

Review on Partial Replacement of Cement in Concrete by Using Waste Materials

G. Anand ^a, N. Tharunkumar ^{b, *}

¹ Assistant Professor, Department of Civil Engineering, K.S.Rangasamy College of Technology, Tiruchengode, Namakkal, Tamil Nadu, India.

² PG Student, Department of Civil Engineering, K.S.Rangasamy College of Technology, Tiruchengode, Namakkal, Tamil Nadu, India.

*Corresponding Author E-mail: ntharunkumar97@gmail.com

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ABSTRACT

Concrete ingredients is different material like binding material (cement+ fly ash), fine aggregate, coarse aggregate and water. Today construction cost is very high with using conventional materials due to unavailability of natural materials. This problem can be solved by total replacement of concrete with different material which is not convenient in terms of required properties. Due to this limitation of unavailability of material which plays the vital role of concrete we have only choice of partial replacement of concrete ingredients by waste materials. Over 4.2 billion tons of cement was consumed globally in 2018 based on survey of world coal association and also cement production emits CO₂ in to the atmosphere which is harmful to the nature. If we can partially replace the cement with the material with desirable properties then we can save natural material and reduce emission of CO₂ in to the atmosphere. This industrial waste dumping to the nearest site which spoils the land and atmosphere as well as it also affects aesthetics of urban environment so use of this waste material in concrete is cost effective as well as environment friendly way to disposal of waste. The primary objective of this study is to select the waste material which gives desirable properties with concrete. This study includes previous investigation done on the mechanical and chemical properties of concrete produced using partial replacement of cement by waste materials.

Keywords: Cement, Partial replacement, CO₂, Environment.

INTRODUCTION

Cement plays the role of a binder, a substance that sets and hardens and might bind alternative materials along. The word "cement" comes from Romans, UN agency used the term "opus caementicium" to describe masonry resembling fashionable concrete that was made up of rock with calcined lime as binder. The volcanic ash and small-grained brick additives (surkhi) that were additional to the calcined lime to get a hydraulic binder were later brought up as cementum, cement, and cement. Cement is widely used by human beings and it is second largest material after water used by human beings. Based on recent survey total amount of cement is used during the financial year of 2012 247 MT and it increases up to 550 MT for financial year 2020. India is second largest country after china based on uses of cement. During production of cement and hydration process of cement carbon dioxide is produced based on experimental investigation it has

been proved that 1 tons of clinker produces around 1 tons of CO₂. This CO₂ production causes serious environmental damages and this can be prevented by two ways described as way-1 use another binding material instead of cement which is not possible right now for unavailability of such a binding material and another way is way-2 partial replacement of cement by appropriate material. Way -2 is quite simple because of lots of references are available as well as enough appropriate material is also available. As per IS 10262:2009 code for practice for mix design of concrete we can save cement by replacing it with fly ash. As per this code if we are designing concrete grade of M 40 with fly ash we can save cement around 80 kg/m³ without loss in performance of concrete so way-2 is more suitable for saving environment from harmful gases. If we find suitable material as a partial replacement of cement then we can save cement and environment also. For doing this research literature survey is required and this paper is based on literature survey.

MATERIALS USED

FINE AGGREGATE

The locally available river sand was used as fine aggregate in the present investigation. The sand is tested for various properties like specific gravity, fineness modulus and water absorption in accordance with IS 383:1970.

COARSE AGGREGATE

Coarse aggregate is the crushed stone, which is used for making concrete. The particles are greater than 4.75mm, but generally range between 9.5 mm to 37.5 mm in diameter. The aggregate is tested for various properties like specific gravity, fineness modulus and water absorption in accordance with IS 383:1970.

REVIEW OF LITERATURE

Wen-Ten Kuo et al. [1] has investigated an effect of ground granulated blast furnace slag (GGBFS). He has tested the mechanical and electricity properties to assess the correlations among flow, compressive strength, water absorption, and electricity at 50 V and 100 V. At the curing age of 28 days, the compressive strength of the control group was in the range of 29.1–1.7 MPa, whereas the compressive strength of PZT was in the range of 26.8–30.0 MPa. The control group exhibited higher result in the electricity property test under 50 V, whereas PZT exhibited lower results. The compressive strength and results of the electricity property tests demonstrated that the compressive strength and electrical resistance decreased as the replacement of GGBFS increased. The strength of the control group was higher than the strength of PZT because 5% of the fine aggregate was replaced by the piezoelectric material and the piezoelectric material was water-resistant. Thus, the piezoelectric material could not be effectively combined with fine aggregate and cement.

F. Baeza et al.[2] has done a research on Blending of industrial waste from different sources as partial substitution of Portland cement in pastes and mortars. He has done Binary and ternary combinations of sewage sludge ash (SSA) with marble dust (MD), fly ash (FA) and rice husk ash (RHA) as replacement in Portland cement pastes, were assessed. He has carried out several tests were carried out at different curing ages: thermogravimetry, density, water absorption, ultrasonic pulse velocity and mechanical strengths. Pozzolanic effects of the mineral admixtures, densities similar to control sample and improved absorptions when combining waste materials were identified. In general, the compressive strength reaches or exceeds the cement strength class, and blending SSA, FA and RHA (30% cement replacement) increase of strength by 9%, compared to the control sample, was achieved.

W.W.J. Chan et al.[3] has conducted a study on the durability of concrete made from various non-reactive waste materials, i.e. carbon black, silts and clays, and with various water

contents were investigated. He has studied different types of test like compressive strength; workability, sorptivity, and water permeability of the concrete. He has also done a detail investigation based on the resulting change in the microstructure and cement hydration in these concrete by X-ray diffraction (XRD), scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) spectroscopy. Workability can be increased by increasing the specific surface area or using super plasticizer. So in present study he has used silt and clay for research in varying proportion and he has found that 25 vol. % of cement replaced with silts and clay using a water/cement (w/c) ratio of 0.5 gives durable concrete. That is, the cement and water contents were less than those in OPC. Also, the cost of concrete will be lowered.

O. Rodriguez et al.[4] has Analysed the chemical, physical, morphological, mineralogical and pozzolanic characteristics of several reservoir sludges and assesses their potential for use as 20% additions in blended cement manufacture. The studied sludges exhibit good pozzolanic properties, especially sample 5 which has high SiO₂, Al₂O₃ and Fe₂O₃ contents. Blended cements prepared with 20% sludge additions complied with the European standard on compressive strength of one of the standardized cements, above 32.5 MPa at 28 days of curing; except for sample 5, which showed similar compressive strength values to the reference cement and up to 2% higher values at long curing times.

Attarietal.(2012) examined the flexural strengthening of concrete beams using CFRP, GFRP and hybrid FRP sheets. This study is conducted to examine the efficiency of external strengthening systems for reinforced concrete beams using FRP fabric (Glass Carbon). A total of seven flexural strengthened reinforced concrete beams are instrumented and tested under repeated loading sequences using a 4-point bending device to complete a failure analysis. This paper highlights the efficiency of external strengthening for RC beams using FRP fabric. The results reveal the cost-effectiveness of twin layer glass-carbon FRP fabric.

A. Khmiri et al. [5] investigated pozzolanic activity of finely ground waste glass, when used as partial cement replacement in mortars. The behaviour of this by-product was examined through two sets of tests: a lime-glass test to assess and explain the pozzolanic phenomena and a compressive strength test carried out to monitor the strength development. Analyses by DSC, XRD and SEM of samples containing 25% Ca (OH)₂ and 75% of ground glass demonstrated that this admixture induced the formation of calcium silicate and calcium aluminosilicate hydrates at the expense of lime as well as hydrated sodium carbonate. The formation of the latter phase allowed us to explain the size stability of prepared mortars by hydrated sodium silicate formation. Compressive strength of mortars containing ground glass with particles size in the range 100–80 μm; 80–40 μm; <40 μm and < 20 μm finenesses indicated that the 20 μm class exhibited a good pozzolanic behaviour. The corresponding strength activity indexes were 82%, 95% and 102% at 7, 28 and 90 days respectively.

Ana Mafalda Matos et al.[6] has derived effect of waste glass on properties of concrete. In this research he has used Crushed waste glass was ground (WGP) and used in mortar as a partial cement replacement (0%, 10% and 20%) material to ascertain applicability in concrete. An extensive experimental program was carried out including pozzolanic activity, setting time, soundness, specific gravity, chemical analyses, laser particle size distribution, X-ray diffraction and scanning electron microscopy (SEM) on WGP and resistance to alkali silica reaction (ASR), chloride ion penetration resistance, absorption by capillarity, accelerated carbonation and external sulphate resistance on mortar containing WGP. Glass particles well encapsulated into dense and mature gel observed by SEM may help explaining enhanced durability results and thus confirming that waste glass powder can further contribute to sustainability in construction. He has concluded that higher resistance to chloride penetration was obtained for WGP containing mortar, increasing with dosage replacement; Sorptivity of glass mixes was equivalent to control due to the effect of similar particle size distribution; Carbonation depth for all blended cement mixtures was greater

than for the Portland cement mixture, increasing with replacement dosage in the trend for pozzolanic materials.

M.R. Karim et al.[7] has fabricated a new non-cement binder (NCB) using slag, palm oil fuel ash (POFA) and rice husk ash (RHA). To activate these materials, sodium hydroxide (NaOH) was used at 2.5%, 5.0% and 7.5% by weight of NCB. Four different mix ratios of the slag, POFA and RHA were designed to fabricate the NCB. Mortar-prisms of NCB were casted using water-to-binder ratio of 0.5 and 0.6 with required super plasticizer. Mortar specimens were immersed in a water bath for curing. NCB was tested for its consistency, setting time, flow, flexural and compressive strengths. XRD, SEM and FTIR analyses of NCB mortars were also obtained. The results revealed that the consistency, setting time, flow and strength of NCB-paste/mortars are greatly influenced by the mix proportion and fineness of constituent materials of NCB, and NaOH doses. Amongst all mixes NCB-mortar containing 42% slag, 28% POFA and 30% RHA with 5% NaOH achieves the highest compressive strength of 40.68 MPa and a flexural strength of 6.57 MPa at 28 days. He has also concluded From the FTIR analysis, NCB-mortars are observed to have silica-hydrate bond with sodium or other inorganic metals (i.e., sodium-silica-hydrate-alumina gel). Therefore, NCB could be fabricated from the aforementioned materials.

E. Tkaczewska et al.[8] has studied the effect of the super plasticizer type on the properties of fly ash blended cement – in terms of hydration heat, setting time and compressive strength. The used admixtures were sulfonated melamine-formaldehyde condensate (SMF), sulfonated naphthalene-formaldehyde condensate (SNF), polycarboxylate (PC) and polycarboxylate ether (PCE). Control sample was Portland fly ash cement CEM II/A-V 42.5R. Super plasticized Portland fly ash cement mortars were prepared taking the values of standard water of consistency with different addition of each type of super plasticizers used. Results revealed that the decrease in water content required was 15% for SMF, 31% for SNF, 42% for PC and 47% for PCE. Polycarboxylates were found to have higher efficiency in improving the hydration heat evolution, setting time and mechanical properties of cement than that of traditional super plasticizers SMF and SNF. Addition to control fly ash blended cement polycarboxylate ether-based super plasticizer gives cement CEM II/A-V 52.5N. So based on this research we can say that this waste material affects differently while using with different super plasticizers in varying proportion.

Mohamed Elchalakani et al.[9] Masdar City (MC) is leading the Middle East in the development of energy and resource efficient low-carbon construction in the United Arab Emirates (UAE). One of its major goals is to develop and specify materials and processes that will help to reducing its environmental footprint through resource and energy conservation, as well as renewable energy generation. In 2010 MC announced on its website a prize-competition for the best proposal of “Sustainable Concrete” and “Lowest Carbon Footprint” to build MC with a total of two million cubic meter of concrete on 4 years period. This paper presents the experimental test results of 13 types of concrete mixes made with high volume of ground granulated blast furnace slag (GGBFS) cement with 50%, 60%, 70% and 80% replacement of ordinary Portland cement (OPC) to reduce the carbon emissions. A fly ash-blended mix made with 30% fly ash was also tested. The paper provides more information on the mix design parameter, full justification of CO₂ footprint, and cost reduction for each concrete type. The hardened and plastic properties and durability test parameters for each mix are presented. The results show that the slag concrete mixes significantly reduce the carbon footprint and meet the requirements of MC. An economical mix with 80% GGBFS and 20% OPC was nominated for use in the future construction of MC with 154 kg/m³ carbon footprint.

Telma Ramos et al.[10] has surveyed that Granitic quarry sludge is an abundant waste from granite rock processing, causing serious environmental concern. The effect of granitic sludge from a quarry in northern Portugal was analyzed as a partial cement replacement in mortar in

terms of strength and durability, so as to envisage its use in concrete. The experimental program included chemical analyses, laser particle size distribution and scanning electron microscopy of granitic quarry sludge, as well as mechanical strength, expansion due to alkali silica reaction and chloride penetration resistance on mortars containing different dosages of cement replacement with granitic quarry sludge waste ground to different fineness levels. Results showed that granitic quarry sludge waste, if ground to sufficient fineness, produces a denser matrix promoting up to 38% reduction in expansion due to ASR and almost 70% improvement in resistance to chlorides, without compromising workability and strength. This surprising improvement in terms of chloride resistance seems to derive from captivation of chlorides by aluminates present in the waste with formation of chloroaluminates.

M.M. Shoaib et al. [11] has estimated large quantities of cement kiln dust (CKD) are produced during the manufacture of cement clinker by the dry process. The technical and economic problems that arise for the semi-manufacture of raw materials used, energy and transportation of dust from the plant to outside, as well as the severe pollution to the surrounding atmosphere show the necessity of utilizing cement dust as one of the main objectives of his investigation. The cement dust contains a mixture of raw feed as well as claimed materials with some volatile salts. The aim of the work was to study the effect of cement dust substitution instead of ordinary Portland cement (OPC), blast furnace slag cement (BFSC), and sulphate resistance cement (SRC) on the mechanical properties of some concrete mixes containing them, and also, to determine the optimum quantity of CKD which could be recycled in the manufacture of these types of cements. Useful conclusions and recommendations concerning the use of different amounts of CKD in the production of some blended cements as a partial substitution from different types of cements were obtained. Also, it was found that the high limit for substitution is not more than 30% for SRC, and 20% for BFSC, and 10% for OPC which gives high ultimate compressive strength for SRC and BFSC, and a critical value for OPC, respectively. Generally, it could be said that direct replacement (mixing) of CKD with SRC or BFSC is more effective than the recycling of dust with cement raw materials, which form sun favored clinker phase during the firing in cement kilns, which was attributed to the effect of high alkalinity of dust on the nature of clinker phases.

CONCLUSION

Today we live in the world full of development and enthusiastic for still more comfort and facilities. This leads to innovations and revolutions in each and every field, but on contrary it has negative impact on environment as resources get depleted and pollution to different natural sources are occurred. So after studying all these research paper we concluded that if we can reduce or reuse some material in field of concrete production which is at its top now- a-days then it largely impact environment and leads to pollution free and soothing surrounding. Thus as concluded from above literature review we can research further more in direction of partially replacing cement, sand and aggregate up to most optimum level we can by reusing or introducing waste material as its option. From studying all these research paper it is clear that positive and favorable results are obtained if further research work and study is carried out in this field. And by using locally available wastes like glass waste, marble dust powder, ceramic waste, quarry dust, GGBS, Fly ash, RHA, CKD, BSFC, Silica fume, silt, clay, sewage sludge ash and different sludge etc. as partial substitution at place of concrete ingredients, it may prove more economical than traditional concrete and question of damping of such waste produced by different industries is also get solved. This waste also create air pollution and land pollution by dumping and also causes water pollution so by using this material in concrete we can save our atmosphere and land. Ultimate goal is to produce economical and eco-friendly concrete with all desired properties and strength which one obtains by regular concrete ingredients.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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