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Study on Microstructure Model of Cement Mortar with Composite Supplementary Cementitious Materials

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ABSTRACT
Modern construction world is focussing on energy efficient and sustainable construction materials. Reducing cement consumption by partial rep lacement of cement with waste supplementary cementious material (SCM) improves the sustainability of concrete and mortar used for construction works. Combination of two supplementary cementitious materials derived from waste materials with cement will yield a ternary blended green cement mortar which is more effective than conventional mortar in terms of both strength and performance. Waste banana leaf and cattle bones are collected, dried and powdered separately using miller machine. Supplementary cementitious material is made with different combination of banana leaf powder and cattle bone powder. Experimental works are carried out on cement mortar with 10%, 20% and 30% partial replacement of cement with supplementary cementitious material. Optimum percentage of SCM for partial replacement of cement is 30%, with 10% cattle bone powder and 20% banana leaf powder. Behaviour of SCM material with cement is discussed based on physical and chemical properties of SCM material. Virtual 3D Microstructure model of cement mortar mix is created and analysed for validating the SCM behaviour.
Keywords - Supplementary Cementitious Material, Banana leaf powder, Cattle bone powder, Microstructure.

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I. INTRODUCTION

Partial replacement of cement with waste materials ash is a worldwide practice. The increasing use of these ecological materials is owing to several performance factors, including improved workability, compressive strengths and used to reduce cement content without reducing its strength. The uses of supplementary cementitious materials not only focus on the performance characteristics, it also decreases the energy depletion and CO2 emissions. Consumption of cement shall be reduced by partial replacement of cement by waste supplementary cementitious materials is an effective way to increase the performance of concrete and makes the concrete more sustainable with low CO2 emissions.

The use of alternative materials derived from waste materials result in two folds advantages conservation of natural resources and disposal/reduction in the size of waste heaps. Banana Leaf is a waste material and is available in plenty of quantity. Though banana leaf is an organic decomposable material, due to its time of decomposition and volume of waste from day to day activities, its disposal is critical. Similarly, Cattle bones are also dumped in large quantities in disposal yards and creates bad odor thereby creates air pollution and diseases. Hence it is necessary to dispose the above said solid waste in short span of time through an efficient way. Hence, Banana Leaf wastes and Cattle Bone wastes are selected supplementary cementious material. It is important to study the behaviour of selected SCM material with cement inorder to check the compatibility of SCM material with other ingredients of cement mortar as an alternate binder. Also it is important to study the role of SCM material in hydration process and to check the final hydrated products.

II. SUPPLEMENTARY CEMENTIOUS MATERIAL

Banana Leaf is a waste material and is available in plenty of quantity. Though banana leaf is an organic decomposable material, due to its time of decomposition and volume of waste from day to day activities, its disposal is critical. Cement has to be partially replaced by banana leaf powder at selected percentage. Similarly, Cattle bones are also dumped in large quantities in disposal yards and creates bad odor thereby creates air pollution and diseases. It is necessary to dispose the above said waste in short span of time through an efficient way. Hence, viability analysis on utilizing the powdered form of these waste materials is selected as supplementary cementitious material.

Identified waste banana leaves and cattle bones are collected and allowed for sunlight drying and percentage of replacement of cement by Composite material. Suitable admixture is added to improve the binding property of composites with cement matrix and also for improving the compressive, tensile and bending strength of cement mortar. The results are compared with that of the control specimen results. Compare the parameters of strength and durability with that of the conventional concrete and comment on the sustainability of the concrete. Combination of waste Banana Leaf Powder (BLP) and Cattle Bone Powder (CBP), when used as SCM increases the strength of concrete and mortar. Such data are being applied to develop better relationships between the cement material properties and performance properties of banana leaf powder and cattle bone powder.

Banana leaf Powder serves as a non-pozzolonic alternate bind ing material whereas Cattle Bone Powder, rich in calcium content acts as a nucleating agent improves the binding property of cementious substances with aggregates thereby improves the bond strength between cement phase and aggregate phase. Partial rep lacement of cement (up to 30%) with supplementary cementitious material made with waste banana leaf powder and cattle bone powder increases the compressive strength of concrete at 28 days without compromising the strength and durability properties. BLP exhibits pozzolonic property and it is also taking part in hydration process. Likewise, a chemical composition of BLP shows the existence of reactive mechanisms, which are responsible for its pozzolonic behavior. Hence Banana Leaf wastes and Cattle Bone wastes are selected as alternate b inding material. The waste materials have more advantages than the natural materials. The utilization of these materials will help in preserving the natural resources as well as protection of environment. Banana leaf wastes and cattle bone powder are separately collected and dried. After drying, banana leaves and cattle bones are crushed separately through milling machine to powder form.

III. BEHAVIOUR STUDY ON SCM WITH CEMENT

BLP is Powder form Non-Pozzolonic SCM material is rich in micro and nano scale fibers. When mixed with cement and subjected to hydration process, surface of the fibers are adsorbed with C-S-H gel and a modified layer is formed around the fibers which participates in binding of cement phase and aggregate phase. At Interfacial Transmission Zone, nano fibers of BLP in surface modified form improve bond strength between cement and aggregate phase. Thus BLP is indirectly participating in pozzolonic reaction. When BLP is used to partially replace cement in concrete, it not only exhibits binding property but also improve the bond strength of cement and aggregate phases.

CBP is also Powder form Non-Pozzolonic SCM material with amorphous calcium (approximately 55%), When mixed with cement and subjected to hydration process. Hydration process takes places in four phases: Initial period of rapid reaction, Period of slow reaction, acceleration period and deceleration period. CBP powder acts as nucleating agent and enhances hydration at accelerating period. Basically, CBP is acting as filler material but being an nucleating agent enhances hydration. Thus CBP, when mixed with cement, indirectly participates in pozzolonic reaction.Compound of portland cement and compound of Cement with SCM are similar in our case.

IV. VALIDATION OF MICROSTRUCTURE MODEL

Virtual cement and concrete testing laboratory software contains underlying computer models and graphical user interface through which a user can create, hydrate and estimate the virtual 3D microstructures model cement mortar. User has more control over mix design of mortar and concrete. User can able to upload, view and edit aggregates properties. It also enables mixing of SCM with real-shape cement particles. Option to add C-S-H seeds to binder for acceleration of hydration is also available. Using this tool, proposed cement (cement plus SCM) is created and used as cementitious material in mortar mix. Hydration of proposed cement paste with supplementary cementitious material is hydrated under different curing condition. The simulated image of dry mix and hydrated mix are shown below. Hydrated model of cement mortar is analyzed for various properties including compressive strength. 3D packing of aggregate phase in cement matrix is simulated. Quantity of C2S, C3S, C3A and C4AF are taken from the simulated image result. Pore size and its distribution in the hydrated model are also taken from the result. Results are found satisfactory and thus hydration of SCM used cement is validated.

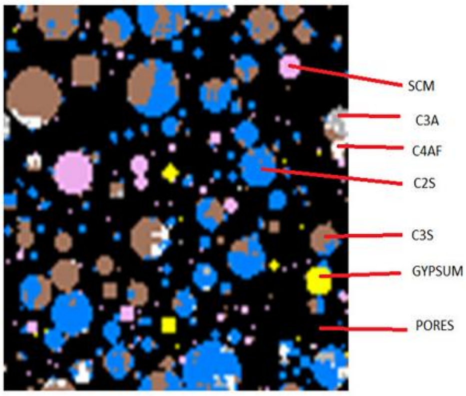

Figure-1 Microstructure image of dry mix

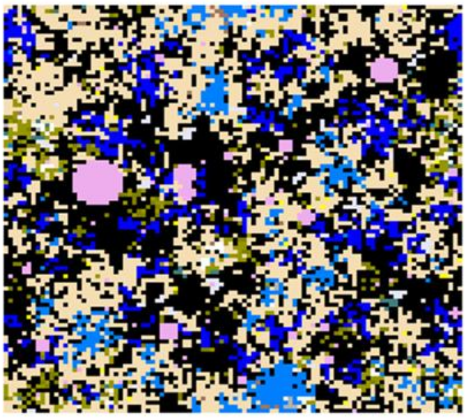
Figure-2 Microstructure image of hydrated mix

V. CONCLUSION

Virtual microstructure image of prepared dry cement Mix "SCM MIX 30" with 30% replacement of cement with supplementary cementitious material shows that mineral composition of image is similar to that of conventional theoretical model. The distribution of SCM partic les in cement matrix is satisfactory. Pore volume is reduced when compared to theoretical model image. Microstructure image of hydrated Mix "SCM MIX 30" with 30% replacement of cement with supplementary cementitious material shows that SCM induces no change in C-S-H gel product morphology. SCM distribution reduces pore volume. SCM exhibits surface modification and passive binding with CSH gel, thus indirectly participating in binding of cement phase with aggregate phase. Hydration compounds of portland pozzolona cement and hydration compound of (Cement with 30% SCM) are similar in our case. The SCM induces no change in C-S-H gel product morphology but due to presence of BLP fibres bond strength is improved and due to presence of CBP powder hydration is accelerated. There is no odd compound formed during hydration process and hence there is no modification required in basic chemical equation of cement hydration process.

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