Sustainable experimental investigation of mortar adopting industrial waste considering environmental effect

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Abstract

Now days, Nanotechnology is introduced in civil industry for ceramics, composites, and mortar to achieve better performance in different mechanical parameters of these materials. At the same time, Environment prevention is pin point for the civil industry because of cement production. As a solution of better performance of structural materials with environment prevention, steel making industry waste powder at Nano-scale giving better enhanced strength of mortar. This research work introducing the acceptable partial replacement of the steel waste powder in place of ordinary Portland cement to minimize environmental pollution due to cement production considering waste disposal solution. In the mortar making process, pure steel making waste used in powder form having compositions of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, Sulphide, Na_2O_3, K_2O, Cl and MnO. Combined effect of these all compositions greatly affected on the mechanical properties of mortar containing this waste powder. To know the effect of this waste powder containing all these compositions in mortar, different mechanical parameters of mortar like compression, tension, flexural, shear and impact test were performed. For this innovative approach, steel making industry waste powder was examined to set consistency for mortar making purpose. To get optimum dosage of waste powder, 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90% replacement were done in place of cement. Physical parameters like Compressive, Tensile and Flexural, Shear and Impact strength were examined using optimum dosage of waste powder. This innovative research work introduced the enhanced strength after 3 days, 7 days and 28 days curing. From this research work, it is advisable to use mortar containing waste powder in load bearing structures which is giving sustainable waste disposal solution including CO_2 reduction in environment. Copyright © 2018 VBRI Press.

Keywords: Mortar, industrial waste, environment prevention, physical properties, enhanced strength.

Introduction

Now days, Nanotechnology is introduced in civil industry for ceramics, composites and mortar to achieve better performance in different mechanical parameters of these materials. At the same time, Environment prevention is pin point for the civil industry because of cement production. Sustainable development is in demand, because of global warming and CO_2 emission. Different industrial sector developing fast to introduce advanced technology, which are also facing waste disposal problem. The waste disposal problem of different sector is responsible for environmental pollution. In recent research scenario of civil industry, the worldwide total production of Portland cement is about 3.7 billion tones, which is widely used in the production of concrete. This production emits the large volumes of CO_2 estimates as high as 5% of total global man made CO_2 emissions, thus its production is responsible factor for global warming and climate-change. [**2**]As a solution of better performance of structural materials with environment prevention, steel making industry waste powder at Nano-scale giving better enhanced strength of mortar. [**2-5**] This research work introducing the acceptable partial replacement of the steel waste powder in place of ordinary Portland cement to minimize environmental pollution due to cement production considering waste disposal solution. In the mortar making process, pure steel making waste used in powder form having compositions of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, Sulphide, Na_2O_3, K_2O, Cl and MnO. Combined effect of these all compositions greatly affected on the mechanical properties of mortar containing this waste powder. [**8,9**] To know the effect of this waste powder containing all these compositions in mortar, different mechanical parameters of mortar like compression test was performed. For this innovative approach, steel making industry waste powder was examined to set consistency for mortar making purpose. To get optimum dosage of waste powder, 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90% replacement were done in place of cement. Physical parameters like Compressive, Tensile and Flexural were examined using optimum dosage of waste powder.

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Experimental

Material Testing: Cement and Waste Powder

Ordinary Portland cement of 53 grade confirming IS 269: 2015 [**10**] was used throughout the work. Cement was tested at the beginning and end of each phase of work to ensure no deterioration in quality of cement during the interim period. The waste was collected from one of the local steel making industry from Hajira, Surat. It was in granular form which was converted in powder form with the help of ball mill situated in Hajira, Surat. The physical and chemical analysis of cement and waste powder are given in **Table 1**.

Table 1. Physical and chemical analysis of cement and waste powder.

Characteristic	Requirement for cement (IS 269:2015)	Cement	Waste Powder
Fineness (m^2/Kg)	Min.: 225	278.4	420.00
Initial setting Time (min)	Min.: 30 min	125	195
Insoluble Residue (%)	Max.:5.0	0.63	0.28
Magnesia Content (%)	Max.6.0	1.89	8.06
Sulfate content (%)	Max.: 3.5	2.2	0.24
Loss on Ignition (%)	Max.: 4.0	2.94	0.29
Chloride Content (%)	Max.: 0.10	0.03	0.001

Aggregate

The fine aggregate as river sand, available locally in Surat, confirming IS 383:1970 [**11**] has been used in this experimental program.

Testing

Cubic specimens with 70.6 mm edge length for compressive tests, Cylindrical specimens with the diameter of 100 mm and the height of 200 mm for split tensile tests, cuboid specimens with 500 mm × 100 mm × 100 mm edges length for flexural tests, Disc specimens with 150 mm diameter and 63.5 mm height for impact test and a special L shape specimens as shown in **Fig. 1** for shear were made. After casting of mortar the moulds were covered with plastic sheets for 24 h. Then the specimens were demoulded and cured in water at a temperature of 20°C in the room condition prior to test days. The strength tests of the samples were determined at 3, 7, and 28 days of curing. Compressive and flexural tests were carried out according to the IS 516:1959 [**12**] standard, split tensile tests were done in accordance to the IS 5816:1999 [**13**] standard, impact strength tests were done in accordance to ACI Committee 544. JSCE-SF6 [3] suggested direct shear method by using beam of size (150 x 150 x 500 mm) and load applied through male–female arrangement and failure under double shear. Another method suggested by Modhera and Bairagi [**1**]**,** arrangement for which is shown in **Fig. 1** where all dimensions are in mm. In this method Load P is given on upper plate until the crack developed on the failure plane in single shear. The failure load P_2 is considered as half of the total load P. The shear stress in N/mm^2 is calculated by Load P_2 divided my shear area which is 60 x 150 mm.

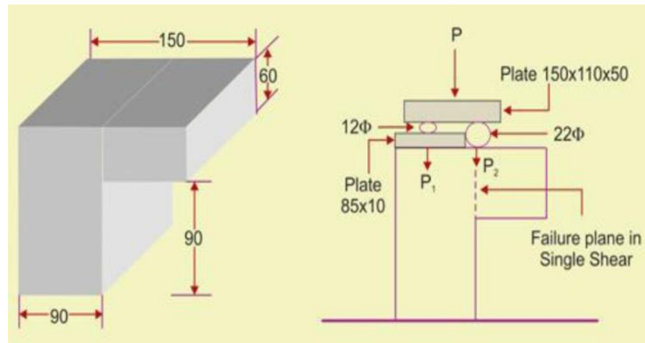

Fig. 1. L shape specimen for shear strength test.

Sharmila P. and Dhinakaran. G[**7**] had given microstructure of nano slag was analyzed by Scanning Electron Microscopy (SEM) to understand its morphology and the results are shown in **Fig. 2** for understanding the micro structure of concrete with nano slag. The SEM images clearly explain the microstructure gets modified due to the addition of nano slag and due to agglomeration the size of particles becomes large. However the process of grinding did not affect the sphericity of particles. It was also observed that sizes of particles were reduced to considerable percentage due to the effect of grinding. SEM images witnessed the above statement.

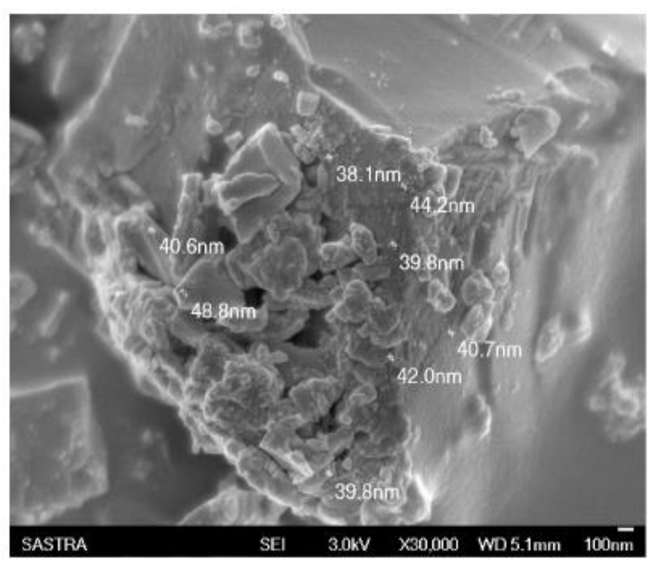

Fig. 2. SEM image of concrete modified with nano slag [7]

Results and discussion

Fig. 3 & Fig. 4 indicates that 50 % cement replacement by waste powder provides better strength in compression for mortar specimens after 3, 7 and 28 days of curing which are all increased by increasing waste powder up to 50%. Using more than 50% waste has reduced the strengths of the specimens and it may be as a result of CaO content in waste lower than Portland cement. This may be reduce $Ca(OH)_2$ and hence C-S-H gel. Roncero and Gettu [**6**] have demonstrated the CH crystals formation by using polycarboxylate. These large crystals weaken the aggregate-paste transition zone and hence decrease the strengths of mortar by decreasing the aggregate-paste bond. **Fig. 5 & Fig. 6** indicates the relation of shear strength and absorbed impact energy with the age of mortar which shows the increase in strengths compare to plain mortar.

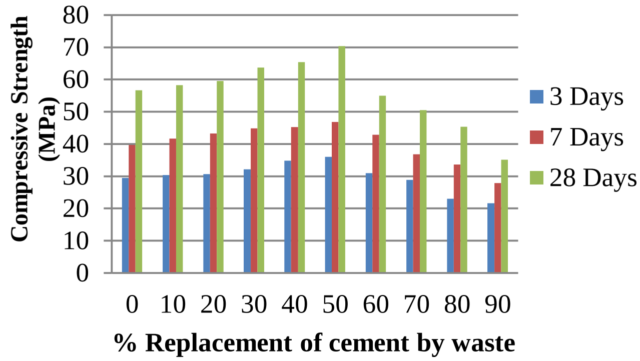

Fig. 3. Relation of compressive strength of mortar with percentage of waste powder as cement replacement.

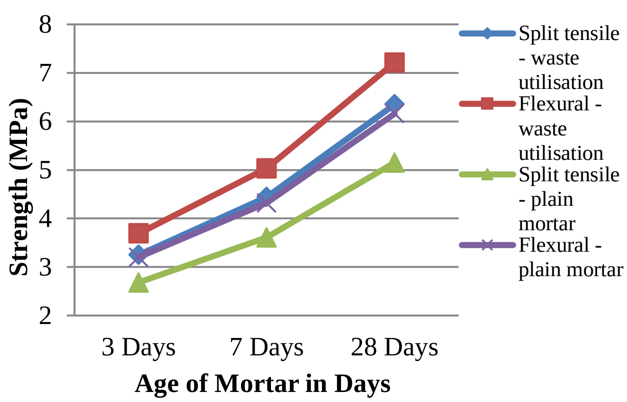

Fig. 4. Relation of split tensile Strengths and Flexural Strength with age of mortar.

Use of waste utilized mortar in low rise construction at Hajira, Surat.

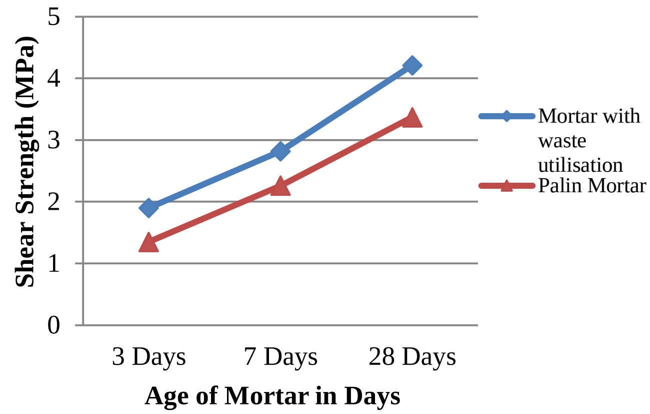

Fig. 5. Relation between shear strength and age of mortar.

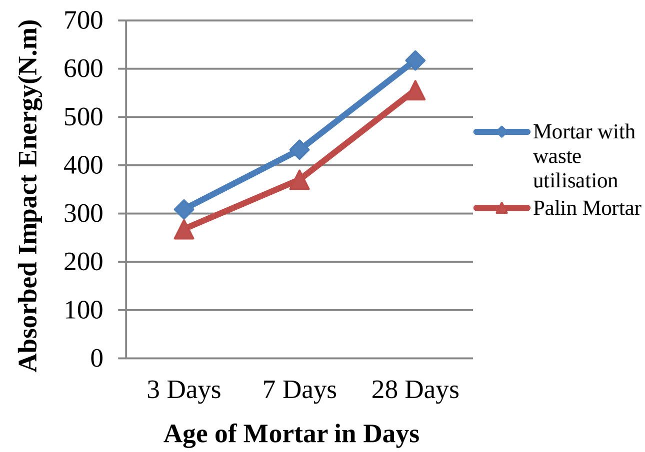

Fig. 6. Relation between absorbed impact energy with age of concrete.

Conclusion

Focusing towards research on steel industry waste as a pozzolanic material, many researchers either studied the performance of waste under normal laboratory concreting conditions or investigated compressive strength of concrete in order to produce economical concrete by reducing cement content. The current research work carried out focused towards exploring the effect of nano slag as cement replacement in mortar. The following conclusions are drawn from the various experimental results reported in the present work.

The mortar produced with 50% waste powder as cement replacement gave optimum strength. The compressive strength development in mortar containing waste powder as cement replacement is influenced by the refinement of microstructure, transformation of CH into CSH gel through the pozzolanic reaction and formation of a denser interfacial transition zone.

The mortar produced with 50% waste powder as cement replacement experiences a higher rate of flexural strength due to homogeneity in the distribution of hydration products in concrete. The addition of waste powder also gives better performance in split tensile strength which is an important parameter of mortar.

The shear strength test results indicate 25% increased strength and impact test results indicate 12% increased strength with 50 % replacement of cement with waste.

This research concludes that it is economical to use steel industry waste as cement replacement with enhanced strength criteria. As well as the use of nano waste powder as cement replacement is sustainable as it gives better fresh and harden properties of mortar and it is also ethical as this mortar can be used in load bearing structures, manufacturing of paver block and some light precast elements.

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