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Properties of cold bonded quarry dust coarse aggregates and its use in concrete

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ABSTRACT

In this study, artificial coarse aggregates are prepared by a cold bonding technique. The waste materials, namely, fly ash and quarry dust, are used for the preparation of the cold bonded artificial aggregate. Portland cement is used as the binder material. The independent variables considered for the preparation of the artificial aggregate are cement and fly ash contents. The properties of the artificial aggregate are determined and regression models are proposed for predicting these properties. The strength and workability of concrete containing artificial aggregate is determined. The slump loss of concrete containing artificial aggregate is found to be gradual. The concretes with strengths of up to 30 MPa is prepared using artificial aggregates. The study promotes the use of waste material and supports sustainable construction practices.

1. Introduction

Crushed stone is a strong and inert material used as aggregate in many engineering constructions. A large quantity of dust is typically produced in the crushing process of stones. Two decades ago, the raw quarry powder was considered only as a waste material and was used for land filling without pre-treatment. The use of quarry powder in the production of concrete is reported by Thomas [1] and El-Mahllawy [2]. The quarry sand is the coarse fraction of the quarry powder and is being used as the fine aggregate in place of river sand in concrete production [3]. The fine quarry dust fraction is commercially unused material [4]. Therefore, utilization of waste material quarry dust in the production of artificial aggregates is examined in this study. Use of fly ash is beneficial to the environment as it mitigates issues involved in its disposal. In the present study, fly ash is also used in the manufacture of artificial aggregate.

Tremendous growth has occurred in the construction industry during the last decade. The demand for aggregates for the production of concrete is increasing correspondingly. On the other hand, waste materials such as fine quarry dust are generated in the same scale of industrialization and urbanization. The disposal of the waste dust becomes extremely costly due to the scarcity of disposal land in the proximity of industries and growing environmental concerns [5].

In India, no database is maintained for auditing the waste generated and utilized in the construction industry [6]. The production of the quarry dust in the processing of natural stone is extensive. Technology Information, Forecasting and Assessment Council (TIFAC) of India estimated that the annual production of virgin stone aggregate is 125 million tones and quarry waste is 17.8 million tones [7]. However, the utilization of the quarry waste is not authorized by the Public Works Department and hence, no record of utilizing the quarry waste is officially reported in India. It is stated in British Geological Survey report that the estimated production of saleable aggregates in UK is 204.3 million tones and quarry waste generated is 22.8 million tones [8]. The benefits of developing salable by-products from quarry residues are reduced environmental impact by stock piling and large quantity disposal, reduction in the cost of waste disposal and generation of additional income for the innovative producers [9]. In France, 400 MT of aggregates are supplied every year for the construction purpose and recycled aggregates are being used about 4% of the total consumption [10]. Based on the data collected by the council on waste statistics in European Parliament, the total waste generated from mining and quarrying is 671,830 million tones [11]. Out of this quantity, the exact quantity of usage of the recycled quarry waste in Europe is not available [12]. In this context, identification of alternate uses of the fine quarry dust is important. The

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enhancement in the demand of aggregates for concrete production can be countered by using alternate aggregates. In this study, cold-bonded pelletized aggregates are prepared using fine quarry dust, fly ash, and cement. The results of the study promote recycling of waste products namely, quarry dust and fly ash. The effective use of waste material helps to maintain a green and sustainable environment. Hence, the present study aims to develop a green technology for the future.

The various methods of manufacturing artificial aggregates are casting in spherical mold, cold bonding, and autoclaving and sintering. Yang et al. [13] produced artificial aggregate by casting in spherical molds. Bijen [14], Kockal and Ozturan [15–18] produced artificial aggregates by cold bonding process. In autoclaving, the green pellets are cured using steam at a temperature of 140 °C [19–21]. Sintering is the process of fusing and formation the green pellets at a temperature between 900 and 1400 °C [5,22–24]. The rate of production of aggregates is higher in cold bonding process when compared other process. The cold bonding process consumes reduced energy as it is carried out at ordinary temperature and causes less secondary pollution as no gaseous emission is involved.

The removal of quarry dust dumps reduces impact on environment and hydro-geological system at stored site. The utilization of quarry dust and fly ash helps to clear-off, expose and reutilization of land beneath the waste piles. The present study promotes the environmental recovery and rehabilitation of land morphology. The drawing potential revenues by exploiting the waste dumps will be a sustainable trade in future and hence the results of this study is important in future planning for green environment. The environmental cost of small quantity of cement used for bonding the quarry dust and fly ash will be defeated by the environmental advantages drawn by using the waste materials such as quarry dust and fly ash. It can be a viable solution when financial analysis of construction projects is made accounting for environmental appraisal based on the use of waste materials in concrete construction.

Artificial aggregates supporting sustainable development are the need of the day. The use of artificial aggregate for the production of concrete has been reported by Bijen [14]. Yang et al. [13] prepared concrete having a strength of 30 MPa using molded artificial aggregates. Tangtermsirikul and Wijeyewickrema [19] reported that the water absorption of cold bonded lignite fly ash artificial aggregate decreases with the cement content and its specific gravity increases with the cement content. Chi et al. [20] reported that the bulk density of cold bonded aggregate containing cement binder is in the range of 850–970 kg/m^3. Chi et al. [20] prepared concrete having a compressive strength of 25–45 MPa using artificial lightweight aggregate. Gesoglu et al. [22] observed that the compressive strength of concrete is found to decrease with an increase in the volume fraction of the artificial cold bonded fly ash aggregate. The test results of Ahmed and Mohamed [18] indicated that the curing period, cement content and water content influence the mechanical properties of the cold bonded artificial aggregate containing manganese fines. Test results of Ramamurthy and Harikrishnan [25] indicated that the specific gravity of the artificial aggregate increases with an increase in the binder content. Jo et al. [26] showed that fly ash based lightweight artificial aggregate is suitable for the production of concrete having a compressive strength of 29 MPa. Manikandan and Ramamurthy [27] reported that the efficiency of pelletizing is influenced by the fineness of the fly ash. Joseph and Ramamurthy [28,29] found that cold bonded fly ash aggregates are suitable for the production of concrete having a compressive strength of up to 30 MPa. Gonzalez-Corrochano et al. [30] reported that loose bulk and dry particle densities of artificial aggregate made using sludge of aggregate washing plant and fly ash are 1200 kg/m^3 and 2000 kg/m^3, respectively. Chang et al. [31] prepared artificial aggregate by molding, using cement, sludge from a stone slab cutting plant and silt from an aggregate washing plant. Shanmugasundaram et al. [32] prepared concrete with a strength of 20 MPa using cold bonded fly ash aggregate. The compressive strength of concrete prepared by Priyadharshini et al. [21] using cold bonded fly ash aggregate was 28 MPa. Sivakumar and Gomathy [33] reviewed various materials and the method of preparation of cold bonded aggregate using cement as a binder. Joseph and Ramamurthy [34] reported that artificial lightweight cold bonded fly ash aggregate is useful in preparing concretes of strength up to 52 MPa. The test results of Gesoglu et al. [35] indicated that the specific gravity of fly ash–ground granulated blast furnace slag artificial aggregate increases with an increase in the cement content. The aggregate made by cold bonding of sustainable materials like fine dust, fly ash, sludge, etc. is being promoted for the sustainable growth of construction industry. The literature on utilization of quarry dust in the production of artificial aggregate is limited. Also, the determination of properties of artificial aggregate is important to evaluate its usability in the manufacture of concrete. In this study, characterization of cold bonded and the artificial aggregate and its usefulness in concrete production are examined.

2. Research significance

Use of artificial coarse aggregate in the production of concrete is a sustainable construction practice. Cold-bond pelletization is one of the popular methods of preparing artificial aggregate. Studies on the properties of artificial aggregate made using quarry dust are limited. The present study fills this void. In this study, the artificial aggregates are prepared using quarry dust and fly ash, with cement used as the binding material. The workability and strength of concrete made using artificial aggregates are also evaluated.

3. Experimental program

3.1. Constituent Materials

Cement, fly ash and quarry dust are used for the manufacture of the artificial aggregate. Artificial aggregate are used to manufacture concrete.

3.1.1. Cement

The fine grained ordinary Portland cement of grade 53 confirming to IS 12,269 [36] is used as the binder for fly ash and quarry dust. The chemical composition of the cement is given in Table 1. The calcium content in the cement is 64% by weight. The physical properties of the cement are given in Table 2. The cement is very fine and fineness is 3360 cm^2/g.

3.1.2. Fly ash

Pulverized fly ash collected from a coal-fired power generation plant is used. Its composition is given in Table 1. The calcium

Table 1
Chemical composition of cement, fly ash and quarry dust.

Sl. No.	Chemical constituents	Weight by percent in materials		
		Cement	Fly ash	Quarry dust
1	SiO_2	21.4	57.1	62.5
2	Al_2O_3	5.1	24.7	18.7
3	Fe_2O_3	2.9	10.5	6.5
4	CaO	64.0	2.5	4.8
5	MgO	1.6	1.4	2.5
6	SO_3	2.0	0.9	1.0