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An Investigation on Properties of Concrete by Partial Replacement of Cement with Ground Glass Blast Furnace Slag

Syed uzma Naseer geelani[1], and Er. Brahamjeet Singh[2]

[1]M. Tech Scholar Structural Engineering, RIMT University, Punjab India
[2]Assistant professor, Department of civil engineering, RIMT University, Punjab, India

Correspondence should be addressed to Syed Uzma Naseer Geelani; Syeduzma355@gmail.com

ABSTRACT- Concrete is a mixture of cement, natural sand, coarse aggregate and water. Nowadays, the most concrete mixture contains supplementary cementitious material, which forms part of the cementitious component. These materials are by-products from other processes according to the industrial wastes. The benefits of supplementary cementitious material are their ability to show cementitious property after replacement of a certain amount of cement, thus cost reduces in using Portland cement. The fast growth in industrialization has resulted in tons and tons of by-product or waste materials, which can be used as supplementary cementitious material such as Ground-granulated blast-furnace slag, fly ash, silica fume, steel slag etc. Further be noted that use of the by-products not only helps to utilize these waste materials but enhances the properties of concrete in fresh and hydrated states also. The Iron industries produce an enormous quantity of blast furnace slag (B.F.S) as by–product, which is a non–biodegradable waste material from that only a insignificant percentage of it is used by cement industries to manufacture cement. In this study, Blast Furnace Slag from industries has been utilized to find its suitability as cement in concrete making. This topic also deals with the advantages and disadvantages of slag being used in concrete. Replacing some portion of cement with slag would lead to moderately large environmental benefits. In this study it is observed that blast furnace slag could be used as alternative construction material. In the present examination, cement concrete has good strength and workability by using ground blast furnace slag as a replacement for cement. The M45 grade of concrete was prepared and examined at the hardened stage. Then different mixes were prepared containing 0%, 43%, 53%, and 63% as partial replacement of cement with ground blast furnace slag in different combinations were used to examine the strength properties.Tests had been conducted for result of slump, compressive strength, flexural strength, splitting tensile strength, rebound hammer , abrasion and acid attack.

KEYWORDS- concrete, cement, ground, glass, blast furnace.

I. INTRODUCTION

Ordinary concrete, which is the most generally utilized development material around the world, has been asserted not to be harmless to the ecosystem [1]. Negative worries incorporate the exhaustion of regular assets, high energy utilization, and development garbage removal [2]. Most monetarily agricultural nations have limited the utilization of virgin materials like totals in development for ecological reasons like the reusing of waste materials and safeguarding of regular assets [3].The improvement business can reuse a lot of these materials and use them as a substitute for customary materials. Such execution will shield regular assets and diminish the requirement for marsh removal of those squandering materials [4].

From last year, there has been an extraordinary expansion in the utilization of materials like fly debris, ground impact heater slag, and so forth as a swap for concrete to expand the strength of cement and to defeat ecological corruption [5]. The point is to make high-strength concrete sturdy, functional, monetary, and naturally eco-accommodating to further develop the strength properties of cement by applying the outer powers brought about by stacking like shear, hub, and flexural [6].

The substitution of fine total and coarse totals is required in view of the accompanying reasons

- To build strength
- Ecological eco-accommodating
- To build functionality
- To monitor regular assets

A. Ground Blast Furnace Slag

Ground impact heater slag is a result from impact heaters that is utilized to create iron. Ground impact heater slag has been broadly utilized as an effective substitution material for Portland concrete in substantial materials to further develop sturdiness, produce high-strength and elite execution concrete, and bring ecological and financial advantages together, like asset protection and energy reserve funds [7]. Blast furnace slag can be used to improve the mechanical properties, workability, and chemical resistance of the conventional concrete mixtures [8]. Since the construction waste and blast furnace slag wastes are available in vast amounts in Turkey, it is economically and environmentally suitable to use these materials as aggregates in the production of more durable concrete mixtures.

II. ADVANTAGES OF GROUND BLAST FURNACE SLAG

It is found that working with GGBFS is easy as it has greater mobility characteristics [9]. This is due to its fineness and the particle shape of the GGBFS particles. These also possess a lower relative density.

- The color is more even and light.
- Lower early age temperature rise, reducing the risk of thermal cracking in large pours.
- Increases the strength and durability of the concrete.
- The alkali-silica reaction is resisted highly.
- Lower chances of efflorescence.
- These make the concrete more chemically stable.
- Gives good surface finish and improves aesthetics.
- Considerable sustainability benefits.

A. Disadvantage of Ground Blast Furnace Slag

In the production of ready mixed concrete (RMC), GGBS replaces a considerable portion of the Portland cement concrete, generally about 45 % to 70% [10]. The higher the portion, the better is the durability. The disadvantage of the higher replacement level is that early age strength development is somewhat slower.

B. Ground Blast Furnace Slag in Concrete

1) GGBS Proportions

In the concrete manufacturing plant, the GGBFS can be added along with the Portland cement, water and aggregates [11]. The normal ratio of the mixture remains the same. The studies show that the GGBFS can be replaced from 30 to 85 % of the cement weight. Most of the instances we replace 40 to 50%.

2) Setting Time

More the GBFS amount more will be the time taken for its setting. But the strength is gained with time. This slow setting would help in the formation of cold joints. But the situations where faster setting time is required, cannot go for this replacement. The GGBS composition stays plastic for a longer period that would help in making a smoother finish. The GGBFS have lesser demand for water and there is a chance of an increase in the setting time of the concrete [12]. When the replacement amount of cement by GGBFS increases the setting time also increases.

3) Strength Gain In GGBS Concrete

Slag concrete compressive strength is mainly based on number of factors for instance slag type, finesses, activity index, and the amount employed in concrete mixtures in addition to other factors for example cement type and water to cementitious material ratio.By and large, compressive strength of slag concrete gradually increases from 1-5 days and lower than that of concrete without slag, but slag concrete strength matches strength of controlled concrete from 7-28 days.

4) Colour

Due to light colour of blast furnace slag, colour of slag concrete is lighter in comparison with conventional concrete. Moreover, deep blue-green colour shown by interior part of slag concrete and can be noticed from slag concrete broken parts. This colour would be lost after adequate exposure to air. The degree of the colour is based on curing condition, percentage of blast furnace slag employed, and oxidation degree.

5) Early Age Temperature Rise

After the placing of concrete, their is thermal cracking due to the reduction in the setting and hardening of concrete. Replacing Portland cement with GGBS reduces the temperature rise and helps to avoid early age thermal cracking. The greater the percentage of GGBS, the lower will be the rate at which heat is developed and the smaller the maximum temperature rise

6) Water demand

The GGBFS as a replacement has lesser water demand because of their glassy texture. The glassy surface of GGBFS particles does not absorb water onto its surface. Inadequate curing of concrete substantially affects degree and rate of hydration and consequently formation of strength-production hydration will be slow [13]. The detrimental consequences of insufficient curing are more profound and outstanding in concrete incorporated with high percentage of slag. Therefore, to avoid uncertainty in the strength and durability, concrete incorporating more than 30% slag is cured for longer period compare with concrete with no slag. Finally, the extension of slag concrete curing time is based on number of factors including ambient temperature, amount and types of cement, the temperature of utilized cement, and percentage of cement replacement [14].

7) Consistency (SLUMP)

The GGBFS particles have a very glassy texture that makes them increase the workability. This can help in reduction of water as well as Super plasticizers to get adequate workability in common situations. They also have fewer chances to get segregated during handling as well as pumping of the material. Pumping is facilitated by the lower relative density and flowing ability of the mix, that is owned by GGBFS. While concretes containing GGBFS have a similar, or slightly improved consistence to equivalent Portlandcement concrete, fresh concrete containing GGBS tends to require less energy for movement [15]. This makes iteasier to place and compact, especially when pumping or using mechanical vibration. In addition, it will retainits workability for longer.

C. Scope of the Study

The scope of the study are given below

- To determine compressive strength characteristics of hardened concrete by partially replacement of cement by Ground Blast Furnace Slag.
- To determine split tensile strength characteristics of hardened concrete by partially replacement of cement by Ground Blast Furnace Slag.
- To determine flexural strength characteristics of hardened concrete by partially replacement of cement by Ground Blast Furnace Slag.
- To determine compressive strength characteristics of hardened concrete by partially replacement of cement by Ground Blast Furnace Slag by using non distractive test i.e. Rebound hammer test.
- To provide green and economical construction.

III. METHODOLOGY

An experimental program was planned in which one lean concrete mix which did not include any percentage of Ground Blast Furnace Slag and otherdifferent mixes with different combinations of Ground Blast Furnace Slag as a replacement of cement were prepared.Cubes [16], cylinder and beams specimens were casted to obtain the mechanical properties of concrete mixes with 43%, 53%, and 63% replacement of cement by Ground Blast Furnace Slag. The non-destructive and destructive properties were examination and suitable quantities of super-plasticizer and materials are added to improve the workability and stability of M45 grade of concrete which was used in preparation [17]. The cube specimens, cylindrical specimens and beam specimens will be tested after the recommended curing time of curing period of 7 days and 28 days respectively.

A. Workability

"The property of concrete which determines the amount of useful internal work, necessary to produce full compaction i.e. workability is the amount of energy to overcome friction while compacting. Also defined as the relative ease with which concrete can be mixed, transported, moulded and compacted"[18]. Workability is considered as property of concrete with its ability to mix, handle, and transport and most important, placing of concrete with a minimum loss of Homogeneity. Various factors which effect workability are; water content of the concrete mix, amount of cement & its properties, aggregate grading (size distribution) , nature of aggregate particles (texture, porosity, shape etc.), temperature of the concrete mix and environment, humidity of the environment, mode of compaction, method of placement of concrete& method of transmission of concrete. Some tests carried for determining the workability of concrete are slump test, compaction factor test and Vee-Bee consistometer method [19]. We used slump test in laboratory to determine workability. The importance and significance of workability are explained as under:
In very simple words we can say that workability of concrete means the ability to work with concrete.
A concrete is said to be workable if

- It can be handled without segregation
- It can be placed without loss of homogeneity
- It can be compacted with specific effort
- It can be finished easily

In every construction work we use different quantitative and qualitative terms to express workability. Before specifying workability for any work a concrete technologist must keep the following things in mind.

- Type of construction work
- Method of mixing
- Thickness of section
- Extent of reinforcement
- Mode of compaction
- Distance of transporting
- Method of placing
- Environmental condition

Concrete that can be placed readily without segregation or separation in a mass dam could be entirely unworkable in a thin structural member [20]. Workable concrete compacted by means of high frequency vibrators would be unworkable if vibrators could not be used and hand tamping were required. Concrete having suitable workability for a pavement might be unsuitable for use in a heavily reinforced section.

B. Detail Specimens

Concrete cube of size 150mm x 150mm x 150mm were casted for determining the compressive strength of concrete. Cylindrical concrete specimen having dimension 150 mm diameter and 300mm height were casted to determine the split tensile strength of concrete and Beam concrete specimen having dimension 100 mm x 100 mm and 500 mm were casted to determine the flexural strength of concrete.
During the assembly of die for use purpose, the joint in between the section of container where coated with oil and similar coating of die with oil at contact surface to ensure that no slurry escaped during filling of container and compaction of container. Also, the interior surface of container coated with oil prevents adhesion of concrete and container during remolding. The test specimens are casted in such a way as produce full compaction of concrete with neither segregation nor bleeding. The compaction is done with tamping rod by filling the container in three layers. All the specimens were cured by putting them in water for 7 days and 28 days before testing.

C. Casting and Curing

A suitable control mix was prepared and subsequently mixes containing replacement of fine aggregate and coarse aggregate with crushed River stone dust in part for fine aggregates and recycled crushed concrete used in part for coarse aggregates. For each trial three standard cubes were used to investigate7 days and 28 days strength. For each batch of concrete mixed, the quantities of various ingredients i.e. cement, crushed river stone dust , fine aggregate, coarse aggregate, recycled crushed concrete, water and superplasticizer were kept ready in required proportions. At first a thorough mix of materials to be used for preparation was ensured in dry form till a uniform mix indicated by a uniform color was obtained. It was assumed that there was no visible concentration of any material. Then after the addition of fine and coarse aggregates the mix was turned over a couple of times for a minute. Water in the prescribed amount was then added and then mixed in layers in the cubes, cylinders and beams. Compaction of each layer was accomplished either manually or by a vibrator and the layer was then given a smooth finish. After that, the specimens were allowed to harden for 24 hours. These were extracted from the mould and identification marks were made to designate them before they were immersed in the curing tank containing clean water. After curing of 7 and 28 days the specimens were removed from tank and were tested to obtain the compressive, split tensile strength and flexural strength results.

D. Rebound Hammer test

Rebound Hammer test is a Non-destructive testing method of concrete which provides a convenient and rapid indication of the compressive strength of the concrete. The rebound hammer is also called as Schmidt hammer that consists of a spring controlled mass that slides on a plunger within a tubular housing. The operation of the rebound hammer is shown in fig.1. When the plunger of a rebound hammer is pressed against the surface of concrete, a spring controlled mass with a constant energy is made to hit the concrete surface to rebound back. The extent of rebound, which is a measure of surface hardness, is measured on a graduated scale. This measured value is designated as the Rebound Number (rebound index). A concrete with low strength and low stiffness will absorb more energy to yield a lower rebound value.

E. Tests on Hardened Concrete

Following tests are conducted to check hardness properties of concrete:

- Compressive strength test.
- Split tensile strength test.
- Flexural strength test.

Figure 1 shows the Compression testing machine, Figure2 shows the split strength testing apparatus and Figure 3 shows the flexural strength apparatus.

Figure 1: Compression testing machine

Figure 2: split strength testing apparatus

Figure 3: flexural strength apparatus

IV. RESULTS

The objectives of the present work are to develop cement concrete with good strength and workability by using ground blast furnace slag as a replacement of cement. The M45 grade of concrete was prepared and examined at hardened stage. Then different mixes were prepared containing 0%, 43%, 53%, and 63% as partial replacement of cement with ground blast furnace slag in different combinations. The properties which were examined are:

- Compressive strength of solidified concrete cube specimens.
- Split tensile strength of solidified cylinder specimens.
- Flexural strength of solidified beam specimens.

Figure 4 showsCompressive strength after 7 days, Figure 5 shows Compressive strength after 28 days, Figure 6 shows split strength after 7 days, Figure 7 shows split strength after 28 days, Figure 8 shows flexural strength after 7 days and Figure 9 shows flexural strength after 28 day.

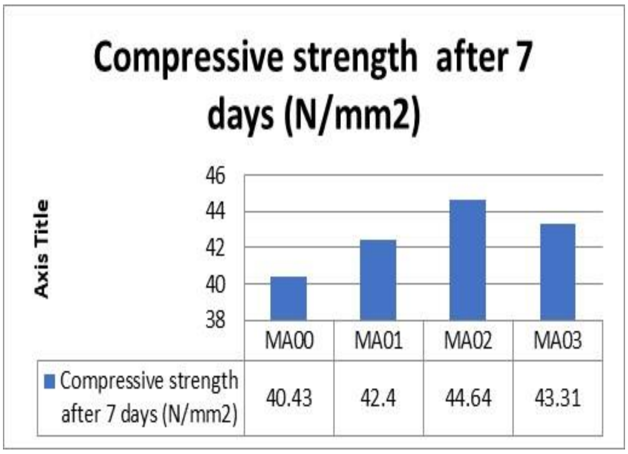

Figure 4: Compressive strength after 7 days

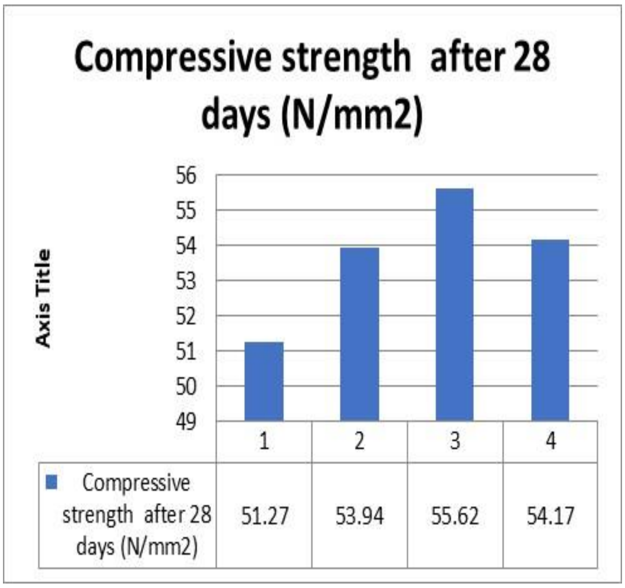

Figure 5: Compressive strength after 28 days

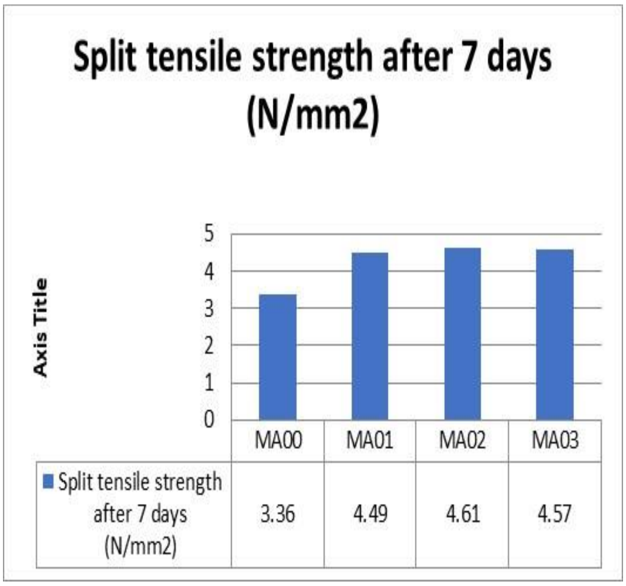

Figure 6: split strength after 7 days

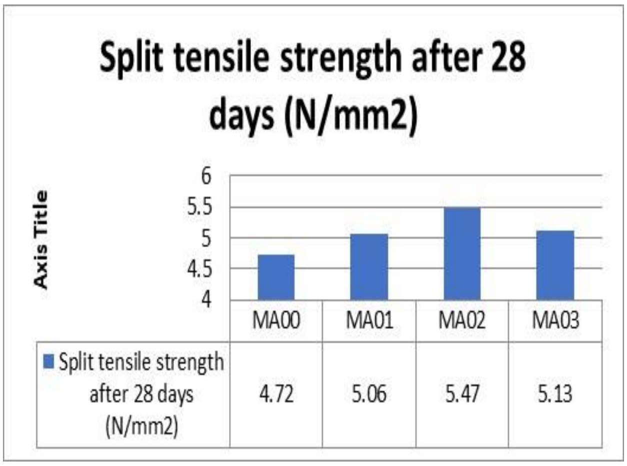

Figure 7: split strength after 28 days

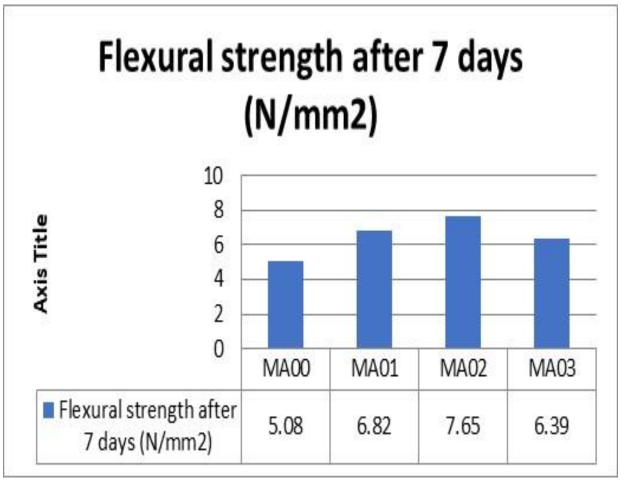

Figure 8: flexural strength after 7 days

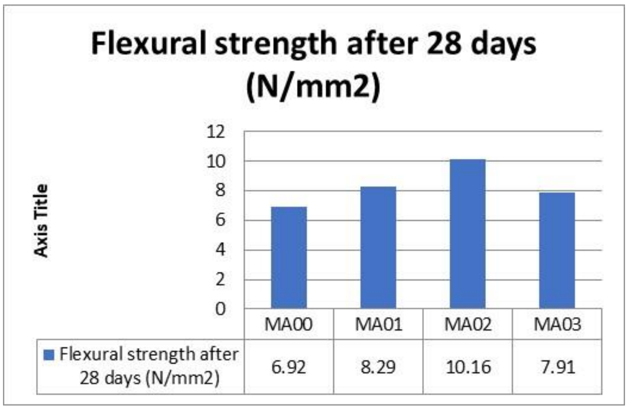

Figure 9: flexural strength after 28 days

V. CONCLUSION

- The maximum compressive strength by using destructive test conditions of M45 grade for 7 days was 44.64 N/mm^2 when the replacements of cement were 63% by ground blast furnace slag and the maximum compressive strength of same grade for 28 days was 55.62 N/mm^2 when the replacements of cement were 53% by ground blast furnace slag.
- The maximum split tensile strength of M45 grade for 7 days was 4.61 N/mm^2 when the replacements of cement were 43% by ground blast furnace slag and the maximum compressive strength of same grade for 28 days was 5.47 N/mm^2 when the replacements of cement were 53% by ground blast furnace slag.
- The maximum flexural strength of M45 grade for 7 days was 7.65 N/mm^2 when the replacements of cement were 53% by ground blast furnace slag and the maximum compressive strength of same grade for 28 days was 10.16 N/mm^2 when the replacements of cement were 43% by ground blast furnace slag.

REFERENCES

[1] AtulDubey, Dr.R.Chandak, Prof. R.K. Yadav, "Effect of blast furnace slag powder on compressive strength of concrete" International Journal of Science & Engineering Research ISSN: 2229- 5518 Vol. 3, Issue. 8, August 2012.

[2] Durai S, Remya M, Dr. P.Muthupriya, Dr.R.Venkatasubramani, "Experimental investigation on high performance concrete using GGBS as admixture"

International Journal of Emerging Trends in Engineering and Development ISSN 2249-6149, VOL. 2, Issue 3, March 2013.

[3] Dr.K.Chinniraju, V.R.Ramkumar, K.Lineesh, S.Nithya, V.Sathish, "Study on concrete using steel slag as coarse aggregate replacement and ecosand as fine aggregate replacement" Intrnational Journal of Research in Engineering and Advanced Technology ISSN: 2320 – 8791, Vol. 1, Issue. 3, (June-July 2013).

[4] GumageriNagaraj, Sreenivasalu D, Shankar Sanni, " Utilization of marginal products in the cement concrete" International Journal of Earth Sciences and Engineering ISSN 0974-5904, Vol 04,No 06 SPL, October 2011, pp. 929-932.

[5] Kamran Muzaffar Khan, Usman Ghani, " Effect of blending of portlant cement with ground granulated blast furnace slag on the of concrete " Singapore Concrete Institute, August 2004 .

[6] Raina, S.S., Singla, E.S. and Batra, D.V., 2018. Comparative analysis of compressive strength and water absorption in bacterial concrete. International Journal of Engineering Development and Research, 6(3), pp.281-286.

[7] Bhatta, D.P., Singla, S. and Garg, R., 2022. Experimental investigation on the effect of Nano-silica on the silica fume-based cement composites. Materials Today: Proceedings.

[8] Singh, P., Singla, S. and Bansal, A., 2021. Evaluation of Land Use and Land Cover Transformation and Urban Dynamics Using Multi-Temporal Satellite Data. Geodetski list, 75(3), pp.257-279.

[9] Kumar, A., Singla, S., Kumar, A., Bansal, A. and Kaur, A., 2022. Efficient Prediction of Bridge Conditions Using Modified Convolutional Neural Network. Wireless Personal Communications, pp.1-15.

[10] Singh, A., Singla, S. and Garg, R., 2020, November. Performance analysis of Papercrete in presence of Rice husk ash and Fly ash. In IOP Conference Series: Materials Science and Engineering (Vol. 961, No. 1, p. 012010). IOP Publishing.

[11] Ashraf, S., Kaur, S. and Singla, S., 2022. Water Quality Assessment of Anchar Lake, Srinagar, India. Civil and Environmental Engineering Reports, 32(1), pp.88-115.

[12] Ahmad, Uzair. (2018). A Study on Effect of Polymers on the Properties of Vg-10 Grade Bitumen. International Journal for Research in Applied Science and Engineering Technology. 6. 2572-2576. 10.22214/ijraset.2018.4433.

[13] Singh, J., Singh, B. and Singla, S., Enhancement of Expensive Soil by Addition of Stone Dust and LDPE Fibre.

[14] Singh, P. and Singla, S., 2023. Estimation of Land Surface Temperature of Srinagar City, India Using Landsat 8 Data. Sustainability, Agri, Food and Environmental Research, 12(1).

[15] Irshad, U and Singla, S.,2019 "Impact of Road Conditions on Traffic Management-A Case Study of Chenab Valley." International Journal of Scientific & Technology Research 8 1179-1186.

[16] Singla, N., Singla, S., Thind, P.S., Singh, S., Chohan, J.S., Kumar, R., Sharma, S., Chattopadhyaya, S., Dwivedi, S.P., Saxena, A. and Issakhov, A., 2021. Assessing the Applicability of Photocatalytic-Concrete Blocks in Reducing the Concentration of Ambient NO2 of Chandigarh, India, Using Box–Behnken Response Surface Design Technique: A Holistic Sustainable Development Approach. Journal of Chemistry, 2021.

[17] Kumar, V., Singla, S. and Garg, R., 2021. Strength and microstructure correlation of binary cement blends in presence of waste marble powder. Materials Today: Proceedings, 43, pp.857-862.

[18] Garg, R., Garg, R. and Singla, S., 2021. Experimental Investigation of Electrochemical Corrosion and Chloride Penetration of Concrete Incorporating Colloidal Nanosilica and Silica fume. Journal of Electrochemical Science and Technology, 12(4), pp.440-452.

[19] Kansal, C.M., Singla, S. and Garg, R., 2020, November. Effect of Silica Fume & Steel Slag on Nano-silica based High-Performance Concrete. In IOP Conference Series: Materials Science and Engineering (Vol. 961, No. 1, p. 012012). IOP Publishing.

[20] Bhatta, D.P., Singla, S. and Garg, R., 2021. Microstructural and strength parameters of Nano-SiO2 based cement composites. Materials Today: Proceedings, 46, pp.6743-6747.