ANALYSIS OF THE POTENTIAL OF RESIDUE FROM A FOOD PROCESSING INDUSTRY AS A SUPPLEMENTARY CEMENTITIOUS MATERIAL

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ABSTRACT. The disposal of waste that are generated from industry and agriculture is a major problem to be dealt with in any developing economy where these wastes are generally discarded in landfills and thus pollute the environment. Testing the potential of waste materials for cementitious properties is one way to valorise them and render them as a supplementary or alternative for cementitious material. Studies have shown that the production of Portland cement (OPC) contributes to 5-8% of global CO_2 emissions. Replacing cement with other potential materials will reduce this contribution. In this study, a silica rich material obtained as a residue from a food processing industry was evaluated for its potential to be used as a supplementary cementitious material. To evaluate the potential of the material, mortars were prepared with ordinary Portland cement (OPC) which was replaced partially by volume with residue material and sand in 1:3 ratio. The setting time, compressive strength, open porosity and bound water content were measured. The initial results show that this material has a potential to be valorised as a pozzolanic supplementary cementitious material.

Keywords: Supplementary Cementitious Material, Waste Valorisation, Food Industry Residue, Cement.

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INTRODUCTION

Ordinary Portland Cement (OPC) is the most widely used construction material particularly in developing nations like India (second in production next to China) [1]. During the production of cement clinker, the carbondioxide (CO_2) is released from both the fuel combustion and the raw meal. As per 2016 report, the CO_2 emission from the oxidation of carbonates (raw meal) accounts for 4% of global emissions and the same amount of emission is estimated from fuel combustion. So, in total the cement clinker production accounts to around 8% of global CO_2 emissions [1], [2]. One way to reduce these CO_2 emissions is by replacing OPC either partially or fully with other materials that can perform similar or better than OPC. The materials which can replace OPC partially are termed as supplementary cementitious materials (SCM) and those materials which can replace OPC in total are termed as alternative cementitious materials. These materials (also called mineral admixtures) can be categorised into three types. Materials of low or no reactivity, pozzolans and latent hydraulic. Low or no reactive materials were used to improve the workability. Pozzolans react with calcium hydroxide at ambient temperatures and form hydration products having the binding capacity. Latent hydraulic materials form hydration products up on the reaction with water in presence of alkaline activator [3], [4]. Many natural and industrial by products are used as mineral admixtures till date. Some of the most used materials are fly ash, ground granulated blast furnace slag, silica fume, metakaolin, limestone, rice husk ash etc. On the other hand, to cater to the needs of the rapidly growing population, the increased production and consumption of resources has resulted in the huge accumulation of waste. These may be generated at various levels in a life cycle of material processing. These wastes are to be decomposed either naturally or dumped as a landfill which again is a major concern to the surrounding environment. The utilisation of these wastes after exploring their potential as a supplementary/alternative cementitious material will benefit the cement industry in ecological, economical and technical manner. Many such wastes like waste glass, brick and tile rejects, stone wastes, municipal solid waste ash, agricultural wastes are already being valorised. In the present study, the potential of waste obtained from a food processing industry to be used as a SCM was evaluated. The possibility for full replacement of OPC with this residue using the alkali activation process is under investigation by the same authors.

MATERIALS AND METHODS

Five different combinations of OPC, slag, fly ash and silicates were studied and the proportions are given in Table 1. Mortars and paste samples with OPC, OPC partially replaced (by volume) with slag, fly ash and silicates were prepared with water to binder ratio of 0.50 and standard sand to binder ratio of 3:1. OPC 53 grade was used in this study. The received silicates were dried in an oven at 105°C and 0% relative humidity (RH) for 12 hours and then ground in the mortar pestle into fine powder form. The obtained silicate powder was sieved through a 300μm sieve and used in the experiments. The density of OPC, fly ash, slag and silicates were determined by Le Chatlier flask [5].

Mortar prisms of 16 cm in length and a square cross section of 4 cm were cast, demoulded after 24 hours and then cured in a desiccator which was maintained at 27 °C and above 90% RH conditions(maintained with saturated potassium sulphate solution)until the time of testing. Compressive strength was measured at 7 and 28 days on the cubes of 4cm side (obtained from the prisms) by loading at a rate of 2.4 kN/s. Open porosity of these mortar samples was determined by following the procedure described in EN 1936-1999 [6].

Table 1 Mixture proportions for mortar specimens in kg/m^3

S. NO	COMBINATIONS (NOMENCLATURE)	OPC KG	FLY ASH KG	SLAG KG	SILICATES KG	WATER KG	SAND KG
1	100% OPC (OPC)	493.4	-	-	-	246.7	1480.3
2	75% OPC+ 25% FA (OF)	414.5	99.3	-	-	256.9	1541.5
3	65% OPC + 35% Slag (OS)	351.0	-	165.4	-	258.2	1549.0
4	75%OPC + 25% Silicates (OS1)	426.4	-	-	84.4	255.4	1532.3
5	65%OPC + 35% Silicates (OS2)	383.8	-	-	122.7	253.3	1519.5

The amount of hydrates formed with time was observed through thermogravimetric analysis. The paste samples for above combinations were prepared and the hydration was stopped at a particular age say 7, 28, 60 and 90 days, by grinding in a motor pestle and subsequent vacuum drying for 2 hours in Alpha 1-2 LD plus freeze dryer at a vacuum less than 0.024 mbar and at -60 °C. Subsequently, the powdered paste samples were stored in a desiccator having silica granules which maintain RH less than 30% until the time of testing. Thermogravimetric analysis (TGA) was carried on these powdered paste samples using Perkin Elmer made STA8000. A sample of approximately 20 mg was subjected to 30–1000°Ctemperature at a rate of 10 °C/min in a through flow N_2 environment purging at a rate of 30 ml/min.

RESULTS AND DISCUSSION

The density of OPC, fly ash, slag and silicates are given in Table 2. Silicates are relatively less dense compared to fly ash, cement and slag particles. The setting time was measured according to IS 4031: Part 5[7]and is given in Table 3. It was observed that the initial setting time of OS1 and OS2 mixtures are almost one sixth of the OPC paste. The setting was retarded when OPC was replaced with fly ash and slag (OF and OS mixtures).

Table 2 Density of OPC, fly ash, slag and silicates

MATERIAL	DENSITY (g/cm^3)
OPC	3.15
Fly ash	2.30
Slag	2.87
Silicates	1.85

Table 3 Initial setting time of OPC, OF, OS, OS1 and OS2 mixtures

MIXTURE	INITIAL SETTING TIME (MINUTES)
OPC	69
OF	166
OS	146
OS1	10
OS2	12

The mechanical strength (Figure 1) was measured in terms of compressive strength on 4 cm cube specimens at 7 and 28 days by loading at a rate of 2.4 kN/s. It is observed that at 7 days the compressive strength of OS1 and OS2 samples is relatively lower than the other mixtures. However, the strength ofOS1 sample has reached the level of OS sample at 28 days.

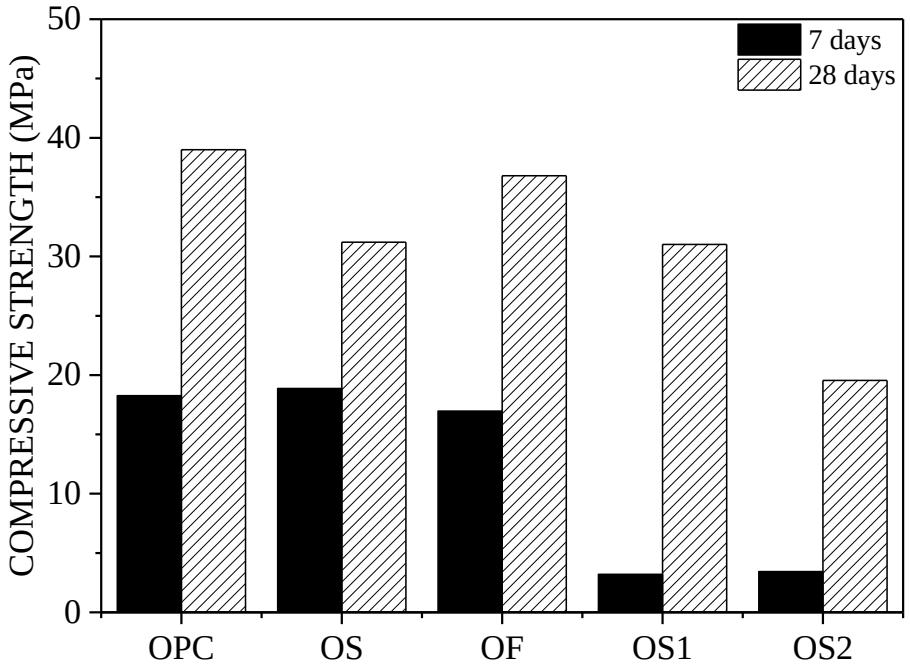

Figure 1 Compressive strength values of OPC, OF, OS, OS1 and OS2 samples at 7 and 28 days respectively.

Compressive strength is majorly governed by porosity and they are inversely related. The porosity of mortar samples was determined by open porosity method and is shown in Figure 2. It is observed that the porosity of OS1 and OS2 samples are significantly higher than OPC, OS and OF samples. The relatively low compressive strength of OS1 and OS2 samples is therefore substantiated with higher porosity values. With age, porosity values are almost the same for OS1 and OS2 sampleshave decreased for OPC and OS samples and have increased for OF sample.

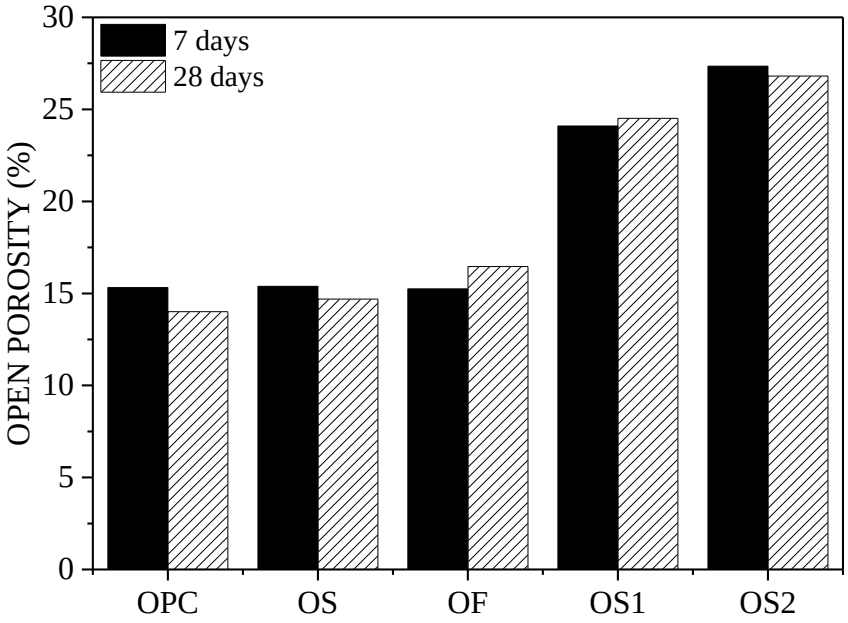

Figure 2 Open porosity values of OPC, OF, OS, OS1 and OS2 samples at 7 and 28 days respectively.

The hydration products formed at 7, 28, 60 and 90 days were analysed by the TGA and plots of all the mixtures are given in Figure3. The corresponding differential (DTG) plots are given in Figure 4. From the DTG plots (Figure 4) it is observed that the amount of CH decomposed (in range of 400-500°C) has reduced with age in OS and OF pastes with a corresponding increase in weight loss below 200°C (related to the decomposition of C-S-H [8]). The decrement in the amount of CH is due to the pozzolanic reaction of slag and fly ash with OPC. In case of OS1 and OS2 samples, with age, there is a decrement in weight loss due to decarbonation (600-800°C) with the corresponding increment in weight loss in the temperature range of 400-500°C (dehydration of CH or brucite) and below 200°C (decomposition of hydration products). The higher amount of carbonates found in OS1 and OS2 samples are contributed from the raw material itself (Figure 4A). The increment in compressive strength from 7 to 28 days for OS1 and OS2 samples (Figure 1) is due to the formation of hydration products as observed from the DTG plots. Further weight loss is observed in OS1 and OS2 samples in the temperature range of 850-950°C. This might be due to the decarbonation of dolomite. The amount of bound water for all the mixtures at 7, 28, 60 and 90 days which is weight loss below 500°C [3] is given in Figure 5. The measured compressive strength results are in good agreement with the amount of bound water. The OS1 and OS2 samples have comparatively less amount of bound water which is reflected by relatively lower compressive strengths.

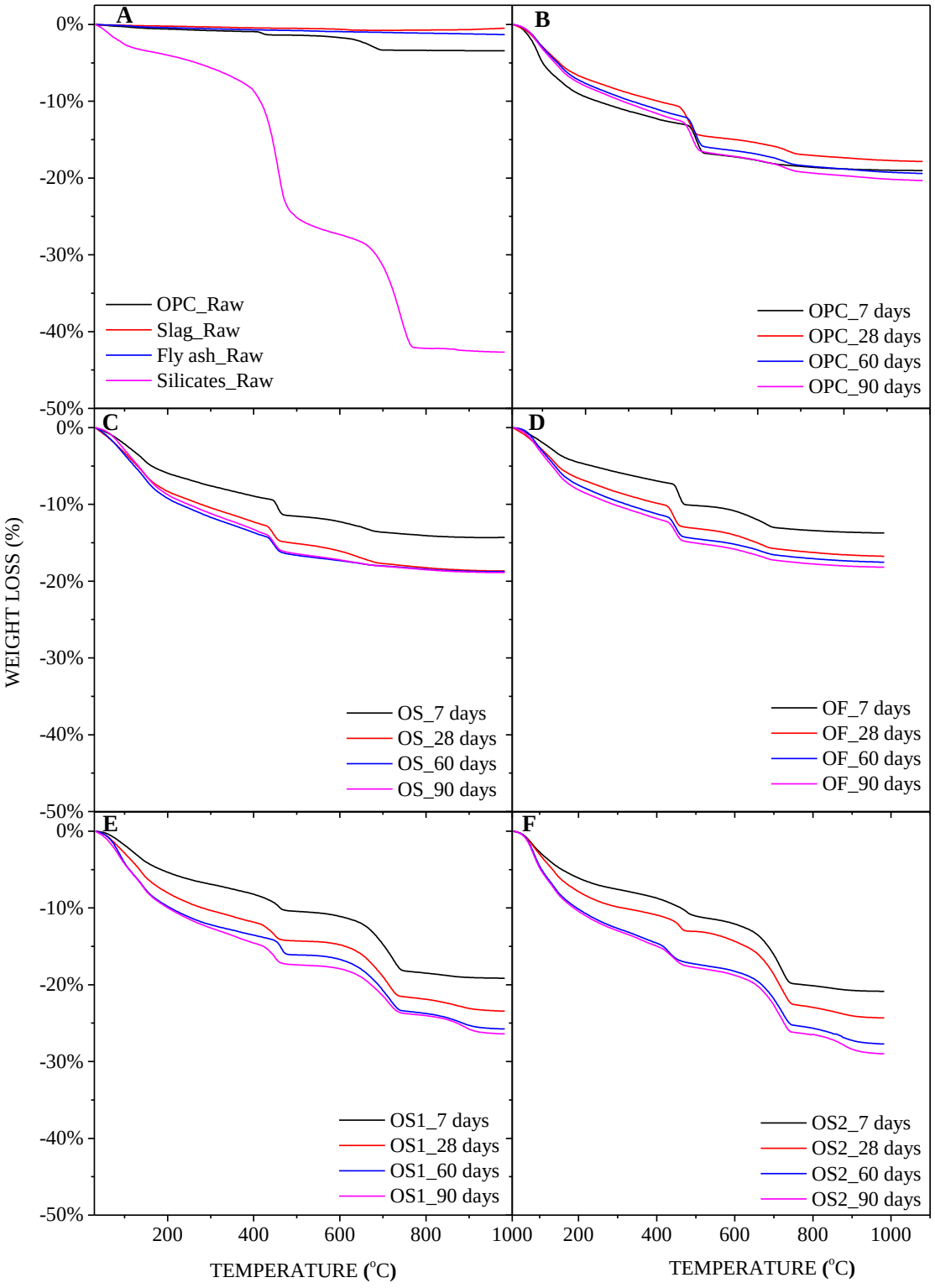

Figure 3 TGA plots of powdered OPC, OS, OF, OS1 and OS2 samples at 7, 28, 60 and 90 days respectively

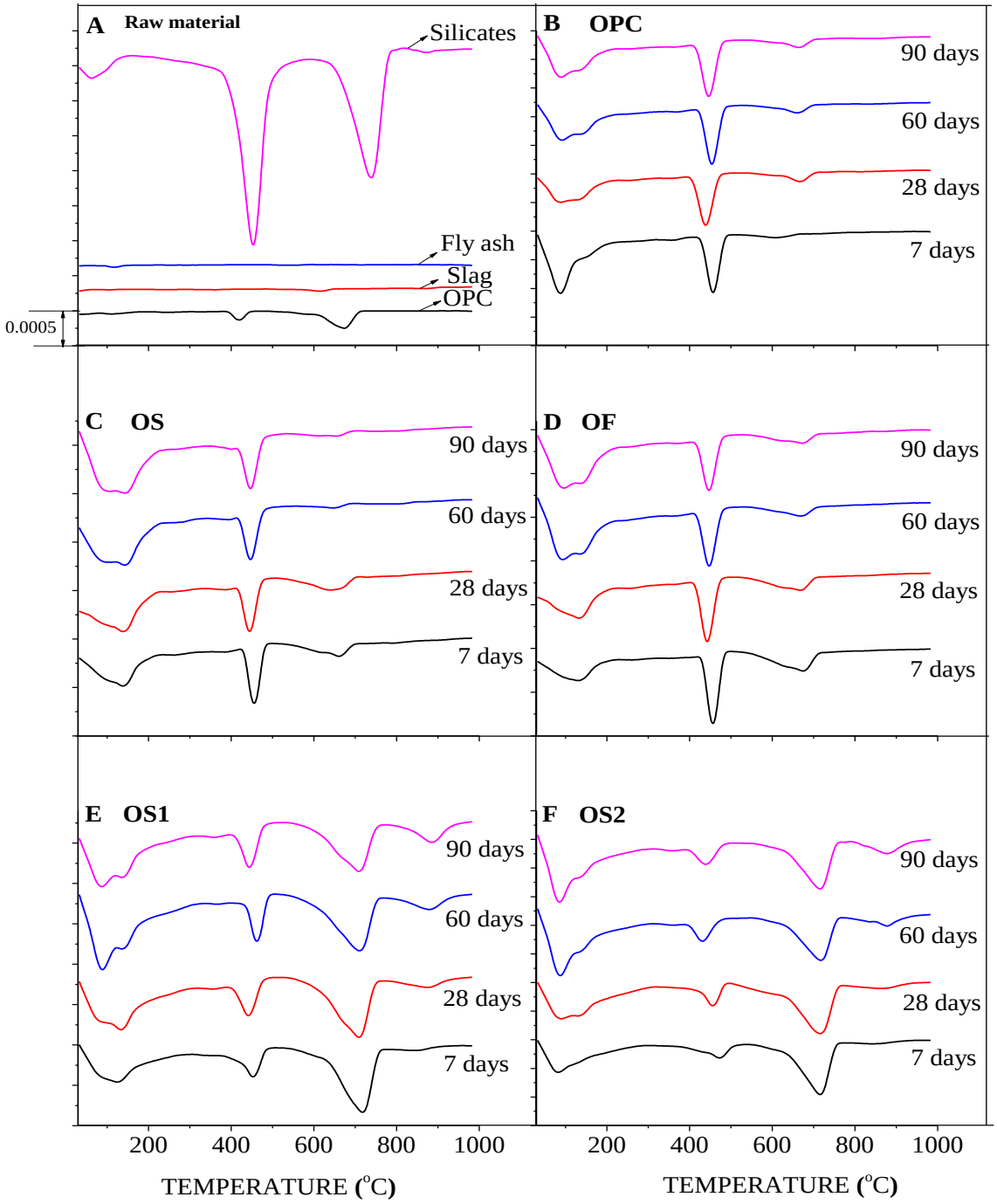

Figure 4 DTG plots of powdered OPC, OS, OF, OS1 and OS2 samples at 7, 28, 60 and 90 days respectively

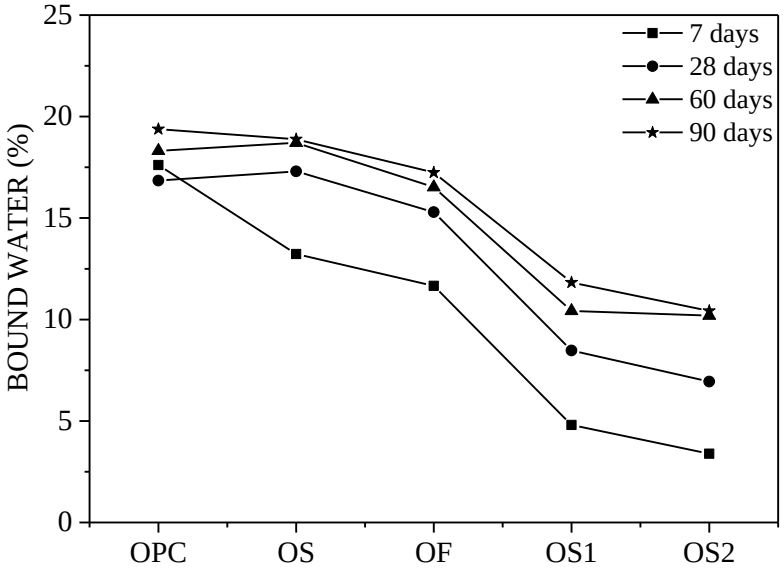

Figure 5 Amount of bound water in OPC, OS, OF, OS1 and OS2 samples at 7, 28, 60 and 90 days respectively

CONCLUSIONS

A possible replacement of OPC with silicates (a food processing residue) similar to fly ash and slag was studied. The amount of carbonates is higher in raw silicates and is reflected in paste samples. The lower compressive strength exhibited by OS1 and OS2 mortar samples when compared to OS, OPC and OF samples is due to high porosity and less amount of bound water or hydrates formed. From compressive strength results, it is observed that these silicates at a 25% replacement level can exhibit strength similar to slag replaced OPC mixtures at 28 days and suggests that the material has an ample potential to be valorised as a pozzolanic material.

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