S.V., Kumar, K.P. (2019). Experimental study on high performance concrete as partial replacement of nano-silica in cement. *International Journal of Technical Innovation in Modern Engineering*, 5(5).

Ramachandran, G., M.Puvithra, M., Sathiyapriya, M., Sivagami, C. (2019). Experimental study on concrete by partial replacement of cement using ggbs and nanoparticles. *International Journal of Advance Research and Innovation*, 6(4), 1-7.

Ramesh, N., Eramma, H. (2016). Behaviour of ggbs and nano-silica on strength properties of concrete. *International Journal of Research in Engineering and Technology*, 5(6).

Reddy, S. V. B., & Rao, P. S. (2016). Experimental studies on compressive strength of ternary blended concretes at different levels of micro silica and ggbs. *Materials Today: Proceedings*, *3*(10), 3752-3760.

Shah, M., Dave, N., Vora, K., Shah, D. (2019). Effect of ggbs and nano silica on the mechanical properties of ternary concrete. *International Conference on Smart Material Research*, 1.

Song, P.S., Hwang, S. (2004). Mechanical properties of high-strength steel fiber reinforced concrete. *Construction and Building Materials*, 18, 669-673.

Suvarna, A., Salunke, P.J., Gore, N.G., Narkehde, T.N. (2015). Silica Fume and GGBS as cement replacement in Fiber reinforced concrete. *International Research Journal of Engineering and Technology*, 2.

Teja, B., Kumar, T.J., Krishna, P.B. (2018). An Experimental study on performance of Ternary blended high strength hybrid fibre reinforced concrete. *International Research Journal of Engineering and Technology*, 5(2), 1815-1821.

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