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# An Experimental Evaluation of Compressive and Flexural Strength Test on Concrete Using Blast Furnace Slag as a Replacement of Coarse Aggregate

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***Abstract –****In these experiment we are using blast furnace slag and air cooled blast furnace slag as a replacement of coarse aggregate as we are using such artificial ingredients for making concrete because we know that now a days natural resources are highly diffusing day by day due to large construction and various development. The combined outcome of ACBFS as replacement for coarse aggregates and fly ash as a limited replacement of cement on the compressive and flexural strength of concrete has been investigated. Six mixes were prepared at different replacement levels of ACBFS (0%, 20%, 40%, 60%, 80% and 100%) with coarse aggregate in all concrete mixes. The compressive strength of concrete and flexural strength was tested after 3, 7 and 28 days of curing. Results indicate that the compressive and flexural strength are in phase with each other. The replacement of ACBFS with coarse aggregates up to 40% increases the compressive and flexural strength of concrete and at 60% there is marginal decrease in both parameters. On further replacement up to 80% and 100% the compressive and flexural strength of concrete mix decreases significantly. As it was observed that compressive and flexural strength increases with replacement up to 40% ACBFS, it is recommended that up to 40% of ACBFS can be used as coarse aggregate in concrete*.

***Keywords- coarse aggregate, fly ash, ACBFS, workability test, split tensile strength test, compressive and flexural strength, marginal, parameters, curing, significantly, replacement****.*

## I- INTRODUCTION

Concrete is a composite manmade construction material, most widely used for the reason that of its strength and longevity and it has emerged as the dominant construction material for the infrastructure needs of the present situation. By different constituents of concrete, depending upon the utility and application, the characteristics of concrete may also be varied. The strength of the concrete composite is based on the strength of different constituents used in the preparation of concrete. In present time the major requirement of concrete is that, it should be more workable, durable and should have high compressive strength then normal concrete by using waste products like silica fume, fly ash, blast furnace slag, etc.

Approximately five billion tons of concrete have been used worldwide every year, and in terms of expenditure it is equal to 25 to 30% of the nation budget. It is also inevitable material in human life due to its enormous usage in modern way of construction and now the per capita consumption is reached to more than 2 kg. India has taken a sound decision on developing the infrastructural development in twenty first century such as express high ways, airports, ports, power projects and tourism projects. As use of concrete is must in construction of each structural member, hence concrete plays a vital role in present scenario of construction industries. Everyone has chosen concrete in infrastructural development because of its characteristics like strength and durability. The continuous usage of natural resources and the consequent energy requirement for this processing has a serious economic impact. More over in the alluvial plain area, where there is no availability of virgin aggregates, such as debris and rubble particles may be recycled and make it into use for new structural applications with variable and effective economy.

The Indian integrated iron and steel industry poses serious challenges to environment through its inherent complexity (Pandey et al., 1996) and may hazardous to environment (Khan and Shinde, 2013). In an integrated steel plant, 2 – 4 tons of wastes (including solid, liquid and gas) are generated for every ton of steel produced. Accordingly, today the emphasis is on the avoidance of waste generation, recycling and reuse of waste, and minimizing the adverse impact of disposal on the environment. Presently, India is the fourth-largest manufacturer of steel (Firoz, 2014; Kumar and Naidu, 2013) following China, Japan and the US. Due to high strength and durability of steel slag its suitability as construction material in many cases is superior to rock material, and use slag in construction also assist to decrease the quantity of land filled (Tossavainen, 2005).

Blast furnace slag is a non metallic material produced from a molten state simultaneously with pig iron in a blast furnace. Various studies have been conducted to reduce severe effect on environment, using by-products like ground slag as partial replacement of coarse aggregate. Air-cooled blast furnace slag (ACBFS) is one of the most commonly utilized reclaimed construction materials, being used as coarse aggregate in cement concrete, aggregate in hot-mix asphalt, road base material, and fill. This means less disruption to the land, less energy consumed and less pollution and greenhouse gases generated from mining and transporting natural aggregate (Morian et al., 2012). Besides, blast furnace slag has properties similar to natural aggregates and it would not cause any harm if incorporated into concrete (Hiraskar and Patil, 2013).

Traditionally unutilized slag is stock piled in the steel plants, and eventually land filled at slag disposal sites. Since the current methods of stockpiling and land filling are not sustainable, disposal of slag has become a significant concern both to slag processor companies and to environmental agencies in the last decades. A number of slag sites around the world have been associated with groundwater and soil contamination from heavy metals and other toxic compounds concentrated in the slag. Therefore, improving the utilization rate of steel slag is an imperative way for the steel enterprise to realize sustainable development. It has been reported that, iron and steel slag have high pozzolanic potential and can be utilized as raw material or blending constituent in cement manufacturing and constructional activities (Khajuria and Siddique, 2014; Huang et al., 2012; Malhotra and Tehri, 1994; Kumar and Bhargavi, 2015).

Aggregate is an important constituent of concrete occupying approximately 70 - 75% of its total volume (Kothai and Malathy, 2015) and directly affecting the fresh & hardened properties. In the present scenario carbon emission and stone mining are major concern due to its hazardous effect to environment and making serious imbalance to the ecosystem. Based on an experimental work by Nadeem and Pofale (2012), it was concluded that the blast furnace (BF) slag could be effectively utilized as a partial replacement for coarse aggregates in all types of concrete. The blast furnace slag aggregates have better shape, size and rough surface than conventional aggregates and thus provide improved adhesion between the particles and cement paste consequently improve the strength of concrete (Pajgade and Thakur, 2013). The increasing popularity of concrete as a construction material is placing a huge burden on the natural resources of the countries. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete. Therefore the use of alternative sources for natural aggregates is becoming increasingly important.

## II- LITERATURE REVIEW

Slag is the result of a high blast furnace residue, produced by steel smelting industries that physically resemble rough aggregates. Iron and steel industry slag, either granulated or crystalline, is considered as a prominent and a useful raw material for developing of modern construction materials. Blast furnace slag is a by product and using it as aggregates in concrete will might prove an economical and environmentally friendly solution in local region. Available literatures in India indicate that there is a lot of opportunity for utilization of integrated iron and steel slag.

The main components of blast furnace slag are CaO, SiO2, Al2O3, and MgO (Chandra, 1997). In last 5 years, an enhancement of over 18% for blast furnace slag and basic oxygen furnace slag has been achieved (GOI, 2013-2014). By continuing thrust on solid waste consumption at the integrated iron and steel plants, total solid waste utilization has increased from 77% in the 2007-08 to 86%; an increase of 9% over the last 5 years (GOI, 2013-2014). The major uses of steel slag in India

Kothai and Malathy (2014) studied on steel slag utilization as a partial replacement material for fine aggregates in concrete and reported that the steel slag, a waste cheap material, can be used as fine aggregates in M20 grade of concrete and also recommends the approval of the material for use in concrete as a replacement material for fine aggregates. The partial substitution of natural aggregates with steel slag aggregates permits a gain of compressive, tensile and flexural strength and modulus of elasticity of concrete up to an optimum value of replacement. The subsequent benefits can also be drawn like cost reduction, social benefits and mass utilization of waste material is possible in construction by using steel slag as a partial replacement material for fine aggregates in concrete'

It is concluded that the strength of M20 and M25 concrete increases with the increase in the quantity of slag as replacement to natural aggregates. It is economical to use the blast furnace slag, as its costs of just about 50% of that of conventional aggregates (Pajgade and Thakur, 2013).

The ground granulated blast furnace slag (GGBFS) is a by-product of iron manufacturing (Suresh and Nagaraju, 2015) which when added to concrete improves its properties such as workability, strength and durability (Arasan et al., 2017).

Concretes containing slag as a partial replacement of cement (up to 40%) had higher compressive and flexural strengths casting and curing at +42°C than those of concretes made with Portland cement alone (Siddique and Kaur, 2012).

The compressive strength of Blast Furnace Slag aggregate concrete is found to be higher than that of conventional concrete at the age of 90 days and it has also reduced water absorption and porosity beyond 28 days in comparison to that of conventional concrete with stone chips used as coarse aggregate (Hiraskar and Patil, 2013).

The physical properties of crusher dust and blast furnace slag are satisfying the requirements of fine aggregate and coarse aggregate. The cost of concrete made with blast furnace slag and crusher dust is less than conventional concrete because the crusher dust and blast furnace slag which were less cast. At 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust there is no reduction in compressive strength with respect to controlled concrete. At 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust that shown only marginal increase in split tensile strength and flexural strength was observed (Dhanasri and Kumar, 2013).

The compressive strength of concrete increases as BF Slag replacement increases up to 40% at all curing ages. The flexural strength of concrete also increases up to 40%, similar to the trend shown by compressive strength. The maximum increase in flexural strength at 28 days curing is 8.33% (Sandhu et al., 2015).

For the replacement of both coarse and fine aggregates from 30 to 50%, the compressive strength of concrete increased by 4 to 6%. However, in case of coarse aggregate the compressive strength increased by 5 to 7% over control mixes in M20, M30 & M40 grade of concrete (Nadeem, 2018).

The coarse aggregate was replaced by blast furnace slag at 10% to 100% and various tests were conducted to determine the optimum level of replacement of blast furnace slag in self compacting concrete (Krishnasami and Malathy, 2013).

The result obtained encourages the use of blast furnace slag in concrete as a partial replacement to fine aggregate up to 25%. The maximum compressive strength of 40.69 N/mm2 was obtained by replacing 25% of fine aggregate with BFS. Workability was found to be a problem with the fresh concrete, and hence usage of super plasticiser was recommended. The usage of BFS will reduce the cost of concrete by 8 to 10% (Babu and Mahendran, 2014).

It was observed that the compressive strength increased up to 35% replacement of coarse & Fine aggregate with slag and is gradually decreased for starting from 40% replacements. Hence replacement of coarse aggregate with 35% replacement will be reasonable (Harikumar et al., 2017).

Normal compressive strength of high quality concrete at age 1, 3,7,14, and 28 days respectively is 33.651 Mpa. 47.871 Mpa. 57.321 Mpa. 53.170 Mpa and 67.567 Mpa. While compressive strength of concrete with slag substitution at age 1, 3,7,14 and 28 days respectively is 43.896 MPa. 71.541 MPa. 77.282 MPa. 70.658 Mpa and 75.958. Thus it shows that high quality concrete made of steel slag as the main constituent aggregate has a compressive strength greater than that of conventional high-quality concrete.

## III-PROBLEM IDENTIFICATION AND RESEARCH OBJECTIVES

Concrete plays the key role in construction and a large quantum of concrete is being utilized in every construction practices. Due to size specification, the material selected to substitute this purpose is steel slag since it is a coarse waste material and its utilization as coarse aggregate replacement could perhaps increase the strength to enhance the properties of concrete at the same time resulting in a cheaper concrete mix. Coarse aggregate, which is one of the constituent used in the production of concrete, has become very expensive and also becoming scarce due to the depletion of natural sources.

With the increase environmental awareness and its potential hazards effect caused by blasting as well as crushing of stone, it become an important issue for construction industry to think about an alternative material for coarse as well as fine aggregate. Utilization of industrial by-product has become an attractive alternative to disposal. The one such type material is aggregate made from Blast Furnace slag and can be used to replace coarse aggregates.

The utilization of this by-product as an aggregate in concrete offers environmental and economic benefits in the form of elimination of waste, decrease in the disposal costs, and reduction in need for mining of the natural materials. However, concerns exist with relation of the influence of these aggregates on the long-term durability of pavement concretes, especially at locations exposed to freezing and thawing environment.

## IV- EXPERIMENTAL PROGRAMME

The main objective of this research was to utilize the BF slag aggregate in the concrete mixture and identify the mechanical and flexural properties of the mixture. The experimental study started by replacing the percentage of the volume of natural aggregates, normally used in the manufacture of concrete , with BF slag in increments of 10% until all the natural aggregates were replaced by the steel slag to find the possible optimum replacement level for the steel slag in concrete.

All concrete mixing was performed in the laboratory of the institute. The experimental program consisted of first finding the optimum replacement level by performing the different tests such as compressive strength for cubic specimens, Split tensile strength for cylindrical specimens, flexural strength for prismatic specimens, Young s Modulus for ‟ cylindrical specimens, determination of Ultimate load carrying capacity in RC beams.

**Concrete mix design:**

The mixture proportioning was done according the Indian Standard Recommended Method IS 10262- 2009 and with reference to IS 456-2000. The target mean strength was 31 N/mm2 for the OPC control mixture, the total cement content was 372 Kg/m3, fine aggregate was taken 790 Kg/ m3 and coarse aggregate was taken 1063.902 Kg/m3. The water to binder ratio was kept constant as 0.5. The total mixing time was 5 minutes; the samples were then casted and left for 24 hrs before de-moulding. They were then placed in the curing tank until the day of testing cement, sand and coarse aggregate were properly mixed together in the ratio 1:2.86:2.12 by weight before water was added and properly mixed together to achieve homogenous material.

Water absorption capacity and moisture content were taken into consideration. Cube and cylindrical and prism moulds were used for casting. The concrete was left in the mould and allowed to set for 24 hours before the specimens were demoulded and placed in a water tank for curing. The specimens were cured in the tank for 7 and 28 days. The details of the quantity of the constituent materials were given in the below. The determination of the quantity of the constituent materials for the M25 grade of concrete designed as per the IS method.

**Concrete Cube Casting:**

Mix proportion of 1: 2.12: 2.86 is chosen according to its ingredients i.e, cement, fine aggregate, coarse aggregates and the water cement ratio is 0.50. For every mix, 6 cubes are prepared to test, each 3 cubes for 7 days and 28 days after curing. Mix the cement and sand with trowel on non-porous plate until uniform colour is achieved. Place the coarse aggregate in the flat surface and place the cement sand mix upon the aggregates and mix the entire materials thoroughly. Then add water to the mixture. The water/cement ratio used in this mix is 0.50. Natural aggregate is replaced by steel slag accordingly in proportion of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% respectively. The time of mixing shall be in any case not less than 3 to 5 minutes. Mixing time is the time elapsed between the water is added to the mix and casting of cubes.

1. Apply thin layer of oil to the interior faces of the mould and firmly hold in position by means of suitable clamps.
2. Place the entire quantity of concrete in the cube moulds and compact the concrete for three layers using tamping rod and place the moulds in the vibratory machine for a period of about 1 minute.
3. At the end of vibration, remove the mould together with the base plate from the machine and finish the top surface of the cube mould by smoothing the surface with the blade or trowel. Make identification mark on cubes.

4. Keep the filled moulds in the atmosphere of at least 90% relative humidity for 24 hours in the humidity chamber after completion of vibration.
5. Remove the cubes from the moulds and immediately submerge them in clean fresh water and keep there until taken out just prior to testing.

Fig 5: Mixing of concrete ingredients

Curing of concrete specimens:

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. Since the hydration of cement does take time days and even weeks rather than hours-curing must be undertaken for a reasonable period of time if the concrete is to achieve its potential strength and durability. Curing may also encompasses the control of temperature since this effects the rate at which cement hydrates.

The curing period may depend on the properties required of the concrete, the purpose for which it is to be used and the ambient conditions, i.e., the temperature and relative humidity of the surrounding atmosphere. Curing is designed properly to keep the concrete moist, by preventing the loss of moisture from the concrete during the period in which it is gaining strength. Curing may be applied in a number of ways and the most appropriate means of curing may be dictated by the site or the construction method.

Fig 6: Curing of concrete specimens Properties of concrete

The properties of concrete are classified into two categories: fresh and hardened. The durability of concrete depends upon the mix design and durability of aggregates. The water cement ratio and addition of admixtures greatly affect the durability of concrete. The properties which affect the strength and durability of a concrete structure change over the life of structure, increasing with time.

**Hardened concrete properties**

To determine the hardened properties of concrete, the Compression test, Splitting tensile test, Young's modulus test, flexural strength test and the Ultimate load carrying test on RCC beams were conducted. Concrete is much stronger in compression than in tension and so the compressive strength of concrete is an important property of the concrete. It is very difficult to directly measure the tensile strength of concrete, therefore the splitting tensile test, an indirect method, was adopted.

Compressive Strength of Concrete

The concrete specimens were tested for compressive strength at 7 and 28 days. Specimens were casted in cubical moulds of dimensions 100mm×100mm×100mm and stored in the water curing tank. Three specimens were tested at each age, on a Compressive testing machine of capacity 2000KN in Concrete lab in the department. The type of fracture of the specimen and the compressive strength were recorded.

Calculations:

fc = Pmax/A

Where

fc = compressive strength.

Pmax = the maximum load that the cube sustained.

A = the cross sectional area of the cube.

Figure 8: Compressive strength testing machine

Flexure strength test of concrete:

For flexural strength test, the specimen of dimensions 500mm×100mm×100mm was placed in UTM, in such a

manner that load shall be applied to the upper most surface, as cast in the mould, along two lines spaced L/3 apart. The load was applied without shock and increased at rate such that, the extreme fibre stress increases at approximately 7 kg/mm2/min, until failure occurs.
The flexural strength of specimen expressed as the modulus of rupture (fb)

fb = 3Pa / bd2
If crack falls outside the load point
fb = PL / bd2
If crack falls within the load point
Where
a = distance between the line of fracture and the nearer support.
P = applied load.
b = width of the specimen.
d = depth of the specimen.
L = clear span of the specimen.

Figure 10: Flexural strength testing machine

Figure 11: Young's modulus test.

Ultimate Load Carrying Capacity:

RCC Beam Design:

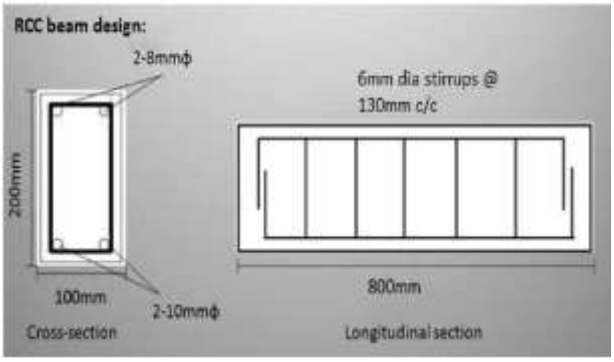


Figure 12: Reinforcement Details

Three point bending Tests were conducted on simply supported RC beams having different volume fraction to estimates the mechanical properties, load at initial crack, deflection of beam at various loading condition and finally ultimate load estimation. RC beams were simply supported over a clear span of 0.7m and tested under three point bending, as shown in figure. Figure 10 shows the Universal Testing Machine (UTM) used for testing the beam. Figure 13 shows the experimental setup for testing of RC beam under three point bending and the arrangement of strain gauge under the loading point which is centre to estimate the centre deflection of the RC beam under incremental load at centre of specimen in three point bending. The load is applied in incremental order of 5kN. The corresponding deflection was noted down as well as the crack pattern was observed for understanding the change in characteristic behaviour in RC beam under different volume fraction. Estimation of load at initial crack for all specimens as well as ultimate load carrying capacity was determined. Three specimens were tested at each age, on a Universal testing machine of capacity 5000KN.

Figure 13: Experimental setup for testing the beam

**V-METHODOLOGY**

The main objective of this research was to utilize the blast furnace slag aggregate in the concrete mixture and identify the mechanical and flexural properties of the mixture. The experimental study started by replacing the percentage of the volume of natural aggregates, normally used in the manufacture of concrete , with blast furnace slag in increments of 10% until all the natural aggregates were replaced by the steel slag to find the possible optimum replacement level for the steel slag in concrete. All materials testing and concrete mixing was performed in the materials testing laboratory of the civil engineering department of the institute.

The experimental program consisted of first finding the optimum replacement level by performing the compressive test to the cube specimens for 7 days and 28 days, and perform different tests such as compressive strength for cubic specimens, Split tensile strength for cylindrical specimens, flexural strength for prismatic specimens, Young s Modulus for ‟ cylindrical specimens, determination of Ultimate load carrying capacity in RC beams.

Materials and their characterization

The raw materials required for the concrete in the present project work are:

1. Cement
2. Fine aggregates
3. Natural coarse aggregates
4. Blast furnace slag aggregates
5. Water

**Cement**

Ordinary Portland cement 53 grade (Ultratech) conforming to IS: 12269 have been used in this experimental study. The physical properties and chemical properties of the cement are shown in table 4 and 5.

Table 4: Chemical properties of cement

| Constituent | Composition (%) |
|---|---|
| Lime (CaO) | 60 to 67% |
| Silica ($SiO_2$) | 17 to 25% |
| Alumina ($Al_2O_3$) | 3 to 8% |
| Iron oxide ($Fe_2O_3$) | 0.5 to 6% |
| Magnesia (MgO) | 0.1 to 4% |
| Sulphur trioxide ($SO_3$) | 1 to 3% |
| Soda and/or Potash ($Na_2O+K_2O$) | 0.5 to 1.3% |

Table 5: Physical properties of cement:

| | |
|---|---|
| Grade of cement | 53 Grade |
| Minimum Compressive Strength (N/mm2) | |
| 3 day | 27 |
| 7 day | 37 |
| 28 day | 55 |
| Fineness Modulus | 7.6% |
| Initial setting time | 92 minutes |
| Final setting time | 195 minutes |

**Fine Aggregates**:

The size of the fine aggregate is below 4.75mm. Fine aggregates can be natural or manufactured. The grade of the aggregates must be same throughout the work. The fine aggregate shall consist of natural sand or other inert materials with similar characteristics, or combinations having hard, strong, durable particles. The use of concrete is being constrained by urbanization, zoning regulations, increased cost and environmental concern. Locally available sand conforming to grading as zone-II of table 6 according to the IS: 383-1970 has been used as fine aggregate in this experimentation.

Table 6: Physical properties of fine aggregate

| S. No | Property | Value |
|---|---|---|
| 1 | Specific gravity | 2.57 |
| 2 | Fineness modulus | 2.46 |
| 3 | Grading | Zone-II |
| 4 | Water absorption | 2% |

**Coarse aggregates**

Natural coarse aggregates: The materials whose particles are of size are retained on IS sieve of size 4.75mm is termed as coarse aggregate and containing only so much finer material as is permitted for the various types described in IS: 383-1970 is considered as coarse aggregate. The properties of aggregate greatly affect the durability and structural performance of concrete. Aggregate was originally viewed as an inert material dispersed throughout the cement paste largely for economic reasons. It is possible, however, to take an opposite view and to look on aggregate as a building material connected in to a cohesive whole by means of the cement paste, in a manner similar to masonry construction. In fact, aggregate is not truly inert and it's physical, thermal and sometimes also chemical properties influence the performance of concrete.

## VI-EXPERIMENTAL RESULTS

The chapter discusses the results obtained from various tests. The results presented in this chapter are the average results when more than one sample each of mixture was tested.

Setting Time: Setting time of concrete may be affected by many factors like temperature and water/cement ratio. With granulated blast furnace slag, the setting time will be extended slightly, perhaps by about 30 minutes. The effect will be more pronounced at high levels of slag and/or low temperatures. An extended setting time is advantageous in that the concrete will remain workable longer and there will be less risk of cold joints. This is particularly useful in warm weather.

Workability of concrete

Workability of a concrete is a term which consists of the following four partial properties of concrete namely mix ability, transportability, mould ability, and compact ability. Cohesiveness and consistency both are concurrent properties of fresh concrete. Cohesiveness is a measure of the compact ability and finish ability of concrete. Consistency is requirement of water to mix the concrete properly. Workability of concrete depend not only the properties of concrete but also the nature of application. A very dry concrete seems to be have low workability and too wet condition seems to have high workability, both of these are not enough to improve the good characteristics of concrete. The test results and slump and compaction factor with different replacements of steel slag aggregate

## VII-CONCLUSION

The main objective of this project was to study the strength properties of concrete and changes in the properties of concrete with steel slag aggregates as replacement of natural aggregates. The use of steel slag as aggregates in concrete will might prove an economical and environmentally friendly solution. The demands for aggregates are increasing rapidly and so as the demand of concrete but the natural resources are very limited. Thus, it's important to find some suitable alternatives for replacement of natural aggregates in the future. A through literature review was conducted to study and investigate the properties of steel slag as a replacement of natural aggregates. The results showed that slag has similar properties as natural aggregates and it would not cause any harm if it can be utilized in concrete. A comparison was made between concrete having natural coarse aggregates and concrete with various percentages of steel slag aggregates. The results of this study were encouraging, since they show that using steel slag as coarse aggregates in concrete has no negative effects on the short term properties of hardened concrete with better strength properties.

## REFERENCES

1. *Pandey, H.D., Bhattacharya, S., Maheshwari, G. D., Prakash, O. And Mediratta, S. R. (1996) Research Needs In Environmental and Waste Management in Iron & Steel Industries, Proceedings: Ns-EWM1996 @NML Jamshedpur, pp. 1-21*
2. *Khan, R. and Shinde, S. B. (2013) Effect of unprocessed steel slag on the strength of concrete when used as fine aggregate, International Journal of Civil Engineering & Technology, vol. 4, no. 2, pp. 231–239, 2013.*
3. *Firoz, A.S. (2014) Long Term Perspectives for Indian Steel Industry, http://steel.gov.in/Long%20Term%20Perspectives.pdf – accessed on 31 August 2018*
4. *Kumar, P. S. and Naidu, V. B. (2013) An Analysis of Indian Steel Industry, Journal of International Academic Research for Multidisciplinary, Volume 1 Issue 3 (April 2013)*
5. *Tossavainen, M. (2005), Leaching Results in the Assessment of Slag and Rock Materials as Construction Material, http://epubl.ltu.se/1402-1544/2005/44/LTU-DT-0544-SE.pdf - accessed on 31 August 2018*
6. *Khajuria, C. and Siddique, R. (2014) Use of Iron Slag as Partial Replacement of Sand to Concrete, International Journal of Science, Engineering and Technology Research (IJSETR), Volume 3, Issue 6, June 2014*
7. *Huang et al. (2012) An overview of utilization of steel slag, Procedia Environmental Sciences 16 (2012) 791 – 801*
8. *Malhotra, S. K. and Tehri, S. P. (1994) Building materials from granulated furnace slag – Some new prospects, Indian Journal of Engineering & Materials Sciences, Vol. 2, April 1995, pp. 80-82*
9. *Kumar and Bhargavi (2015) An Experimental Study on Effect of Silica Fume & Fly Ash in Slag Concrete, International Journal of Engineering Sciences & Research Technology, 4(9): September, 2015*
10. *Kothai, P. S. and Malathy, R. (2015) Effective Utilization of Wastes from Steel Industries in*

*Concrete, Nature Environment and Pollution Technology An International Quarterly Scientific Journal, ISSN: 0972-6268 Vol. 14 No. 2 pp. 419-422*

11. *Nadeem, M. and Pofale, A, D. (2012), Utilization of Industrial Waste Slag as Aggregate in Concrete Applications by Adopting Taguchi's Approach for Optimization, Scientific Research, Open Journal of Civil Engineering, September 2012.*
12. *Pajgade, P.S. and Thakur, N.B. (2013) Utilisation of Waste Product of Steel Industry. International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, www.ijera.com, Vol. 3, Issue 1, January -February 2013, pp.*
13. *Siddique, R., Kaur, D. (2012). Properties of concrete containing ground granulated blast furnace slag (GGBFS) at elevated temperatures. Journal of Advanced Research (2012) 3, 45–51*
14. *D. Suresh, D. and Nagaraju, K. (2015). Ground Granulated Blast Slag (GGBS) In Concrete – A Review. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE). Volume 12, Issue 4 Ver. VI (Jul. - Aug. 2015), PP 76-82*
15. *Arasan, G.V., Dhanya, R., Ramasamy, G. (2017) Study on Strength Properties of Concrete Using GGBS and Steel Fiber as Partial Replacement of Cement. Jr. of Industrial Pollution Control 33(s2)(2017) pp 1255-1259*