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# Strength Characteristics of Slag Based Steel Fiber Reinforced Concrete with Partial Replacement of Steel Slag in Coarse Aggregate

**K. Dilli Bai, A. Krishna Rao, V.M. Southararajan**

***Abstract: The current research work represents the various test results from an experimental program for the influence of mineral admixture, stone dust, steel slags and rapid hardening (accelerator) type of chemical admixtures along with the inclusion of steel fibers for various mixture proportions on the mechanical properties of concrete. The different strength properties considered the cubical size for compressive strength, prism for flexural rigidity and monitored the ultrasonic pulse velocity test including water absorption (sorptivity) test for different curing days was evaluated. The outcome results for concrete shows that when the percentage of steel slag is increased then there will be a good workability in fresh concrete than normal aggregates. In overall 100% of stone dust, if the portion of steel slag is more than 40% with replacement of coarse aggregate and binding material as slag will lead to minimum workability, there is no change in the proceding workability area in the further addition of super plasticizer. Also, the study indicates that the crimped steel fiber matrix interaction gives considerable results to enhance the bending stress in flexural rigidity caused by the introducing of steel fibers.***

***Keywords: Slag, steel slag, Steel fiber, Stone dust, Strength, Flexural rigidity, sorptivity.***

## I. INTRODUCTION

The research efforts in the past have been very successful in obtaining the high desirable strength concrete using slag as a good binding cementitious material in the eco-friendly construction field. However, the maximum addition of slag in concrete is to be restricted up to 20% by weight-binding materials. This type of materials is primarily due to delay the pozzolanic reactivity process of slag during the hydration of gel formation in cement and the effects the strength gain when compared to normal practicing plain cement concrete. However, to shot out these problematic key issues while adding the chemical admixtures in concrete and thus results was considerably to improve the setting properties [1-7].

Matrix envisages the improved flexural rigidity in concrete while using the steel fibers with rapid hardening (chemical admixture) to accelerate the rate of hardness for various mixes. Usually, an increase in time of setting is expected when slag is used as a partial replacing material for Portland cement in concrete mixtures. The degree of hydration is affected due to the dependency on the initial temperature, the proportion of the blend mix used, the water-binding material ratio and the characteristics of the Portland cement. However, the setting properties of concrete were considerably greater when slag content is more than that of plain concrete [8-13].

Slag based concrete setting time required is considerably more than Portland cement-based concrete, probably due to the smoothness and glassy textured particles present in the slag can delay the setting properties during the hydration process and also at low ambient temperatures. Extending in the setting time is more profitable in construction industries for stable and the workability for a longer period thus results, easy to transport, placing and finishing the concrete at early stages. Further, it was noted that the higher amount of slag used in Portland cement shows the shortage of water requirement during the consistency and workability test in freshly obtained concrete. Therefore, the usage of slag was restricted in concrete up to 30% replacing in Portland cement [14-16].In Further step, this test was performed based on the rate of water movement through the capillary suction pores from the bottom surface of concrete before that it is required necessary curing for all the samples and thus resulting data is to be carefully noted, the less sorptivity index due to usage of mineral admixtures presents that special part indicates the good quality of micro-structural on the durability properties.

Therefore, the Portland Blast Furnace Cement produces the high quality improved, hardening and durability properties of concrete and also including the High Slag Blast Furnace Cement (HSBC) with slag content starting with a preceding range from 30 to 70% by the weight of binder particle content [17-20]. This special advantaged concrete is more suitable for ready-mixed concrete or site-batched concrete.

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* Correspondence Author

**K. Dilli Bai***, Pursuing M.Tech – Structural Engineering at CMR Institute of Technology, Kandlakoya, Medchal Road, Hyderabad – 501401, Telangana, India.

Email: knandhini304@gmail.com

**Prof. A. Krishna Rao**, Professor, Department of Civil Engineering/HOD, CMR Institute of Technology, Kandlakoya, Medchal Road, Hyderabad – 501401, Telangana, India.

Email: akulakrishnarao@gmail.com

**Dr V.M. SOUNTHARARAJAN***, Professor, Department of Civil Engineering, CMR Technical Campus, Kandlakoya, Medchal Road, Hyderabad – 501401, Telangana, India.

Email: researchsoundar@yahoo.in, sounthararajan.civil@cmrtc.ac.in

Also, to reduce the risk of damages due to alkali-silica reaction which leads to higher corrosion and also highly reactive to the chemical attacks by sulfuric acid attack, hydrochloric acid attack and other chemicals attacks to which the concrete is exposed to the open environmental conditions [21]. The present research work focused on the influence of incorporation in slag with crimped steel fibers in concrete. The results from these studies can be very much effective for the large scale utilization of GGBS in the eco-friendly construction industries. In addition to this, there is an increasing trend to study the characteristics of slag concrete and make it a more versatile in construction material on earth. The dealing study, benefits the results attained gives a good test results with the usage of industrial waste materials used in concrete and promising the quality of materials in construction industries.

## II. METHODLOGY

OPC 53 Grade of cement is more durable than another type of cement and conforming to IS 12269-1987 [22] with a designed target strength obtaining 55.5 MPa for 28 days of cement to mortar (C: M) ratio of 1:3 and specific gravity value is 3.15. Stone dust used for fine aggregate with a specific gravity of 2.69 and fineness modulus of 2.55. The crushed stone type of coarse aggregate (CA) is partially replaced with steel slag (SS) 0-40% ( as shown in Figure 1) and average particle size around 12.5 mm size down was used and specific gravity of CA is 2.75 and SS value is 2.56. The Conplast SP-430 type of superplasticizers used as a chemical admixture to obtain desirable workability in fresh concrete and crimped steel fibers were added at a different dosage level of 0% to 1.5% by volume fraction (Vf). The mineral admixture of slag (GGBS) type of binding materials was used for different percentage in the range of 0 to 35% by weight of binding materials. The detailed concrete mixture proportions are represented in Table I. The overall eight different concrete mixture proportions were arrived based on the M30 grade of concrete with low water- binding material ratio 0.3. A rotating and tilting drum type of concrete mixture machine having a capacity of 40 liters and cast in standard steel cube mold size of 150 x 150 x 150 mm is required for testing the compressive strength of concrete and also to measure the ultrasonic pulse velocity. Also, to determine the bending stress in flexural rigidity on the concrete for the standard beam size of 100 x 100 x 500 mm is required. After casting each mix specimen maintain 24 hours before removal of steel plates present at the outer surface of the hardened concrete. In further stages, each sample is needed for necessary potable water-curing for various mixes. However, before testing the compressive strength (special case) of a sample, it is mandatory to measure the UPV for various mixes.

**Fig. 1. Image of sintered metal steel slags**

**Table- I: Mix details**

| Mix - Id | Cement | Slag | Stone dust (Fine-aggregate) | Coarse aggregate | Steel slag (coarse aggregate) | w/b | Steel finer (%) |
|---|---|---|---|---|---|---|---|
| | F/c ratio= 0.6 (kg/m$^3$) | | | | | | |
| J-1 | 473 | 0 | 672 | 1113 | 0 | 142 | 0 |
| J-2 | 449 | 24 | 672 | 1113 | 56 | 142 | 1.5 |
| J-3 | 426 | 47 | 672 | 946 | 111 | 142 | 1.5 |
| J-4 | 402 | 71 | 672 | 804 | 167 | 142 | 1.5 |
| J-5 | 378 | 95 | 672 | 868 | 223 | 142 | 1.5 |
| J-6 | 355 | 118 | 672 | 662 | 334 | 142 | 1.5 |
| J-7 | 329 | 144 | 672 | 615 | 390 | 142 | 1.5 |
| J-8 | 307 | 166 | 672 | 690 | 445 | 142 | 1.5 |

*Note: 1% of accelerator was added (by weight of binding materials)
for various mixes

## III. EXPERIMENTAL TEST RESULTS AND DISCUSSIONS

### A. Compressive strength

The experimental test result for various curing days of concrete as shown in Figure 2. It was observed that the higher compressive strength of composites materials in concrete consisting of 25% of slag with 25% of steel slag along with 1.5% of steel fibers produced strength was 43.50 MPa at 28-days when compared to plain cement concrete. There is an increasing trend was observed from J-2 to J-6. It was also clearly proved that the slag and steel slag materials used in framing a constructional concrete are more suitable as alternate binding materials in construction industries.

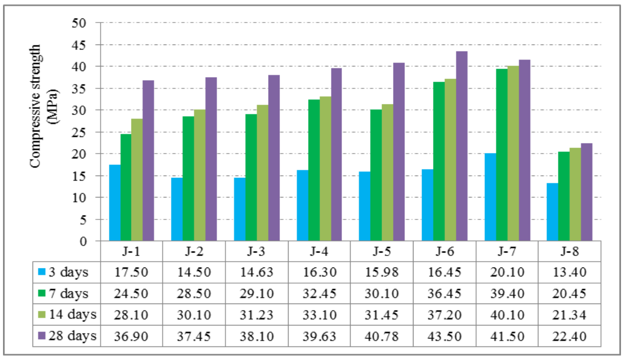


**Fig. 2. Compressive strength of concrete at different curing days**

### B. Flexural rigidity

Figure 3 shows the flexural rigidity in concrete for various proportion mixes. The improved desired workability for all mixes with help of low water-binder ratio along with 1.5 % of superplasticizer. The replacement level of cement up to 25% in slag along with 25% of metal steel slag replaced in coarse aggregate produced the higher flexural rigidity of concrete (J-6 mix).

The important role of steel fibers addition up to 1.5% gives the limitation of the initial crack and also increases the toughness of the member. This can lead to delay the cracking after reached the ultimate stress. Further, it's gradually increase the strain hardening after the failure of the specimen therefore it is evidence to enhance the post-cracking in toughness and also improved the impact resistance in FRC.

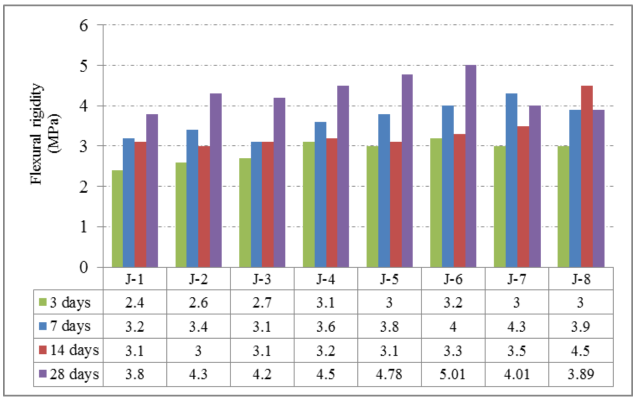


**Fig. 3. Flexural rigidity for different age of concrete**

### C. Ultrasonic pulse velocity

Figure 4 shows the UPV test values for various mixes, after saturation of concrete specimens for 3, 7, 14 and 28 days recorded values for various mixes. All the concrete specimens had a noticeable increase in the ultrasonic pulse velocity values and specific values, when compared to standard code and providing the higher rate of hardening after 28 days. However, it was also recorded that the less UPV values after seven days because there is an incomplete reactions during the hydration process and after reaching 14 days, the gradually increased trend was noted.

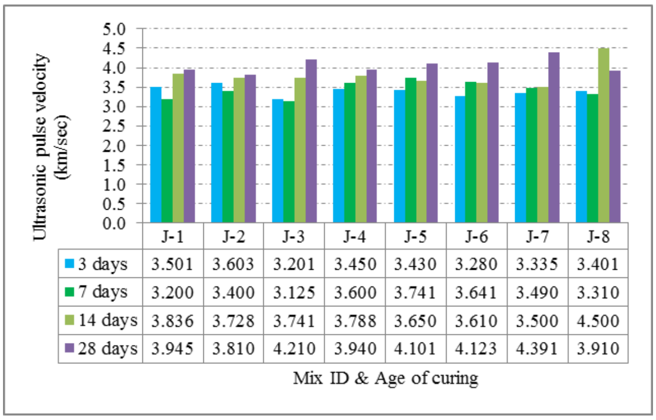


**Fig. 4. UPV for different age of concrete**

### D. Sorptivity

Figure 5 shows the water absorption test for various mixes, which is dependent on the rate of porosity and permeability of the concrete. The initial stage of unsaturated concrete has shown less absorption than conventional mixes. A careful selection of mix proportion with a natural type of coarse aggregates along with steel slag (artificial coarse aggregate) and proper adequate compaction has less water absorption for various mixes. Further, it was noted that, the less water penetration after 90 days in the mix of J-6 and the same similar trend was made by Saleh et al [23].

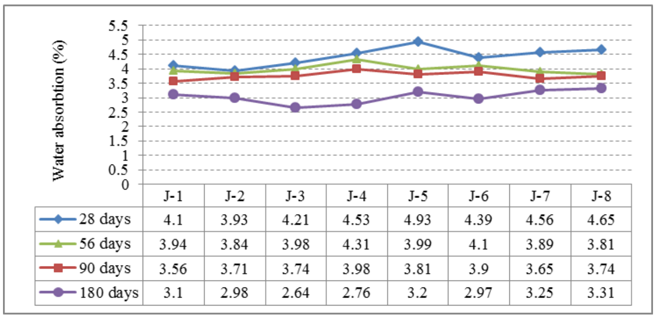


**Fig. 5. Water absorption test results for various curing days**

## IV. CONCLUSION

The various laboratory experimental test results showed that the rapid hardening setting properties of concrete can be more useful in fast track construction mainly in pavement applications etc. Also, the addition of crimped steel fibers showed significant effects on the various special properties of concrete.

The careful selection of the test variables such as cement to aggregate ratio and fine to coarse aggregate ratio had shown a significant effect on the compressive properties of specially designed concrete.

The increase higher compressive strength was noted in the combination of 25 % of slag, 1.5% of steel fiber with 40% of steel slag for 7 and 28 days was increased up to 48.77% and 17.89% respectively and water absorption is subjected to quality of materials with proper compaction shows the less rate of water absorption for all mixes after reaching the saturated condition in the concrete after 56-days of curing.

This is evident that an excellent improvement in microstructural property while usage of slag, fine aggregate to coarse aggregate material ratio 0.6 with waste by-products has envisages promised quality of concrete. However, the addition of accelerator has a direct contribute effecting the early setting and results produced in the short duration of 14 days than 28 days. The potential usage of superplasticizers can be realized in high strength concrete incorporating the mineral admixtures of which the delayed strength gain can be offset and easily strength gain can be achieved.

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## CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

## AUTHORS PROFILE

**K. Dilli Bai,** Pursing M.Tech in Structural Engineering at CMR Institute of Technology, Hyderabad, India. She has published Two International Journal papers.

**Prof. A. Krishna Rao** working as a Professor/HOD at CMR Institute of Technology, Hyderabad and he has more than12 years of teaching experience and 10 years of industrial experience. He has published 7 research papers, conducted 10 workshops, attended 6 workshops, delivered 3 guest lectures and guided more than10 batches for M.Tech.-Projects. He is pursuing PhD at University College of Engineering, Osmania University, Hyderabad, Telangana-India.

**Dr V.M. Sounthararajan** working as a Professor in the Department of Civil Engineering at CMR Technical Campus, Hyderabad, Telangana. He has 9.5 years teaching as well as research experience. Also, eight years of Industrial experience. He is a reviewer for more than four reputed journals. He is a Member of Indian Society for Technical Education. He has received the best research awards at VIT University in the year of 2012 and 2013. He has published more than fifty-three research papers in various National and International journals and conferences.

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