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QUARRY DUST IN FOAMED CONCRETE: A SUSTAINABLE BUILDING MATERIAL

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ABSTRACT: Foamed concrete is a versatile construction material, which is light in weight as well as thermally resistive. It can be made in different densities in the range of 300 to 1800 kg/m^3 by adjusting the quantity of stable foam. Since there is depletion of river sand, an attempt has been made in this paper to study the possibility of utilizing manufactured sand as fine aggregate. Further, quarry dust, an industrial waste material, has been used as a substitute for manufactured sand for the production of foamed concrete. Quarry dust has been added at different percentages from 50 to 100. Protein type foaming agent has been used for the production of stable foam. It has been observed that 70% of manufactured sand can be replaced with quarry dust to achieve the maximum compressive strength compared to that of control cube. Thermal conductivity has been observed to be decreased with increase in quarry dust content.

KEYWORDS: *Foamed Concrete, Manufactured Sand, Quarry dust, Stable Foam, Sustainability*

I. INTRODUCTION

Construction industry is developing tremendously all over the world. Existing resources are depleting at a higher rate, which urges the researchers to search for alternate materials. The biggest concern in the present situation is the rapidly decreasing non-renewable source of energy along with the natural resources and also the production and handling of the industrial waste materials. Sustainable development is not only the future of construction industry, but also the savior of the environment. Hence, more precaution has to be taken for the conservation of the natural resources and also for the reduction of the waste materials.Foamed concrete (FC) is a type of a light weight concrete, which has lower density compared to that of conventional concrete. The main peculiarity of FC is the absence of coarse aggregate. Manufactured sand is produced by the crushing of hard rocks and during this process; nearly 25 % of the stone is converted into fine dust called quarry dust (QD). It refers to very fine material or a residue/tailing material subsequent to the mining and dispensation of rocks to develop tiny aggregates, whose, sizes are below 4.75 mm. This residue is usually less than 0.075 mm in size, whose properties vary with rock type. This waste is inert and non-hazardous unlike the waste from many other processes. However, the production of waste is creating various problems to the environment, particularly problems related to water contamination, respiratory problems to human and animals, wastage of land etc. Hence, this study is focused on introducing a new method for the development of foamed concrete by substituting manufactured sand with quarry dust, and thereby producing a more reliable and sustainable concrete. While adding stable foam into the base mix (mix containing cement, sand and water), it covers the bubbles and during degeneration of the foam, the paste will get adequate potency to keep up its shape around the voids. A suitable foaming agent along with a standard foam generator is the major requirements for making stable foam.

Reddy, 2010, has conducted studies on concrete with stone dust as a fine aggregate substitute and ceramic scrap as coarse aggregate substitute and has reported that both of these waste materials can be very effectively utilized for the production of concrete in a very economical way and thereby a sustainable building material can be produced. Concrete of any desired strength can be produced using these materials. It has been experimentally proved that ceramic scraps can be used to replace 10 to 20% by weight of conventional coarse aggregate without compromising the compressive strength. Sivakumar and Prakash, 2011 have conducted studies on concrete by completely replacing river sand with quarry dust. The experimental results have shown that the addition of quarry dust for fine to coarse aggregate ratio 0.6 was found to enhance the compressive properties as well as elastic modulus. It has been experimentally proved that conventional concrete and quarry dust concrete are having almost similar strength. Raman et al., 2011, have conducted studies on rice husk ash (RHA) based concrete using quarry dust and have reported that there was a decrease in compressive strength and the other mechanical properties of the hardened concrete due to the addition of quarry dust, which can be compensated with the combined utilization of super plasticizer and mineral admixture such as rice husk ash.

Dewah, 2012 has conducted studies on self-compacting concrete (SCC) with the addition of quarry dust, silica fume and fly ash in it. It has been identified that the quarry dust powder fills the micro pores in concrete more effectively than fly ash and silica fume. Also, it has been reported that the water cement ratio adopted for achieving the highest compressive strength was 0.38. Further, it has been identified that the very fine nature of quarry dust powder has caused the increase in compressive strength of SCC. Bahoria et al., 2014, have conducted studies on the influence of quarry dust and waste plastic fibres as a substitute for sand in concrete and have reported that there was an increase in compressive strength by the addition of waste plastic fibres up to 6%. The compressive strengths of M30 and M40 concretehave reached up to 42 MPa and 58 MPa respectively, by the addition of these waste materials. It has also been assured that the cost of production can be reduced considerably by the addition of these wastes.

Prakash and Rao, 2016, have conducted studies on concrete with quarry dust and it has been reported that the presence of quarry dust in concrete has enhanced the mechanical properties as well as the elastic modulus. Literature reveals that quarry fines can be used to replace natural sand up to 50% without compromising compressive strength. From the experimental results, it has been proved that the concrete with similar strength as that of conventional concrete can be produced even with the sand replaced with 40% quarry dust. It has been observed that the increase in compressive strength may be due to the formation of a strong bond between the fine aggregates and the coarse aggregates due to the addition of quarry dust. It has also been revealed that there has been reduction in workability due to the water absorption property of the quarry dust, when quarry dust has added excessively.Jagadeesh et al., 2016, have conducted studies on quarry dust-based concrete has been revealed that the water demand of manufactured sand was high for getting better workability. It has been experimentally proved that the compressive strength has been increased with respect to the increase in addition of quarry dust. Most extreme results have been obtained when the inclusion of quarry dust was at the rate of 40% by weight of fine aggregate. The maximum compressive strength achieved was 40 N/mm^2.

Kankam et al., 2017, have studied the stress-strain characteristics of concrete with quarry rock dust. It has been reported that for all grades of concrete, 25% sand replacement level has the higher value of modulus of elasticity. Also, it has been noted that the average ratio of prism compressive strength to the cube compressive strength was higher for concrete with 25% sand replacement.Even though papers are there on concrete with quarry dust, papers describing foamed concrete using quarry dust are only few in numbers. Also, in most of the studies, river sand was used as fine aggregate, the extraction of which is nowadays completely banned by the government. Hence, it becomes unavoidable to carry out a systematic study on FC totally utilizing manufactured sand instead of river sand. Since, manufactured sand is also a costlier material; the feasibility of substitution of it with quarry dust is explored in this study. Also, in order to make this study different from the other studies, vegetable protein type foaming agent, which is cheaper than synthetic type foaming agent has been used for the study. From the above observations and findings, the following conclusions have been made. (1) All the studies conducted earlier were focused on the characteristic studies on normal concrete with quarry dust as an alternative for river sand (2) Low density FC blocks having practically reasonable compressive strength makes it a feasible alternative to the traditional bricks or hollow/solid concrete blocks, which have densities ranging between 1800 kg/m^3 and 2300 kg/m^3. Very few works have been reported on the possibility of FC as a material for building units. (3) The feasibility of the integration of a large quantity of industrial waste materials for the manufacture of building units will lead to a better practice for achieving sustainability in construction. (4) In most of the studies, rich mixes with cement sand ratio 1:1 and 1:2 were used for making high strength foamed concrete.Consequently, this study is focused on the development of a design method for the manufacture of foamed concrete building blocks, with comparable compressive strength, using quarry dust as replacement for manufactured sand. The effect of quarry dust on FC mixes on its properties is explored. The major characteristics studied in this research are 28 and 56 days compressive strength, dry density, thermal conductivity and water absorption.

II. EXPERIMENTAL INVESTIGATIONS

Materials : Ordinary Portland cement of 53 grade with a specific gravity 2.93 has been used as the binder material. Protein (vegetable protein) type foaming agent of specific gravity 1.05 has been used for the production of stable foam. Foaming agent has been mixed with water in the proportion 1:35 to get stable foam of density 58.65 kg/m^3. Manufactured sand of specific gravity 2.37 and fineness modulus 1.74 referring to zone IV has been used as the fine aggregate. Quarry dust of specific gravity 2.59 and fineness modulus 1.68 referring to zone IV has been used to replace manufactured sand. The mix has been designed based on the provisions given in ASTMC 796/97 and IS 2185:2008.

Casting and testing of specimen : To make the concrete more economical, the study has been oriented towards designing a leaner mix of proportion 1:3. Quarry dust has been added at the rate of 0%,50%, 60%,70%,80%,90% and 100% by weight of manufactured sand and cube specimens have been prepared accordingly. At first, a base mix (mix of cement, manufactured sand and water), has been prepared. Stable foam has been prepared using a hand drill with paint mixer attachment and was then mixed thoroughly with the base mix. After getting a uniform mix, it has been poured into the cube moulds without any compaction. After 24 hours the cube specimens have been taken out from the mould and kept for watercuring. The specimens after proper curing have been tested for compressive strength, dry density, water absorption and thermal conductivity. Altogether 7 design mixes have been prepared and 63 cube specimens have been made for performing various tests.

III. RESULTS AND DISCUSSION

The test results are presented in Table 1. The variation of compressive strength with respect to the quarry dust content is presented in Figure 1.From the graph, it is clear that, the compressive strength is getting increased by the addition of quarry dust up at 70% by weight of manufactured sand. The presence of very fine particle in quarry dust may make the base mix more consistent and may cause the bubbles to be closer so as to make the concrete denser leading to increase in compressive strength. Very good cohesiveness may be achieved by the presence of finest quantity of quarry dust. The angular shape of quarry dust may create better packing between the particles, which may lead to an upsurge in compressive strength. Also, it can be revealed that, the finer particles present in quarry dust can maintain the stability of stable foam, which in turn leads to an enhancement in compressive strength of foamed concrete. It can also be understood that the presence of high silica content in quarry dust may form calcium silicate, which in turn cause an increase in compressive strength of FC. Water absorption is observed to be increased with respect to the addition of quarry dust, which depicts the water demand of quarry dust. But, it can be observed that the water absorption much lower than that of country burnt clay bricks. Further, it is to be noted that the addition of quarry dust decreases the thermal conductivity of FC, which makes it more thermally resistive. This may be accredited to the fact that greater boundary area can be achieved by quarry dust, which may act as a thermal blockade leading to a reduction in thermal conductivity.

Table 1 Properties of foamed concrete

Sl No	Mix ID	Compressive Strength (N/mm^2)		Dry Density (kg/m^3)	Water Absorption (%)	Thermal Conductivity (W/mK)
		28 days	56 days			
1	QD0	2.38	2.63	1451	3.45	0.353
2	QD50	3.20	3.54	1456	3.86	0.321
3	QD60	3.71	3.92	1511	4.80	0.305
4	QD70	4.41	4.37	1540	5.46	0.287
5	QD80	3.39	4.13	1518	6.27	0.265
6	QD90	3.06	3.78	1524	7.18	0.243
7	QD100	2.88	3.65	1458	8.79	0.216

Effect of quarry dust content on the compressive strength of foamed concrete : The variation of compressive strength with quarry dust content is shown in Fig.1. It can be seen that the compressive strength is increasing with the increase in quantities of quarry dust up to 70% by weight of manufactured sand beyond which, there is a decrease in compressive strength. The increase in compressive strength may be due to the very fine nature of quarry dust, which makes the formation of large quantities of minute foam bubbles. The close packing of these bubbles lead to a hike in compressive strength of foamed concrete. But, the addition of more quantities of quarry dust may decrease the cohesiveness and consistency of foamed concrete due the high water demand of quarry dust.

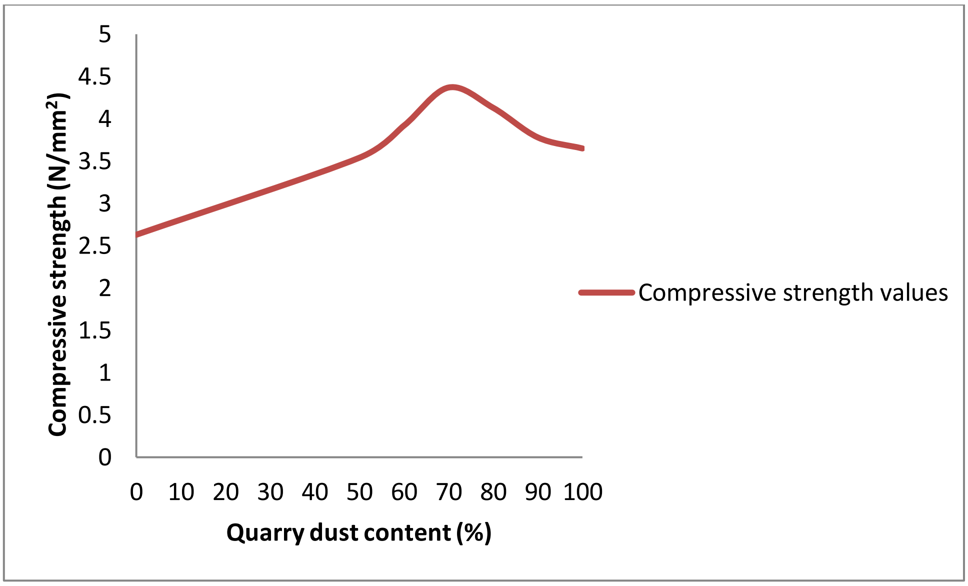

Fig.1 Variation of compressive strength of foamed concrete with quarry dust content

Effect of quarry dust content on water absorption of foamed concrete : The variation of water absorption with quarry dust content is shown in Fig.2It can be seen that water absorption is increasing steadily with quarry dust content. The increase in water absorption may be due to the higher water demand of quarry dust. But, the water absorption percentage is well below the allowable percentage of water absorption as per IS 2185: Part IV (2008).

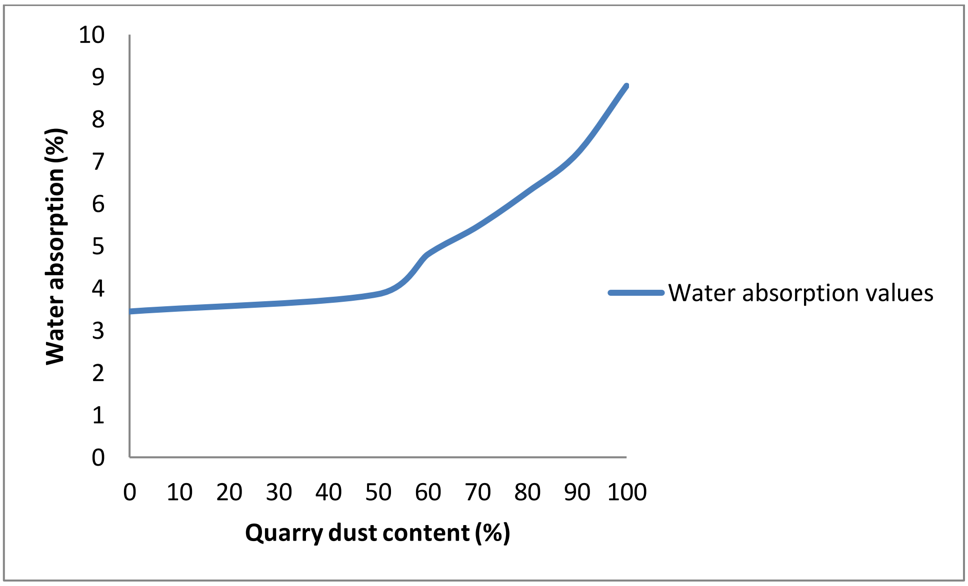

Fig.2 Variation of water absorption of foamed concrete with quarry dust content

Effect of quarry dust content on thermal conductivity of foamed concrete : The variation of thermal conductivity with quarry dust content is shown in Fig.3. It can be seen that there is a drop in thermal conductivity due the addition of quarry dust. This may be due to the formation very high surface area of both manufactured sand and quarry dust leading to the formation of a thermal blockade causing decrease in thermal conductivity. Hence, it can be concluded that, foamed concrete blocks made up of quarry dust can be very effectively utilized for thermal insulation purposes**.**

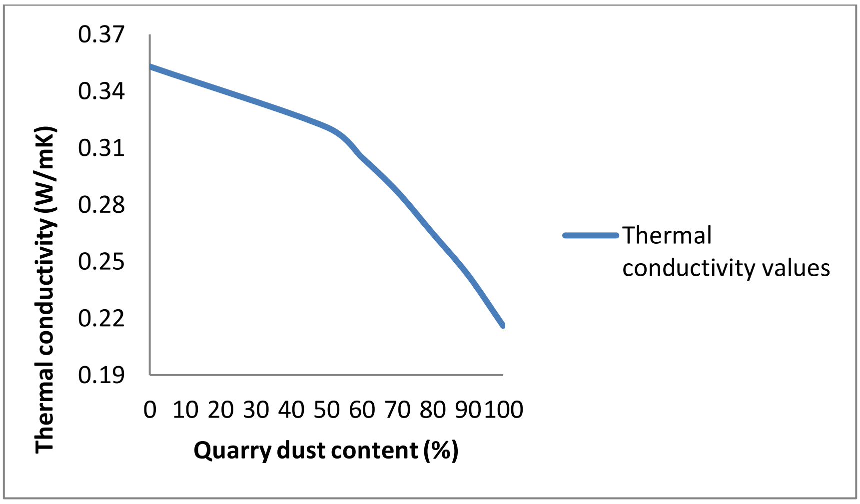

Fig.3 Variation of thermal conductivity with quarry dust content

IV. CONCLUSIONS

Investigation has been carried out on the influence of quarry dust on the properties of foamed concrete. The conclusions drawn from the study are summarized below.

- The optimum compressive strength is obtained for manufacture sand replaced with 70% quarry dust, the increment being 66.16% of conventional foamed concrete.
- The water absorption of foamed concrete is found to be steadily increasing, still the values are well below the allowable limit of water absorption of foamed concrete blocks.
- Thermal conductivity of foamed concrete is decreasing with the addition of quarry dust. The maximum reduction in thermal conductivity is 38.81%.
- The environmental issues related to the improper disposal of quarry dust can be reduced effectively to a greater extent by reusing the same in making foamed concrete.
- Foamed concrete using quarry dust is found to be highly efficient, economical and eco-friendly as well as thermally resistive.
- Since there is no coarse aggregate, it can be very efficiently used for the production of pre-cast elements.

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