Effect of Ground Granulated Blast Furnace Slag on the Properties of Sea Shell Concrete

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Abstract. This paper opens up how the properties of seashell mix concrete influenced by the effect of ground granulated blast furnace slag (GGBS). This experimental program consists of thirteen concrete mixes. One is conventional concrete & other concrete mixes are formed by the partial replacement of fine aggregate with crushed seashell and cement with GGBS. The proportion of crushed seashell was added 0, 10 %, 20 % & 30 % to the conventional concrete. Then seashell mix concrete of 10 % was blended with 10 %, 20 % & 30 % of GGBS mix concrete and like this 20 %, 30 % of seashell mix concrete was intermixed with 10 %, 20 % & 30 % of GGBS mix concrete respectively. For this experiment M30 grade concrete mix was prepared. Tests like slump test for workability of concrete were carried out on different mixes of fresh concrete. Also, on hardened concrete samples of different mix, test like compressive, split-tensile & flexural strength test were allotted after 7 days and 28 days of curing under water. From the experimental observations show that use of seashell in concrete decreases the strength gradually but in case of GGBS, the strength increases gradually in all type of concrete mixes. The result declares higher compressive, flexural and split-tensile strength at 10 % partial replacement of fine aggregate with crushed seashell and 20 % partial replacement of cement with GGBS.

1. Introduction

Food, Cloth and Shelter are basic need of human. We use varieties of materials for our shelter. Concrete mainly contains water, fine and coarse aggregates which are granular in nature and cement. We have been used these ingredients from way back. Since ancient time we use lime, stone, sand and aggregate for creating our homes, monuments, some huge structures etc. Now a days concrete is employed as an artifact for any form of construction work. We can directly prepare the concrete on the site. It is very easy to prepare. The demand for concrete as construction material is increasing constantly. Even though it is economical, it is not very eco-friendly. To deal with the negative impacts on environment, sustainable construction materials are being researched in huge amount. On the other hand, industrial byproducts have also become headache lately. Estimations revealed that the cement’s production rose from about 1.5 billion tonnes in 1995 to 3.2 billion tons in 2016. The demand of key ingredients of concrete are increased also. So there are chances of shortage of these materials in future because it is available from nature and it takes long time to refill the erode space. So in this experiment our main moto is to use the waste material and form a new generation concrete which is not only eco-friendly but also has the equal and more load bearing capacity or strength.
In this experiment we use the seashell which is the dead shell of sea animals. Our India is surrounded by sea around its three sides. So there are a lot of places where we can get these seashells. The seashell has the most amazing properties of binding because it consists of lime. We can use this seashell as a replacing material of cement, fine aggregate, coarse aggregate. In this project we use the seashell for partially replacing fine aggregate. For this effective use of seashell, the natural source like sand which has eroded from sea bank or river bank will somehow reduce. So, overall concrete plays key role in infrastructural development. But there are downsides of using concrete as well. One of which is its bad effects on environment (as it produces heavy amount of carbon dioxide gas). One practical approach for solving this problem while expecting optimal results is using supplementary material which are also cementitious in nature i.e. fly ash, slag etc. A recycled aggregate can successfully replace natural aggregate in concrete. Recycled aggregates are composed of substances that have previously been used in construction and later collected after demolition of the constructed infrastructure. GGBS is produced as a by-product in the construction of pig iron. It is slightly alkaline in nature and does not pose any threat to reinforcement of concrete. So the second waste which has used in this project is ground granulated blast furnace slag (GGBS). Steel furnace slag (SFS) along with Blast furnace slag (BFS) go back a long way to be used as industrial byproducts. GGBS is partially substituted cement in this experiment. We should take care of our environment as well as give our best to the nature and for the development of our construction practices [1-10].

In this project our main purpose is to make an economical, eco-friendly, sustainable concrete and study the effect, and the properties of ground granulated blast furnace slag on seashell mix concrete. Some of the researchers have investigated the effect of cementitious material over crushed seashell concrete Adewuyi and Adegoke [1] used periwinkle shell as a coarse aggregate substitution with a percentage of 35.4% and 42.5 % and getting a 28 days cube strength value of 21 N/mm² and 15 N/mm² for concrete mix 1:2:4 and 1:3:6 respectively. Chakravarthy and Mutusva [2] analyzed that in early stages it was found that partially adding and increasing the seashells as coarse aggregate reduces the workability of concrete. Mohanlaxmi et al. [3] researched about how replacement of sea shell as fine aggregate could increase overall strength of concrete. Panda et al. [4] analysed that with increase in seashell amount, workability gradually lessened. When 10 % crushed seashell is employed in place of fine aggregate as well as 20 % RHA is employed in place of cement, it provides best results for concrete mechanical properties. Padhi and Panda [5] partially replaced the fine aggregate with fine rubber (FR) and cement with Silpozz in a proportion of 5 %, 10 % and 15 %. The result shows that, as quantity of FR rises, workability of both conventional and self compacting concrete lessens. In case of FR replacement, the compressive strength decreases and the flexural strength increases up to 5 % replacement of FR. Silpozz enhances the strength of SCRC. Panda and Pradhan [6] partially replaced cement by Silpozz and lime stone powder. The result shows concrete specimens having lime stone powder result in increased workability. Jena and Panda [7] replaced sand with crusher dust in cement concrete and finally found out a suitable mixture proportion that also helped in retaining quality. They used seven number of mix sample for this experiment. The result was obtained that at 28 days curing, with 100 % replacement of sand with crusher dust compressive, flexural and split tensile strength rises. Lenka and Panda [8] used the supplementary cementitious material as Metakaolin (MK). The authors used MK as the replacing material of cement from 5 – 20 % for both SCC and CC. The outcome reveals that concrete having MK had great impact on strength. This paper focuses on the properties of seashell mix concrete influenced by the effect of ground granulated blast furnace slag (GGBS).

2. Material Used

2.1 Materials
Portland Pozolana Cement (PPC), Natural fine aggregate (fineness modulus 2.30, water absorption 0.70 and specific gravity 2.62) and natural coarse aggregate (fineness modulus 6.08, water absorption 0.82 and specific gravity 2.80). the results obtained from the testing of the materials as per the code IS:
Sea shell and GGBS are used in this experimental study. Seashells’ passing through 4.75mm IS sieve, fineness modulus 2.28 and specific gravity 2.50 are collected from Balasore. The uncrushed seashell and crushed seashell are displayed in Figure 1 and the particle size distribution curve of sea shell is displayed in Figure 2.

**Figure 1.** Uncrushed and crushed seashell below 4.75 mm

**Table 1.** Chemical constitution and physical features of GGBS

| Chemical constitution | RA (%) | Physical features          |
|-----------------------|--------|----------------------------|
| Silica (SiO$_2$)      | 31-37  | Colour off-white           |
| Alumina (Al$_2$O$_3$) | 22-27  | Specific gravity 2.9       |
| Magnesia Oxide (MgO)  | 4-10   | Maximum dry density 2.56gm/cc |
| Calcium Oxide (CaO)   | 30-50  | Optimum moisture content 20 % |

GGBS is used as partial replacement of cement which is supplied by Rourkela Steel Plant, Rourkela. GGBS is processed under a temperature of 800°C with containing a higher percentage of CaO (30-50 %) and having some additional mineral in it i.e. SiO$_2$, Al$_2$O$_3$ and MgO. The chemical constitution and physical features of GGBS are presented in Table 1.

**Figure 2.** Particle size distribution curve of sea shell
2.2 Mix Proportion
For the concrete, the material which is used in this experiment were PPC, sand (NFA), natural coarse aggregate (NCA), Sea shell (C) & ground granulated blast furnace slag (GGBS). The grade of concrete was M30 which was designed as per IS: 10262-2009 [10]. Here the mix proportions 1:1.6:2.8 were taken in this experiment. The three different mix of concrete design were 10 %, 20 %, and 30 % for sea shell and GGBS replaced with natural fine aggregate and cement respectively. The same mixes have been tested in a constant water cement ratio 0.375 for conventional concrete. In this study total thirteen concrete mix proportions are used, first mix i.e. MC0G0 which stands for conventional concrete. In next three concrete mixes seashell is replacing NFA by 10, 20 & 30 %. Second three mixes were made by replacing cement with GGBS by 10, 20 & 30 % with a constant percentage of seashells (10 %). Third three mixes were made by replacing GGBS with cement by 10, 20 & 30 % with a constant percentage of seashells (20 %). The last three mixes were made by replacing GGBS with cement by 10, 20 & 30 % with a constant percentage of seashells (30 %).

2.3 Mixing and casting
For the concrete NCA, NFA, GGBS and seashell were weighted and placed in the concrete mixer and thoroughly mixed until the mixture become equivalent. The required sum of water was mixed to the respective mix during the mixing. The above procedure is done for casting & curing. Then after the discharge of the concrete mixture from mixture machine, immediately workability test was done such as slump test. From the mix design calculation, the slump value must come within 25 – 50 mm. The test specimens were cast in steel mould of cube (150 x 150 x 150 mm), cylinder (100 mm diameter x 200 mm height) and prism (100 x 100 x 500 mm). Then it compacted by using of table vibrator and demoulded after 24 hours. There after the curing was done for period of 7 and 28 days. For the slump test with different percentage of replacement of sea shell with NFA and GGBS with cement, degree of workability is described in Table 2.

| Mix Identity | Water/Cement Ratio | Slump Value (mm) | % of Change of Slump value w.r.t Control Specimen | Degree of Workability |
|--------------|--------------------|------------------|---------------------------------------------------|----------------------|
| MC0G0        | 0.375              | 48 mm            | 0                                                 | Medium for all concrete mixes |
| MC10G0       | 0.375              | 43 mm            | -10.41                                            |                      |
| MC20G0       | 0.375              | 37 mm            | -22.91                                            |                      |
| MC30G0       | 0.375              | 34 mm            | -29.16                                            |                      |
| MC10G10      | 0.375              | 45 mm            | -6.25                                             |                      |
| MC10G20      | 0.375              | 52 mm            | 8.33                                              |                      |
| MC10G30      | 0.375              | 48 mm            | 0                                                 |                      |
| MC20G10      | 0.375              | 39 mm            | -18.75                                            |                      |
| MC20G20      | 0.375              | 42 mm            | -12.5                                             |                      |
| MC20G30      | 0.375              | 46 mm            | -4.16                                             |                      |
| MC30G10      | 0.375              | 37 mm            | -22.91                                            |                      |
| MC30G20      | 0.375              | 43 mm            | -10.41                                            |                      |
| MC30G30      | 0.375              | 48 mm            | 0                                                 |                      |

3 Discussion
To analyse concrete’s workability slump test was conducted. It was noticed that increase in quantity of crushed seashell in place of fine aggregate causes decrement in the value of slump. Also with both increment in replacement level of cement with GGBS and increment in crushed seashell, again results in the workability of concrete regaining its value. Angular shape and asymmetrical texture of seashell are the reason behind reduced workability.
3.1. Compressive strength

Figure 3 represents the test result of compressive strength. The graph shows 7 days and 28 days compressive strength of different concrete mixes. Compressive strength of MC0G0 after 7 and 28 days curing are 37.70 MPa and 51.25 MPa respectively. The graph shows that with increment in the partial substitution of crushed seashell in concrete from 10 % to 30 %, the compressive strength starts to decrease gradually. The compressive strength after span of 7 and 28 days of curing for specimen MC10G0 is 33.10 MPa and 47.25 MPa respectively, for specimen MC20G0 30.25 MPa and 43.70 MPa and for specimen MC30G0 25.60 MPa and 37.70 MPa in 7 days and 28 days respectively. The decrease in strength is due to adding of more percentage of seashells in conventional concrete. While increasing the percentage of seashells, the binding between crushed seashell and cement become loose due to the more water absorption of seashell that of fine aggregate. As the cement is partially substituted by GGBS and mixed with the different percentage of seashell concrete, the compressive strength starts increasing. The compressive strength is high in 10 % substitution of fine aggregate with crushed seashell and 20 % substitution of cement with GGBS. The compressive strength which is maximum in MC10G20 concrete mix is 41.5 MPa and 55.75 MPa in 7 days and 28 days respectively.

![Figure 3. Compressive strength vs concrete mix.](image)

3.2. Flexural strength

Figure 4 represents the test result of flexural strength. The graph shows 7 and 28 days flexural strength of different concrete mixes.

![Figure 4. Flexural strength vs concrete mix.](image)
From Figure 4 flexural strength of MC0G0 after 7, 28 days curing are 5.95 MPa and 7.20 MPa respectively. The decrease in strength is due to adding of more percentage of seashells in conventional concrete. While increasing the percentage, the binding between crushed seashell and cement become loose due to the more water absorption of seashell that of fine aggregate. When cement is partially replaced with GGBS and mixed with the different percentage of seashell concrete, there is increment in flexural strength. The flexural strength is high when the percentage of partial substitution of fine aggregate with crushed seashell is 10 % and that of cement with GGBS is 20 %.

3.3. Split tensile strength

Figure 5 signifies the test result of 7 days and 28 days split tensile strength of different concrete mix. As the replacement level of crushed seashell in concrete is increased from 10 % to 30 %, the split tensile strength starts to decrease gradually. Strength reduction is due to addition of more percentage of seashells in conventional concrete. While increasing the percentage the binding between crushed seashell and cement become loose due to the more water absorption of seashell that of fine aggregate. The split tensile strength which is maximum in MC10G20 concrete mix is 3.65 MPa and 4.75 MPa in 7 and 28 days respectively.

![Figure 5. Split tensile strength vs concrete mix.](image)

4 Conclusion

In this paper, the effect of normal concrete and seashell concrete with their mechanical properties is investigated. The result of different concrete mix is evaluated to find out the best composition which gives excellent mechanical properties. GGBS is replaced with cement and seashell is used on behalf of natural fine aggregate in a proportion of 10 %, 20 % and 30 %. It is noticed that with increasing the percentage of replacement of NFA by seashell, concrete’s workability is lessening. Likewise, with increasing seashell quantity, concrete’s strength is lessening. Concrete’s strength and workability increase as the GGBS is added to the seashell mix concrete. Utmost strength is attained with 10 % seashell and 20 % of GGBS. There is growth in compressive strength of concrete upto 10 % substitution of seashell and 20 % substitution of GGBS, there after there is lessening in compressive strength. Rise in split tensile strength is perceived up to 10 % substitution of seashell and 20 % replacement of GGBS, there after it decreases. Flexural strength of concrete increases up to 10 % changeover of seashell and 20 % substitution of GGBS, there after it decreases. Water absorption yielded higher value for all mixes containing seashell and GGBS. It is found that with increase in days, all the three test strength increases. But when the percentage of seashell increases as NFA, the strength decreases.
References

[1] Adewuyi A and Adegoke T 2008 Exploratory study of periwinkle shells as coarse aggregates in concrete works ARPN Journal of Engineering and Applied Sciences 3 1-5

[2] HG N C and Mutusva T 2015 Investigation of Properties of Concrete with Seashells as a Coarse Aggregate Replacement in Concrete MATTER: International Journal of Science and Technology 1

[3] Mohanalakshmi M V, Indhu M S, Hema M P and Prabha M V 2017 Developing concrete using sea shell as a fine aggregate International Journal for Innovative Research in Science and Technology (IJIRST) 3 282-6

[4] Panda K C, Behera S and Jena S 2020 Effect of rice husk ash on mechanical properties of concrete containing crushed seashell as fine aggregate Materials Today: Proceedings 4 049

[5] Padhi S and Panda K 2016 Fresh and hardened properties of rubberized concrete using fine rubber and silpozz Advances in Concrete Construction 4 049

[6] Pradhan S and Panda K 2017 Assessment of fresh and hardened properties of concrete using supplementary cementitious materials Materials Today: Proceedings 4 9837-41

[7] Jena S and Panda K 2017 Influence of crusher dust on the properties of concrete Indian Journal of Civil Engineering and Technology 8 93-603

[8] Lenka S and Panda K 2017 Effect of metakaolin on the properties of conventional and self compacting concrete Advances in Concrete Construction 5 031

[9] 1970 IS 383:1970: Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete (Second Revision), Bureau of Indian Standard, ManakBhavan, Bahadurshah Zafar Marg, New Delhi, India

[10] 2009 IS: 10262:2009, Guide lines for concrete mix design proportioning, Bureau of Indian Standards, New Delhi, India