EFFECTS OF CERAMIC TILE WASTE AS PARTIAL REPLACEMENT OF COARSE AGGREGATE ON GEOPOLYMER PAVER BLOCK- A REVIEW

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Abstract - *Paver block are used in various areas street road and other construction places. Due to rapid infrastructure development the use of cement increasing day by day. Cement emits large amount of carbon dioxide (CO_2) and this leads to global warming. Today researches on waste management lead to an eco-friendly product called geopolymer mortar and concreteTo support the development of pavement construction in the civil engineering industry, a new approach to predicting the performance of the geopolymer paver block (GPB) has been proposed. A huge quantity of ceramic waste is generated during processing, transportation and handling. This ceramic waste can be used as an alternative material to natural coarse aggregate. Fly ash and Ground Granulated Blast-furnace Slag (GGBS) are activated using alkaline solution such as sodium silicate and sodium hydroxide to get cementitious binder. There are various paper and research works based on natural coarse aggregate replaced by various percentages of other industrial waste material and cement replaced by various percentage of other waste material and found that increased in strength, durability, and reduction in cost and utilization of waste material. Various waste material can be used for improving strength of paver block. The primary objective of this review is to understand the properties as well as economical and environmental benefits of GPB using ceramic tile waste corresponding to M40 grade based on earlier researches. The review work also focus on selection of various percentages of ceramic tile waste for replacing natural coarse aggregate and an overview of common tests conducted in GPB.*

***Key Words*:** Geopolymer Paver Block, Fly Ash, GGBS, Cementitious binder ,Alkaline solution, Ceramic tile waste,

1. INTRODUCTION

Concrete is the world's most adaptable, durable and reliable construction material. Large amount energy was also used for the cement production. Therefore, seeking an alternative material to the existing most expensive, most resource-consuming Portland Cement is inevitable. Geopolymer concrete is an innovative material that is made by reacting aluminate and silicate bearing materials with alkali activator. Commonly, waste materials such as fly ash or slag from iron and metal production are used, this will helps lead to clean the environment. Interlocking Concrete Block Pavement (ICBP) technology has been introduced in India in construction for specific requirement like footpaths, parking areas etc.

Nowadays, sources of natural aggregates are in the process of depletion and their extraction also has harmful consequences for the environment. For these reasons, it is prime to optimize the consumption of natural aggregates as well as to enhance their replacement by other alternative sources. One of the method is the use of ceramic tile waste in concrete. The composition and performance between ceramic tile and natural coarse aggregate is very close. The usage of waste materials in concrete production is very much helpful to reach the goal of the sustainable construction. Aggregates consist of 70% to 75% of volume of concrete. So reduce the consumption of natural aggregates, waste ceramic tile or crushed tiles as coarse aggregates can be used as in the field of sustainable concrete. M35 to M45 grade concrete are used for Medium Traffic as per IS 15658:2006. There are several studies conducted on the utilization of waste materials or using these products as binding material. Geopolymer concrete is very helpful in providing a new approach towards sustainability. This makes the geopolymer concrete a substitute for traditional concrete with the increase in understanding the behaviour of geopolymer concrete from several research studies.

2. LITERATURE REVIEW

2.1 STUDIES ON ALKALI ACTIVATED SLAG CONCRETE

Yang, et.al, (2013) are carried out their research to establish an evaluation method for reducing AA concrete's CO2. In addition, with reference to practical examples where ground granulated blast-furnace slag (GGBS) cement is substituted by AA GGBS binder, CO_2 reduction for secondary precast concrete items is also studied. For various types of concrete, the performance efficiency metrics for the binder were also calculated The study concluded that, with its compressive strength, the CO_2 emission of concrete increases, showing that the contribution of the binder to the overall CO2 footprint is more visible in OPC-based concrete than in AA concrete. When the compressive strength is above 40 MPa, the CO_2 emissions of OPC + SCM concrete are around 80 percent of those of OPC concrete. On the other hand, the CO_2 emission reduction rate of AA concrete relative to OPC concrete commonly ranges between 55 and 75%, although the CO_2 reduction of AA concrete is somewhat hooked in to the sort , concentration, and dosage of the added alkali activators. The CO_2 reduction rate in secondary precast concrete products using AA GGBS binder, substitute of GGBS cement can be evaluated to be approximately 20% when the total aggregate-to-binder ratio ranges between 3.0 and 4.0. [12]

Ngernkham, et.al, (2015) examins the effects of sodium hydroxide and sodium silicate solutions on the properties of fly ash (FA) - granulated blast furnace slag (GBFS) geopolymer. His study related to Constant liquid alkaline to binder ratio of 0.60 was used for all mixes. There are Three types of geopolymer pastes: FA paste, FA + GGBS paste and GGBS paste and three types of alkaline solutions: sodium hydroxide solution (NH), sodium silicate solution (NS), and sodium hydroxide plus sodium silicate solution (NHNS) were used. From the study he concluded that, the FA paste contains amorphous NASH gel and a few crystalline phases of the remain of ash. The GBFS content increased the compressive strength of geopolymer pastes also increased due to the formation of additional CSH. The utilization of NH and NHNS solutions resulted in crystalline CSH and amorphous gel, whereas the utilization of NS solution resulted in mainly the amorphous products. For the FA and FA + GBFS pastes better strength development was obtained with the utilization of NHNS solution. For the GBFS paste, the presence of silicate enhanced the strength development and thus pastes containing NS solution performed better. Relatively high 28-day compressive strengths of 171.7 and 173.0 MPa were obtained for GBFS pastes with NHNS and NS solutions, respectively. [10]

Thunuguntla, et.al(2018) investigates the mechanical and durability efficiency of Alkali Activated Slag Concrete (AASC) prepared as the sole binder material using ground granulated blast furnace slag. The effects of the concentration of sodium hydroxide (1 M and 8 M), the binding content (300 kg / m3 and 450 kg / m3) and the alkaline solution / binding ratio (0.4 and 0.55) on the mechanical and toughness properties of alkaline activated slag concrete (AASC) are being reported. The durability performance of AASC, which involves sorptivity, acid attack (up to 56 days) due to sulphates, chlorides and nitrates, has been tested in various tests. He concluded from the analysis that NaOH concentration was found to be the most influential parameter of AASC's mechanical and durability characteristics. The capillary sorptivity of AASC is low, which indicates it offers high resistance to water absorption, also offers high resistance to nitrates and chlorides compared to sulphates. The deterioration of AASC specimens immersed in sulphuric acid started at corners and progresses inwards, few pop outs were also observed on the surface of specimens. AASC mixes with higher NaOH concentration exhibited better resistance to acid attack as compared to mixes with lower NaOH concentration, which may be attributed to high alkalinity and strong porous structure of concrete. [11]

2.2 STUDY ON GEOPOLYMER PAVER BLOCK

Jonbi, et.al (2020) carried out a study which aims to produce some compositions of geopolymer paving block (GPB) using different ratios of $NaOH/Na_2SiO_3$ combined with fly ash. The empirical models were developed to predict the performance of the GPB samples through the verification of the water absorption and compressive strength. The results showed that an optimum performance of GPB sample is predicted for the $NaOH/Na_2SiO_3$ ratio range of 0.4 to 0.67 and it was verified at 28 days of the GPB age. The hardness of GPB sample increases rapidly by using a high enough concentration of NaOH in activator leading to significantly increase the compressive strength of paver block. His study concluded that, the water absorption of GPB sample used $NaOH/Na_2$-SiO_3 ratio of 0.4 has the lowest value of 2.93% at 28 days of the GPB age. The maximum compressive strength of 32.45 MPa for the suggested GPB sample of highest workability can be verified at 28 days of the GPB age by using the Na_2SiO_3 portion of 2.5. The new empirical models of predicting the GPB performance have been suggested to contribute to the development of pavement construction to hardening the parking lot for many cities of Indonesia in the future. [7]

Devaki. R, et.al (2017) carried out an experimental research on geopolymer mortar and concrete with industrial products such as fly ash and GGSS is enabled by R, et.al (2017) using alkaline solution to obtain cement binder. Similarly, without using traditional cement, geopolymer concrete is prepared and it can be self-cured. The main objective of this research is to understand the properties of geopolymer concrete, as well as the economic, technical and environmental benefits In this analysis, both geopolymer concrete and mortar are prepared to be healed at ambient temperature and tested for compressive strength. Her research concluded that, from both strength and durability considerations, GPC are good construction material. Geopolymer concrete has significant potential to be a material for the future, because it is not only environmentally sustainable, but also has outstanding mechanical properties. Due to the lower internal energy (almost 20 percent to 30 percent) and lower CO_2 emission content of geopolymer-based composite ingredients compared to traditional PPC concretes, modern composites can be considered more environmentally friendly and thus need to be produced and promoted to be useful in practical applications. [5]

Basil M.Mali, et.al (2016) analysed in his paper the properties of the geopolymer concrete paver block with the M40 grade mix. Test results show that geopolymer concrete pavers based on low calcium fly ash have excellent compressive strength within a short time (3 days) without water treatment and are ideal for practical applications. The geopolymer mix of fly ash, fine aggregate and course aggregate was taken on the basis of the base proportion of the OPC mix. The ratio between alkaline liquid and flying ash was 0.35. 2.5 was the ratio of sodium silicate to sodium hydroxide. The sodium hydroxide concentration was 10M. Slump values need to be between 0-10 cm or 100 mm for effective casting. He concluded from his research that Geopolymer concrete is an excellent alternative to Portland concrete cement. Geopolymer concrete carried out on the basis of this experimental study can be used effectively for the development of precast concrete paver blocks Geopolymer concrete pavers based on low calcium fly ash have excellent compressive strength within a short time (3 days) and are suitable for functional applications. For GPC, there is no need for water curing, which can save manufacturing units a lot of curing time and space. On the 7th day, the GPC paver block reached greater strength than the OPC pavers at 28 days, i.e. 49.32 N / mm^2 for OPC and 53.12 N / mm^2 for GPC. The GPC paver block variance is very small at 7th day strength to 28 day strength. So it can be concluded that the GPC paver attain early strength than OPC pavers. [3]

Aaron Darius Vaz, et.al (2012) studied the use of geopolymer concrete in precast concrete paver blocks. The mix design with a target strength of 47 MPa was developed to create paver blocks suitable for highways. The mix proportions of paver blocks was taken as base proportion. 530 kg fly ash, 636 kg fine aggregate and 1060 kg of coarse aggregate for 1m^3 of concrete were mixed with 0.35 water to cement ratio. Ratio of alkaline liquid to fly ash was taken as 0.35. Ratio of sodium silicate to sodium hydroxide was taken as 2.5. The concentration of sodium hydroxide was varied from 8M to 12M. For good casting slump values need to be between 0 to 10cm or 100mm. Super plasticizer about 2.65 kg/m^3 may be added to get the required workability. Based on the experimental study he concluded that geopolymer concrete can be effectively used for manufacture of precast concrete paver blocks. GPC paver block have high compressive strength for the same mix proportion and high strength to gain. This can save lot of curing time and space at manufacturing units. GPC paver blocks outperform OPC paver blocks under freezing and thawing conditions. [1]

2.3 CERAMIC TILE AS COARSE AGGREGATE IN CONCRETE

Md Daniyal, et.al (2015) found out that the utilization of ceramic materials is increasing day by day in the form of tiles, sanitary fittings etc and among that, a huge quantity of ceramic materials convert into wastage during its processing, transporting and fixing due to its brittle nature. Therefore, using these wastes in concrete production it could be an effective measure in maintaining the environment clean and improving the properties of concrete. In his study, the crushed waste ceramic tiles were used in concrete as a replacement for natural coarse aggregates with 10%, 20%, 30%, 40% and 50% of substitution. After examine the results, the optimum value of waste ceramic tile to be used within the concrete mix with a water/cement ratio of 0.5 was determined as about 30%. The compressive and flexural strength of optimum percentage replacement concrete was found 5.43% and 32.2% higher than reference concrete respectively. He concluded that, the optimum value of waste ceramic tile to be used within the concrete mix with a water/cement ratio of 0.5 was determined as about 30%. The compressive and flexural strength of optimum concrete was found 5.43% and 32.2% higher than reference concrete respectively. Flexural strength of Optimal Waste Ceramic Concrete was 32.2% higher. The optimal case of using waste ceramic tiles as coarse aggregates is found to be 10 to 30 percent.[8]

Ajamu, et.al (2018) suggested that a large percentage of industrial waste comes in the form of ceramic waste, resulting in the collection of industrial waste in various forms such as ceramic powder, broken tiles and slurry waste, and the disposal of these waste causes environmental pollution. These waste materials may also be used to substitute cement, fine aggregate , coarse aggregate and even serve as an extra concrete addition. His research focused on the structural impact of Ceramic Tile Waste (CTW) as a partial replacement of coarse aggregates in the manufacture of concrete. Different concrete samples were produced with a 10% step content of 0-40% as a partial replacement of granite with CTW and 100% CTW as coarse aggregates. On coarse aggregates, fresh and hardened concrete, tests were conducted. The test result showed that workability of the mixes increased with increased percentage of CTW content up to 30% and for more than 30% workability decreased. There was slight decrease in the compressive strength of the test samples with increase in the CTW content having a minimum permissible value of 20.03 N/mm^2 at 28 day for 40% inclusion of CTW. From the research he carried out the following conclusions, Aggregate impact value of the granite used for this study is lower compared with that of Ceramic Tiles Waste which implies it was tougher than CTW. The slump test showed that the concrete becomes less workable as the CTW percentage increases beyond 20%. Compacting factor increases with increase in the percentage of CTW up to 20% above which the value began to fall. The compressive strength of concrete reduced with the increase in percentage of CTW replacement. Use of CWT to replace granite as coarse aggregates up to 30% in the production of concrete is established. [2]

Y.Tabak, et.al (2012) discovered an environmentally sustainable solution to waste material disposal, which in today's world is a difficult problem to deal with. The use of floor tile waste aggregates in concrete greatly decreases the harmful impacts of natural resources on the environment and fatigue. It is possible to use as aggregates in the production of concrete in order to reuse and thereby decrease the amount of ceramic waste that occurs during the production of ceramic products. He concluded that, concrete that produced from floor tile waste has some more better physical and mechanical characteristics than conventional concrete. The best water absorption value was displayed by Floor Tile waste aggregate concrete ie; 1.394 %. Ceramic waste can be transformed into useful crushed stone aggregate instead of natural coarse aggregate. The properties of ceramic waste coarse aggregate are within the range of the values of concrete making with natural aggregates. [6]

3. CONCLUSIONS

Interlocking Concrete Block Pavement (ICBP) has been used over traditional pavements in many places as a specialised problem-solving method, which is less durable due to many operational and environmental constraints. Replacing high volumes of supplementary cement materials (SCMs) with Portland cement lowers CO_2 emissions by around 51 to 75 percent. From the literature review, Geopolymer concrete using Ceramic tile waste as course aggregate shows good potential as an alternative material to traditional Portland cement concrete. Fly Ash showed higher strength properties and also increasing the GGBS percentage the strength increases. Geopolymer ceramic tile concrete has various advantages over OPC, such as low impact on the environment, high strength and rapid strength gain. In the context of reducing CO_2 emissions, the one prospect currently practiced is replacing Portland cement with high volumes of supplementary cementitious materials (SCMs). In the manufacture of concrete, efficient use of locally accessible SCMs such as fly ash and ground granulated blast furnace slag (GGBFS) decreases the burden on landfills and environmental pollution. Using high NaOH concentrations in the activator, the hardness of the Geopolymer paver block sample increases rapidly.

It was known from the literature review that the geopolymer paver block can be used as an alternative to traditional cement paver block.

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