Experimental Investigation on Paver Blocks using Steel Slag as Partial Replacement of Aggregate and Sludge as Partial Replacement of Cement

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Abstract: ***The scarcity of raw materials required for construction is increasing day by day due to globalization. The metallurgical steel slag from industries creates great concern to the environment. These steel slags may be used as substitution of natural aggregate in the field of construction. The magnitude of the sludge derived from the chemical processing of textile industry is larger than other industries. Since the pollutants in the sludge lead to problems of ground water pollution, extreme change in soil condition, adverse effects on plants and poor productivity of soil. It is necessary to develop a suitable technology for conversion of the textile sludge and slag into Eco-friendly and useful construction materials. In this study, it is proposed to utilize the textile sludge as partial replacement of cement and steel slag as partial replacement of coarse aggregate in the production of sludge based paver blocks. Paver blocks were cast with sludge as cement replacement material at 0, 10, 20, 30 and 40 percent and Steel slag at 0, 10, 20, 30 and 40 percent as coarse aggregate replacement for the above combinations. Tests for compressive strength at 7 days were conducted. Compressive strength on 28 days, flexural strength, and rapid chloride permeability test (RCPT) and water absorption at 28 days are to be conducted on the paver blocks. It is proposed to carry out the cost analysis for the paver block mix combinations (sludge and steel slag) with commercial paver blocks.***

Keywords: Textile Sludge, Steel slag aggregate, Rapid chloride permeability test (RCPT), Paver Blocks

1. Introduction

In the past few decades, the rapid process of industrialization and urbanization has increased the generation of waste materials at tremendous rates, and landfills are filling up faster than the exploration of new sites. This situation has raised alarming concerns over many municipalities, particularly in densely populated areas. The sludge generated from wastewater treatment has posed a problem, as waste disposal becomes extremely costly due to the scarcity of land and the governing concern on the environment. This sludge creates more negative impacts in many ways as far as the correct disposal techniques are not adopted. There is a growing need to find alternative solutions for textile sludge management. The textile sludge has a high calcium and magnesium content, which comes mainly from coagulating chemicals (magnesium salts and lime). The presence of high calcium and magnesium indicates the potential use of this sludge as partial replacement of various non-structural materials.

Steel slag is a by-product formed during the steel manufacturing process. It is a non-metallic ceramic material formed from the reaction of flux such as calcium oxide with the inorganic non-metallic components present in the steel scrap. The use of steel slag reduces the need of natural rock as constructional material, hence preserving our natural rock resources and reducing the need for dumping ground. In actual fact, these by-products are valuable and extremely versatile construction materials. In relatively recent years, the need for maximum utilization and recycling of by-products and recovered waste materials for economic and environmental reasons has led to rapid development of slag utilization. In some areas, nearly all of the iron and steel slags are now being used, and use is rapidly growing. However, the use of steel slags a cementing component should be given a priority from technical, economical, and environmental considerations. In this investigation, the effect of steel slag as coarse aggregates, dry textile sludge is proposed to use as a partial replacement of cement in the production of paver block.

2. Experimental Study

In this study, it is proposed to utilize the textile sludge as partial cement replacement material and steel slag as partial replacement of coarse aggregate in the production of sludge based paver blocks. Paver blocks were cast with sludge as cement replacement material at zero, 10, 20, 30 and 40 percent and Steel slag at zero, 10, 20, 30 and 40 percent as coarse aggregate replacement for the above combinations. Steel slags were tried up to 100% replacement of coarse aggregate. Tests on the compressive strength at 7 days and 28 days, flexural strength, water absorption and Rapid Chloride Ion Penetration Test (RCPT) at 28 days are to be conducted on the paver blocks.

3. Selection of Materials

3.1 Sludge

The industrial sludge samples were collected at the CETP from waste water treatment unit from textile industry. The sludge, which requires proper handling and disposal, was examined in this study for reuse of construction industry. The textile sludge was obtained from the Veerapandi combined effluent treatment plant (CETP), Tirupur town, Tirupur district, Tamilnadu State, India. The sludge was collected from the sludge drying beds and land filling areas by Systematic sampling procedure. The sludge had a roughly 30% moisture content. The sludge was dried in a hot air oven for 24 h at 100#C. After drying, the sludge was ground manually in a dry clean steel tray with the use of trowel. The dried sample were then ground in a ball mill for 30 mm to reduce to size of smaller and uneven particle into powder form and then directly used into cement substitute.

3.2 Cement

In this study the OPC 53 grade has been used. For OPC 53 grade Cement, the following tests has been carried out as per IS 456-2000 and conforming to IS 4031 (part1): 1996.

3.3 Steel slag

Steel slags are the byproducts of steel industries, which form during reduction process of iron melting. The chemical composition of it changes depending to the melting procedure. Its mineralogical composition also varies based on the cooling procedure. Air cooled Steel slag contains significantly higher calcium oxide and iron oxide compared to granite rock. Granite rock contains high silica and alumina content and is generally hydrophilic. Physical and chemical compositions were studied in this study.

Table 1: Physical properties of steel slag

Property	*Value*
Specific Gravity	> 3.2 - 3.6
Dry rodded Unit Weight, kg/m3	1600 – 1920
Water Absorption	up to 3%

Table 2: Mechanical Properties

Property	*Value*
Los Angeles Abrasion	20 – 25
Sodium Sulfate Soundness Loss	<12
Angle of Internal Friction	40° - 50°
Hardness	6 – 7

Table 3: Chemical composition given from lab

Constituent	*Composition (%)*
Aluminum oxide (Al_2O_3)	1-3
Calcium oxide (CaO)	40-52
Chromium oxide (Cr_2O_3)	-
Iron oxide (FeO)	10-14
Magnesium oxide (MgO	5-10
Manganese oxide (MnO)	5-8
Phosphorus oxide (P_2O_5)	0.5-1
Potassium oxide (K_2O)	-
Silicon oxide (SiO_2)	30-35
Sodium oxide (Na_2O)	-
Titanium oxide (TiO_2)	-
Water Absorption	0- 3
SSD Specific Gravity	3.2-3.6

3.4 Quarry dust

The Quarry Rock Dust obtained from local resource was used in concrete and also conforming to grading zone I of IS 383-1970 (BIS, 1970) was used in this experimental work. For quarry dust test has been carried out and conforming to IS 2386 (part I)-1963.The physical and chemical properties of Quarry Rock Dust were obtained by testing the samples as per Indian Standards.

3.5 Fine aggregate (Natural river sand)

River sand having density of 1460 kg/m3 and fineness Modulus (FM) of 2.51 was used. The specific gravity was found to be 2.6.

3.6 Coarse aggregate

Natural granite aggregate having density of 2700kg/m3 and fineness modules (FM) of 6.80 was used. The specific gravity was found to be 2.60 and water absorption as 0.45%.

3.7 Water

The Water used for mixing concrete should be portable drinking water having pH value of 7 and the water is free from organic matter and the solid contents should be within the permissible limits as per IS 456-2000 & and conforming to IS 3025.1964.

3.8 Mix proportions

Trial mixes were carried out with different mix proportions of cement, fine aggregate and coarse aggregate where fine aggregate includes 75 percentage of quarry dust and 25 percentage of sand. Compressive strength test was carried out at 28 days for the trial mixes and the appropriate mix ratio was selected for M50 grade (Mix ratio: 1:1.6:1.4 (w/c ratio =0.32)) from the results obtained. For the present study, twenty five batches were prepared. Paver blocks were cast with sludge as cement replacement material at zero, 10, 20, 30, 40 percent and Steel slag at zero, 10, 20, 30, 40 percent as coarse aggregate replacement for the above combinations. Steel slags were tried up to 100% replacement of coarse aggregate. The mix proportions are given in the table 6.

Table 4: Mix proportions

Batch no	*Cement (%)*	*Textile (%)*	*Steel slag*	*Batch no*	*Cement (%)*	*Sludge (%)*	*Steel slag*
1	100	-	-	14	90	10	20
2	100	-	10	15	90	10	30
3	100	-	20	16	90	10	40
4	100	-	30	17	80	20	0
5	100	-	40	18	80	20	10
6	100	-	50	19	80	20	20
7	100	-	60	20	80	20	30
8	100	-	70	21	80	20	40
9	100	-	80	22	70	30	0
10	100	-	90	23	70	30	10
11	100	-	100	24	70	30	20
12	90	10	0	25	70	30	30
13	90	10	10	26	70	30	40

3.9 Casting and testing

Moulds of size 200mm × 120mm × 60mm were used for the preparation of the rectangular test specimens. First the materials required like cement, sludge, fine aggregate, coarse aggregate, steel aggregate, quarry dust are taken in the required designed amount and mixed together by adding required water. The hydraulic compressive load was applied on the mould. The specimen was de moulded and cured.

4. Results and Discussions

The compressive strength was found in a compression testing machine as per BIS specifications. For various percentages of sludge eight samples were made and subjected to a compressive strength test after the 7 days and 28 days curing period and average strengths were obtained as shown in the table 2, 3, 4, 5, 6 and 7. These results shows the compressive strength decreases where adding the textile sludge partially replacement of cement. Addition of steel slag causes increase in the compressive strength up to 60% and keeps on decreasing from 70% to 100 %.

From the Figure 2, it was found that the compressive strength at 7 days and 28 days decreased when the percentage of sludge was increased from 0 to 40%. IS 15658:2006 recommends a minimum strength of 30 MPa for the paver blocks to use in Building premises and public gardens/parks. Hence from the test results obtained, for combinations with sludge up to 30% satisfied the above requirements.

Further it was concluded that all the combinations were satisfied the minimum strength requirements of 30 MPa as per IS 15658: 2006.Therefore the optimum percentage of sludge we can use may be up to 30%.In all the combinations of steel slag with sludge we get more than the minimum strength 30MPa for the paver blocks as per IS 15658:2006.

All the Mix combinations have satisfied the minimum requirement and it can be used for paver block production. The flexural strength for the paver blocks are around 800 psi (6MPa). This shows that the paver blocks with steel slag aggregates and sludge performs well. Thus the paver blocks from these mix combination can also be used for residential driveways, light vehicle/public pedestrian and commercial paths.

The rapid chloride penetration tests are conducted on the specimen and results are shown in the table. This clearly shows that the chloride penetration very low up to 80 % of steel slag replacement and for 100% we obtain low chloride penetration value. This proves the paver blocks are durable enough if we use steel slag as aggregate.

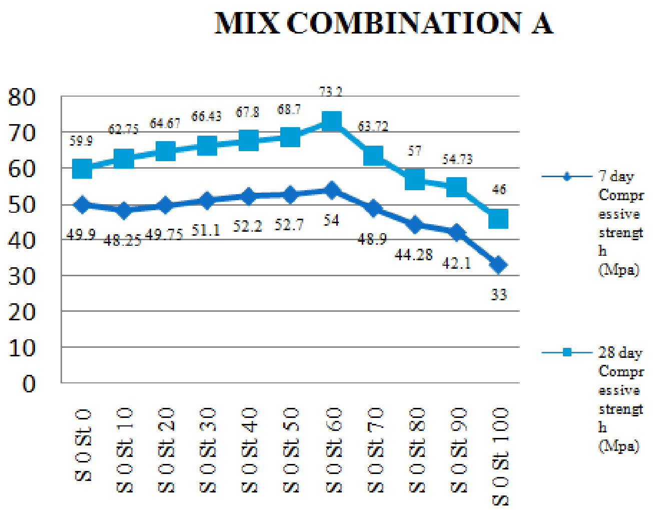

Figure 1: Compressive strength (Steel slag 0 to 100%)

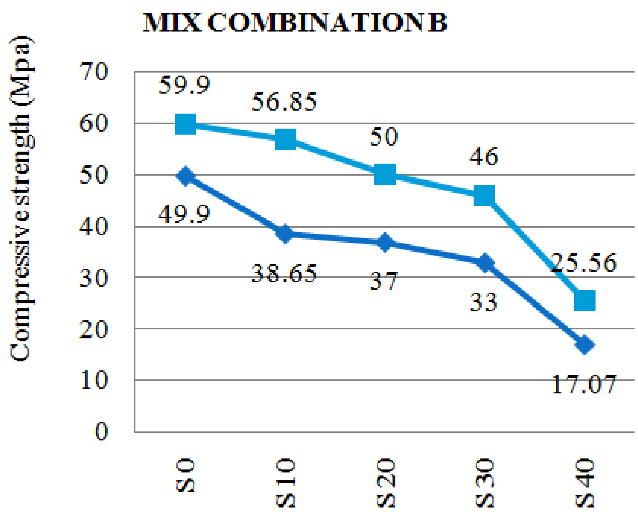

Figure 2: Compressive strength (Sludge 0 to 40%)

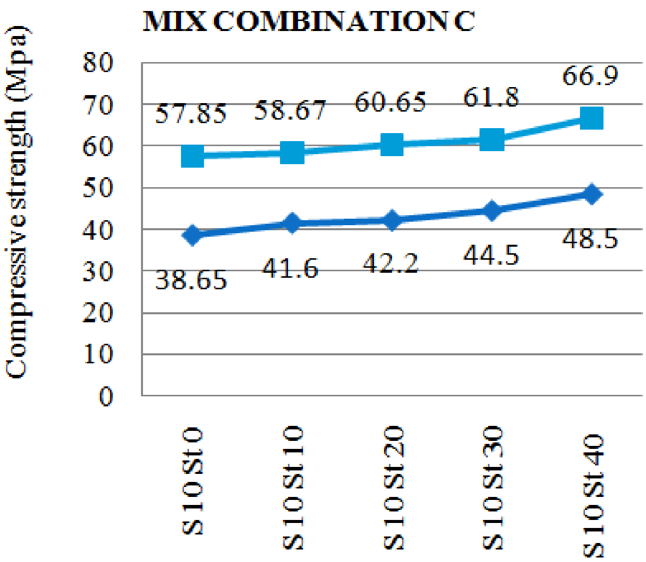

Figure 3: Compressive strength (sludge 10% & steel slag 0 to 40%)

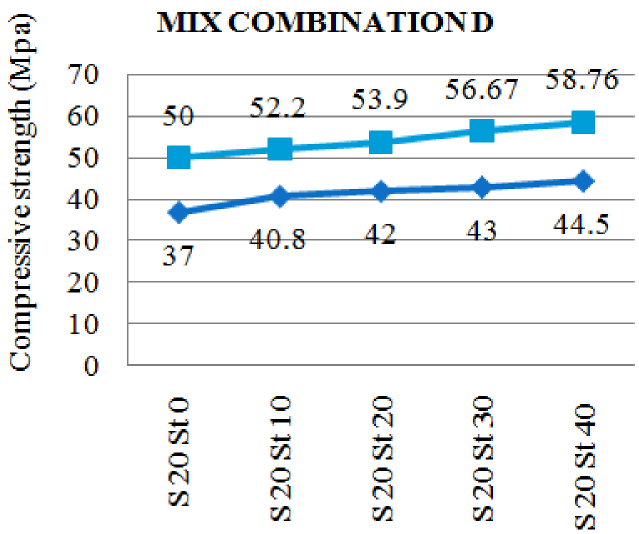

Figure 4: Compressive strength (Sludge 20% & Steel Slag 0 to 40%)

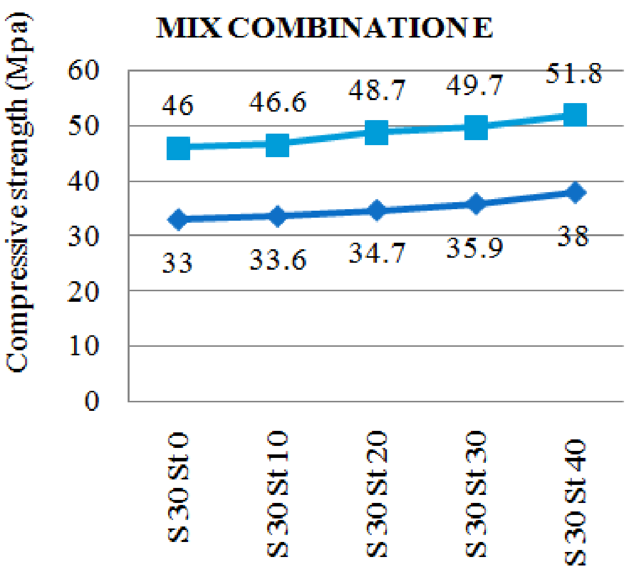

Figure 5: Compressive strength (sludge 30% & steel slag 0 to 40%)

Flexural Strength Test

The variation of flexural strength at 28 days of the paver blocks are shown below.

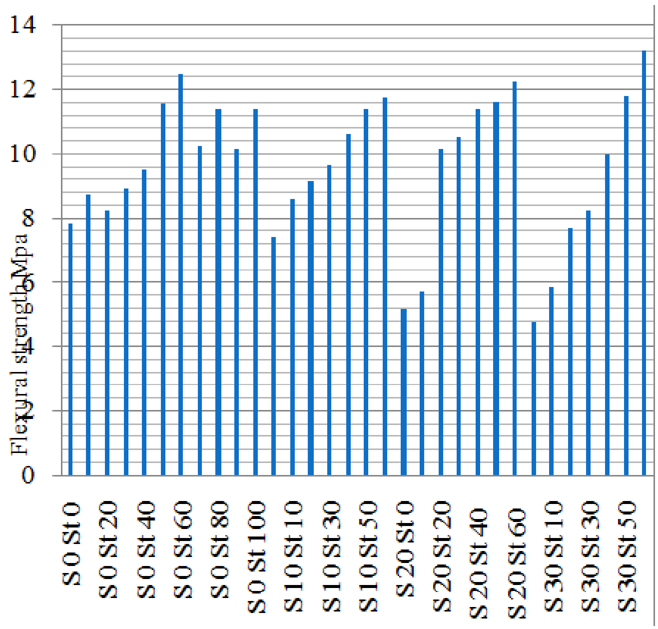

Figure 6: Flexural Strength Vs Mix Combination

Table 5: Chloride Ion Penetration Test readings

Mix combination	*Charge passed (coulombs)*	*Chloride ion penetrability*
S 0 St 0	54	Negligible
S 0 St 10	48	Negligible
S 0 St 20	63	Negligible
S 0 St 30	51.1	Negligible
S 0 St 40	90	Negligible
S 0 St 50	663	Very Low
S 0 St 60	709	Very Low
S 0 St 70	846	Very Low
S 0 St 80	950	Very Low
S 0 St 90	1499	Low
S 0 St 100	1874	Low

5. Determination of Heavy Metals by Atomic Absorption Spectrophotometer (AAS)

The leaching of heavy metals presented in the textile sludge based paver blocks was estimated by TCLP test. Heavy metals such as cadmium, mercury, copper, nickel, chromium were estimated in the TCLP leachate of the sample. Table 8 shows the heavy metal concentration in the TCLP leachate of sample.

Table 6: Test results on heavy metals by AAS

Contaminants	*Regulatory limit mg/l*	*Concentration in the TCLP leachate of Paver block Sample mg/l*		
		Sludge 10%	*Sludge 20%*	*Sludge30%*
Cadmium	1.0	0.387	0.543	0.882
Mercury	0.2	BDL	BDL	BDL
Copper	--	0.054	0.092	0.127
Nickel	--	BDL	BDL	BDL
Chromium	5.0	BDL	BDL	BDL

BDL- Below Detectable Limit

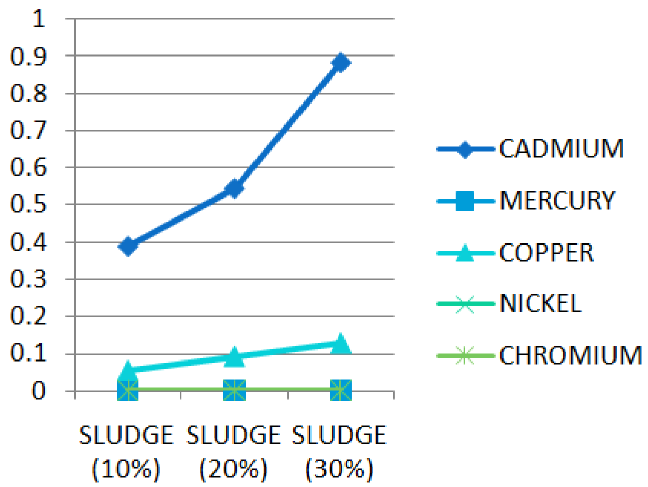

Figure 7: Test results on heavy metals by AAS

The concentration of heavy metals cadmium and mercury present in the leachate paver block samples with 10, 20 and 30% sludge are within the regulatory limits in accordance with US-EPA and the same cannot contaminate the soil structures.

6. Conclusions

From this study, it is possible to conclude that the use of textile sludge up to a maximum of 30%substitution for cement may be possible in the manufacture of non-structural building materials. Steel slag up to a maximum of 60% substitution for aggregate may be possible in the manufacture of non-structural building materials. The use of textile sludge and steel slag in these applications could serve as an alternative solution to disposal. However, the addition of sludge to the cement delays the setting process of the building components. Detailed leach ability and economic studies need to be carried out as the next step of research.

Reference

[1] T Balasubramanian J, Sabumon P.C., John U. Lazar and Ilangovan.R (2006)" Reuse of textile effluent treatment plant sludge in building materials" Waste Management vol-26 ,pp 22–28, 2006

[2] Baskar.R, Meera Sheriffa Begum K.M and Sundaram S (2006),"characterization and reuse of textile effluent treatment plant waste sludge in clay bricks" Journal of the University of Chemical Technology and Metallurgy, 41,pp:473-478, 2006

[3] Hema Patel and Suneel Pandey (2009) "Exploring the Reuse Potential of Chemical Sludge from Textile Wastewater Treatment Plants in India-A Hazardous Waste "American Journal of Environmental Sciences 5 (1): pp:106-110, 2009

[4] Lewis D W, February,(1982) (Statistical updates for 1992 have been provided) investigated the, "Properties and uses of iron and steel slags" Journal by national slag association Vol no-18,pp:24-30, 1982

[5] Emery J J, Prepared For Concrete International, 1980,London, April 13-18/80 "Pelletized lightweight slag aggregate" Journal of Environmental engineering 24 ,pp 111-116, 1980