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Durability properties of multiple blended concrete

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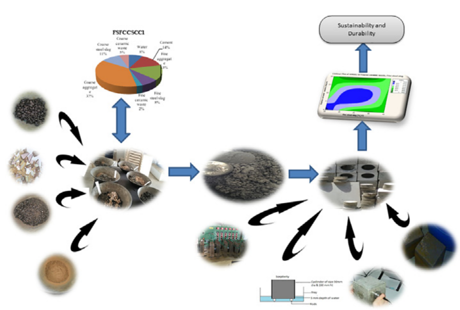
HIGHLIGHTS

- Steel slag and ceramic waste is used as a combination material for replacement of aggregates in concrete.
- Combination replacement provides better durability properties.
- Optimized new percentage of replacement is found for multiple blended concrete.

GRAPHICAL ABSTRACT



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ABSTRACT

In construction industry, concrete is the largest synthesized material. Aggregate is one of the constituents in concrete. Enormous studies have been conducted concerning the protection of natural resources, finding solution for the disposal problem, and for reducing the cost of construction by using the waste material. In this research, steel slag and ceramic waste is used as a replacement material for natural aggregates and its durability properties are studied. Durability depends upon the cement content, compaction, curing, cover and permeability. The chemical attack will result in volume change. Various tests like acid resistance to hydrochloric acid and sulphuric acid, water absorption, corrosion of reinforcement (Rapid chloride penetration), water sorptivity were performed for the combination of the mix. Using Taguchi analysis, optimization is made to find out the outstanding combo mix of steel slag embedded ceramic concrete. 30% coarse steel slag and 40% fine steel slag replaced concrete shows greater loss in weight when immersed in strong acid. The combination of 21% coarse steel slag either with 8% coarse ceramic waste or with 28% fine steel slag replacement has better durability characteristics.

1. Introduction

Durability is the property of concrete, which has the ability to withstand weathering action, chemical attack, abrasion or any other process of deterioration. Concrete should have trouble free performance. Entrained air to resist freeze and thaw, minimum impurities like chlorides and sulphates, well-graded aggregate will make the concrete to remain durable. The aggregate, which makes up 70% of the concrete volume, is one of the main constituent materials in concrete production. The non hazardous waste material can be partially added to produce a sustainable construction material. By means of recycling process waste materials can be transformed to secondary raw material [1]. Steel slag which is a byproduct of steel manufacturing plant can be used to improve the engineering properties of clay soil. When the addition of steel slag to the clayey soil increases, the plasticity, swelling potential and cohesion decreases whereas the angle of internal friction and dry density increases [2]. Steel slag can be used as aggregate and as supplementary cementitious materials in concrete. Due to the low hydraulic property and latent volume instability of steel slag, it can be used only in low quantity as replacement binding material in concrete [3]. The lowest water penetration depth and highest freeze-thaw resistance

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are observed in coarse steel slag aggregate, where as higher values of water penetration depth and lowest freeze-thaw resistance are obtained for fine steel slag concrete [4]. The steel slag aggregates have expansive characteristics and would cause cracking in concrete [5]. The amount of elements released to the environment is less metal rich for ferrous slag than the non ferrous slag generated during base metal extraction. Ferrous and non ferrous slag can be reprocessed for metal recovery but only ferrous slag like Blast furnace slag can be used for construction and environmental application. These slags are also responsible for some environmental contamination by its leachate [6]. With huge creative and technological potential, steel slag can be used as an anthropogenic raw material into high quality products, which will reduce the disposal problem and create new job opportunities [7]. In case of localized failure, the Cement-based materials which are rigid, brittle, and structurally sensitive, is regarded as failure. While adding the slag aggregates, modification can be made in the properties of concrete [8]. Glasses and ceramics have significant role in the immobilization of nuclear wastes. Ceramics are the competitors to the baseline borosilicate glass for the immobilization of high- and intermediate-level nuclear waste. Ceramics are in different forms and can be effectively used by advantageous processing technique [9]. When ceramic electrical insulator waste is added as a coarse aggregate the permeation characteristic is higher than those of conventional concrete. By decreasing the water to cement ratio, the permeation also decreases for both conventional and recycled aggregate concrete [10]. The ceramic waste powder that is settled by sedimentation and then dumped away, results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health [11]. There is scarcity of research and lack of standards in regulating the reuse the ceramic waste as construction material. Reusing ceramic waste offers technical, economical and environmental advantages which are of great importance [12]. When construction and demolition wastes are used as fine aggregate, the strength and the durability of concrete decreases due to the increase in porosity. But the strength increases by adding steel slag as coarse aggregate, whereas further increase in strength is observed when half the portion of cement is replaced by fly-ash, which in turn produces an environmentally friendly concrete [13]. To enhance the durability properties of coal fly ash blast furnace slag geo polymer concrete bio-additives such as terminalia chebula and natural sugars are added. It has proven that the loss in weight and compressive strength is lower for the concrete with additives than other [14]. Alkali activated blast furnace slag geopolymer is used as a fire resistant coat, in which the coat offers lower density, higher strength, higher fire resistance and reduced cost. Geopolymerization can be used to convert industrial by-products into attractive construction materials [15]. The paste content is the influential factor for compressive strength. When the size of coarse aggregate increases, porosity increases and hence decrease in strength will be observed [16]. Ceramic waste as a recycled aggregate, in the blast furnace slag concrete has good workability, mechanical properties and chemical resistance than the conventional concrete, which is environmentally suitable and economical [17]. The electric arc furnace slag is a non-hazardous material and it can be utilized as one of the raw materials safely for ceramic tile production. The chemical composition of EAF (Electric arc furnace slag) steel slag is similar to the composition of raw material needed to manufacture ceramic tile. The concentration of heavy metal leaching is within the limits prescribed by department of environment, Malaysia [18]. The influence of steel slag when added to clay for the making of construction ceramics shows that it has the potential to be recycled. Steel slag can be used as a raw material using uniaxial pressure to the forming process for the production of new materials that can be applied in construction industry [19]. When steel slag is added to ceramic manufacturing, CO_2 (Carbon dioxide) emission will be reduced and less energy will be consumed. The addition of 10 to 30% steel slag also improves the drying process by reducing the water requirement. The clay ceramics incorporating steel slag is environmental friendly [20]. Using multi response optimization methods, the desired level of heat insulation and the acceptable level of compressive strength can be achieved. To find the optimal mixture proportions of concrete, with polymers, Taguchi method can be used [21]. Analysis of Variance method is used to determine the significant level of experimental parameters and to indicate how factors affect the strength and ultrasonic pulse velocity. Using Taguchi, maximum strength and ultrasonic pulse velocity can be obtained [22]. In this research, the combination of waste materials, steel slag and ceramic waste is used as a replacement material for fine and coarse aggregate in concrete. Using optimization the exact percentage combination of waste materials that can be used in concrete is found, which paves the way for disposal problem and depletion of natural resources can be reduced. In addition, the trash material can be transformed to generate revenue.

2. Materials

Cement is the binding material, which is used to bind fine and coarse aggregates together. Ordinary Portland Cement (OPC) of 53 grade, conforming to (Indian Standard) IS 8112-1989 and similar to (American Section of Testing Materials) ASTM type III (C150 – 95) was used, under the trade name as Chettinad Cement, Karur, Tamilnadu, India. Specific gravity of the cement is 3.15, fineness 300 m^2/kg, Initial setting time 45 min and consistency 29%. It is tested as per Indian standard specification (IS 4031-1996) and then used to fill the gap with the presence of water. The fine aggregate used in concrete is chemically inert clean, well graded and containing sharp and angular grains. Blast furnace steel slag is used as replacement material. Broken tiles are used in combination replacement. Natural river sand with fraction passing through the 4.75 mm sieve and retained on 600 μm sieve was used and tested as per IS: 2386. Coarse aggregate contributes more than 80% volume of concrete and their impact on various properties of the concrete is predominant. Good quality crushed granite aggregates of maximum 20 mm size were used. The specific gravity of steel slag is greater than the river sand. Water absorption of steel slag in fine form is almost similar to conventional fine aggregate whereas it's much greater for coarse aggregate. The properties of steel slag and ceramic waste in fine and coarse aggregate form is compared to conventional aggregates along with Indian standards and is shown in Tables 1 and 2. Sieve analysis of Steel slag and ceramic waste compared to conventional concrete is shown in Figs. 1 and 2. The porosity of coarse steel slag is higher than the conventional aggregates. Mix proportioning of concrete was done as per IS: 10262-1982. The reference mix or the control mix (CM) was completely prepared with natural aggregates like crushed granite jelly and river sand, while the other mixtures were prepared from the slag obtained from steel plant and broken ceramic tiles. For the entire test, the designed mix was taken as 1: 1.81: 3.84 with the w/c ratio 0.55 with which the partial replacement is made. Complete knowledge of the properties of ingredients is required for concrete mix proportioning. The mix proportioning of (Mix) M20 grade concrete with steel slag and ceramic waste in coarse and fine form as a replacement material in combination is made. The collected waste materials are converted to powder form, fine aggregate and coarse aggregate form and partially replaced on volume basis.

2.1. Mix designation

Factors such as coarse steel slag with levels 20%, 30%, 40%, Fine steel slag with 20%, 30%, 40%, coarse ceramic waste with