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Comparative Study on the Production Cost of Geopolymer and Conventional Concretes

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Abstract

Globally there has been a growing demand for new construction materials that have low greenhouse gas emissions and effect sustainability during the past few decades. The boom in the industrial sectors has paved way for the consumption of cement and other natural resources in a massive manner. Depletion of these natural resources at such an alarming rate could affect sustainability with nothing to be conserved for our future generations. The main objective of any research is to discover a new or environmental friendly product. The underlying fact in every research is savings in cost, so that there is no hindrance on its adoption on a large scale or mass production. Only when the products are cost effective they will reach the common man. Geopolymer concrete is a very versatile material and also cost effective when compared to OPC concrete. The use of GPC precast elements will help speed up the construction process and also prove to be economical in the long run. In this paper, the cost of producing $1m^3$ of GPC and OPC are calculated based on the market rates of the ingredients required and compared for socio-economic feasibility. Based on the cost calculations, it was seen that the cost of production of OPC concrete is higher than the cost of production of GPC for higher grades. For M30 grade of GPC concrete the cost of production is marginally (1.7%) higher than OPC concrete of the same grade whereas for M50 grade, the cost of OPC concrete is 11% higher than GPC of same grade. Hence it can be concluded that savings in cost can be attained in the production of Geopolymer concretes of higher grades as well as lower grades with only a marginal difference.

Keywords: Sustainability, Greenhouse gas emissions, Geopolymer concrete, OPC

1. INTRODUCTION

Sustainable concretes should be made with the abundantly available resources on earth and with recycled materials with low energy requirements and produced with little or no wastes, so that they may have a minimal impact on the environment [1]. The use of green materials which have less energy and resource requirement and which utilizes a large proportion of recyclable materials can be used to make high performance cements and concretes with high durability and low maintenance.

Concrete is an artificial stone like material used for various structural purposes. Today's concrete is made mixing a binding material such as ordinary Portland cement and various aggregates (inert materials) such as sand, stone chips, gravel with water and allowing it to harden by hydration. Admixtures and chemicals are also added to modify its properties accordingly to give better performance characteristics. As one of the key ingredients of modern concrete, cement has been around for nearly 12 million years. (Source:www.nachi.org/history-of-concrete.htm). The advent of Cement started during the period when the earth itself was undergoing intense geological changes. The year 1860 marked the beginning of the era of Portland cements of modern composition. But production of 1 ton of cement requires twice as much as raw materials (Limestone and Shale) and releases CO_2, NOx and Particulate Matter 10(PM10) which severely affects the respiratory tract when inhaled. Also mining of limestone has significant impacts on the land use pattern, no regulatory measures tater profiles and air quality. Fugitive emissions during the manufacture of cement poses major problems as there are no regulatory measures to prevent it. The cement industry extracts its raw materials by mining and uses energy that are non-renewable and ultimately manufactures a product that cannot be recycled. Through proper waste management and by the utilization of industrial by-products, the usage of energy involved in these processes can be reduced considerably. This paves way for reducing the greenhouse gas emissions and also cuts down raw material costs. Although high volume fly ash concretes containing less than 50% cement content were used extensively in place of ordinary Portland cement concrete, recent interests have been found to be focused on the use of concrete which completely eliminates the usage of cement. One such emerging material is **"Geopolymer concrete"** which uses only mineral admixtures in place of cement. Geopolymer concretes were eventually developed with the aim of reducing the carbon footprint by eliminating the usage of cement and reduce the cost by use of industrial by products which otherwise would be dumped as waste materials [3].

The main objective of any research is to discover a new or environmental friendly product. The underlying fact in every research is savings in cost, so that there is no hindrance on its adoption on a large scale or mass production. Only when the products are cost effective they will reach the common man. Geopolymer concrete(GPC) is a very versatile material and also cost effective when compared to OPC concrete. The use of GPC precast elements will help speed up the construction process and also prove to be economical in the long run [2], [4], [6],[12],[24] & [25]. In this work, the cost of producing 1 m3 of GPC and OPC are calculated based on the market rates of the ingredients required and compared for socio-economic feasibility.

2. INGREDIENT MATERIALS AND THEIR COST

The ingredients of GPC and OPC and their cost are shown in Table 1. The materials required for the manufacture of OPC and GPC were purchased in bulk from local suppliers. Sodium Silicate (Na_2SiO_3) and Sodium Hydroxide(NaOH) pellets were from M/s.Mahalakshmi scientific, Coimbatore. Bottom ash (BA) was obtained from Mettur thermal power plant, Mettur. Ground Granulated Blast Furnace Slag(GGBFS) was obtained from Agni steels, Ingur. As both BA and GGBFS were coarse they were ground to increase the surface area.

Table 1: Ingredient materials and their cost

S.no.	**Material**	**Rate in Rs./per**
1.	Bottom ash	100/MT
2.	GGBFS	1.5/kg
3.	River sand	800/MT
4.	Foundry sand	100/MT
5.	Coarse aggregate	600/MT
6.	Cement	420/50 kg
7.	Na_2SiO_3 solution	25/kg
8.	NaOH flakes	25/kg
9.	Superplasticizer (Carboxylic)	200/litre

Bottom ash is collected from the boilers of electrostatic precipitators as they are coarser than fly ash. They are not obtained in a dry state and hence discarded as a waste material. Nearly 20% of bottom ash only is used and the remaining is used in landfills. Bottom ash was collected free of charge and the cost of this material includes only the transportation cost. Foundry sand is discarded as waste from foundries and consists of sand which has been used in moulds repetitively for molding. It consists of high percentages of silica and hence was attempted to use in this work. Foundry sand is also collected free of cost. GGBFS is obtained as a byproduct from steel industries and are coarser. They have to be ground prior to its use in order to increase the surface area. The cost of GGBFS would include the transportation cost and power required for grinding.

3. COST ANALYSIS FOR GEOPOLYMER CONCRETE AND ORDINARY PORTLAND CEMENT CONCRETES

The cost of production of 1 m^3 of OPC of grades M30 and M50 are calculated based on the quantities of the ingredient materials and is shown in Table 2.

Table 2 Cost of production of 1m^3 of OPC concrete

S.No.	Material	Rate in Rs	Unit	M30		M50	
				Quantity in kg	Amount in Rs	Quantity in kg	Amount in Rs
1	Cement	420	50 kg	350	2940	450	3780
2	Fine aggregate	800	MT	642	514	425	340
3	Coarse aggregate	650	MT	1270	826	1381	898
4	Superplast cizer	200	kg	7.5	1500	8	1600
Total				**Rs.5780/-**		**Rs.6618/-**	

The cost of production of 1m^3 of GPC is shown in Table 3. As in the case of OPC, super plasticizers are not required for the manufacture of GPC as they do not have a significant effect on workability and strength [5] & [7].

Table 3 Cost of production of 1m^3 of GPC

S.No	Material	Rate in Rs	Unit	M30		M50	
				Quanity in kg	Amount in Rs	Quanity in kg	Amount in Rs
1	Bottom ash	100	MT	514	51	514	51
2	GGBFS	1.5	Kg	514	771	514	771
3	River sand	800	MT	420	336	420	336
4	Foundry sand	100	MT	420	51	420	51

5	Coarse aggregate	650	MT	840	294	840	294
6	NaOH flakes	25	Kg	7.1	177.5	13.3	332.5
7	Na_2SiO_3 solution	25	Kg	103	2575	137.14	3428.5
8	Cost of Electricity			600		600	
Total				**Rs.5883.5/-**		**Rs.5864/-**	

The savings in cost can be determined by comparing the cost of production of 1m^3 of OPC with that of cost of production of 1m^3 of GPC and is shown in Table 4.

Table 4 Savings in cost of production for GPC and OPC concretes

Grade of concrete	Cost of production of 1m^3 of OPC	Cost of production of 1m^3 of GPC	Savings in Cost (Rs)	Savings in %
M30	5780	5883.5	-103.5	-1.7 %
M50	6618	5864	754	11%

4. CONCLUSION

Based on the above calculations, it may be seen that the cost of production of OPC concrete is higher than the cost of production of GPC for higher grades. For M30 grade of GPC concrete the cost of production is marginally (1.7%) higher than OPC concrete of the same grade whereas for M50 grade, the cost of OPC concrete is 11% higher than GPC of same grade. This is in agreement with the findings of Anuradha et al (2012). Hence it can be concluded that savings in cost can be attained in the production of Geopolymer concretes of higher grades and lower grades with a marginal difference.

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