Feasibility Study on Utilization of Compost as a Partial Replacement of Fine Aggregate in Conventional Concrete

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Abstract. Solid waste management is the biggest challenge due to population growth. Lack of awareness about onsite processing of solid waste implies production of huge quantity of solid waste which is unmanageable. In this study an attempt is made to utilize the degraded solid waste called compost which is collected from municipal site and is used as a filler material in concrete. Compost is replaced for fine aggregate with 5%, 10%, 15% and 20% in conventional concrete. The compressive strength results at the age of 28 days are 30.5, 19.8, 16.8 and 18.2 N/mm2 respectively. Result indicates 5% replacement of compost is effective in concrete. The concrete specimen made with compost (CVC) and conventional concrete (CC) are exposed to an elevated temperature of 200°C, 400°C, 600°C and 800°C respectively. Result indicates the conventional concrete shows 5.3%, 6.1%, 15% and 24% compressive strength loss whereas 5% compost replaced specimen shows 10%, 11 %, 23.2% and 58.2% respectively. At an elevated temperature, both conventional concrete and compost-based concrete lost its strength. The reason could be thermal incompatibility between the aggregates and concrete. However, the loss of compressive strength is almost double in CVC than CC. The possible reason could be volatile compounds may evaporate in CVC at high temperature. The weight lost is observed in CC varies from 2.4 % to 4.5 % whereas CVC shows 6% to 7% from 200°C to 800°C. Weight lost is 3% more in CVC specimen than CC specimen.

Introduction

Concrete is considered as composite material which consists of cement, fine aggregate, coarse aggregate and water and it is used all over the world. Every material in concrete plays a vital role in making structure strong. For example cement binds all the material together and brings hardened structure. Coarse and fine aggregate fill the pores in concrete. Particularly fine aggregate fills fine pores in concrete thus making structure impermeable. Coarse and fine aggregate occupies 70% of total volume in concrete [1]. Common river sand is used as fine aggregate in concrete. Over exploitation of river sand affects natural resources, river bed and its eco system. Currently manufactured sand (M sand) is a quarry dust replaces river sand which is obtained from crushing of stone. If the same condition persists, there is a demand for M sand may occur in future.

Effective solid waste management is major important problem in India. Lack of responsibility is major reason for production of more volume [2]. Improper disposal leads dangerous problem such as unhygienic condition, stagnation of rain water, mosquito breeding, attractive to rats, odour problem, spreading of diseases, affecting cattle and ground water contamination. A priority is to move from waste dump to waste management system [3]. Most of the time liners are damaged in waste dumpsite and affect ground water nearby. Sustainable and maximum resource extraction from waste is an urgent requirement in current scenario for protecting the environment [2,4]. It is an urgent need to utilize the solid waste for useful purposes continuously for solving these issues. In recent past, the waste material from one industry can be used as a raw material for other industry. For instance, bagasse waste from sugar industry is used as a raw material in thermal power plant industry, paper and pulp industry, agricultural fertilizer etc. Similarly fly ash from thermal power plant is used as a raw material for replacement of cement in construction industry, soil amendment in agricultural sector.

Many of the researches are moving towards utilization of waste from industries and agro waste for building construction [1,5]. Many researchers used rice husk ash, bagasse ash, groundnut shell ash for replacing cement [6,7,8]. Many researches had undergone their research by replacing fine aggregate in concrete [1,5]. For instance, the waste product from ceramic industry is used as a fine aggregate in building construction [9]. [10] used bio deposited recycled mortar aggregate in building construction. [11] used construction and demolition waste as fine aggregate in building construction. Some researchers attempted to utilize agro waste for building construction. For instance [12] used ground shell ash for sand. Ganion 2014 used partially replaced saw dust as fine aggregate in concrete. Table 1 shows different waste materials used for replacing fine aggregate.

Table1 Waste material used for fine aggregate in building construction

Author	Material Replaced	Remarks
[14]	Fine Aggregate - Partial replacement of waste glass powder	In this work fine aggregate is partially replaced with glass powder with 2 and 2.5%. The compressive strength is linearly increases upto 2 % and then decreases.
[15]	Fine Aggregate -Partial replacement of ceramic waste	Ceramic waste is replaced for fine aggregate with 20%, 25%, and 30% in concrete. Compressive strength at 20% replacement is high.
[5]	Fine Aggregate -Partial replacement of agro - waste.	In this review article different waste such as bagasse ash, sawdust ash, and oyster shell, ground nut shell, rice husk ash, tobacco waste and giant reed is replaced for fine aggregate and optimal replacement is given.
[16]	Fine Aggregate -Partial replacement of paper sludge.	Her paper sludge is replaced for fine aggregate. The optimal proportion is 5% to 10% respectively
[13]	Fine Aggregate - Partial replacement of Saw dust	In this study saw dust is used as fine aggregate. It is recommended to use in interior walls of the buildings. The sawdust reduces 56% of the total cost.
[17]	Fine Aggregate - Partial replacement Cork	Cork is used for replacing fine aggregate and cork has low thermal resistance and good sound absorption.

[18]	Fine Aggregate - Partial replacement Groundnut shell	Ground nut shell is replaced at 0, 5, 15, 25, 50 and 75% with fine aggregate.
[19]	Fine Aggregate - Partial replacement of Compost	In this compost is replaced for portland cement

According to planning commission report 2014, in the year 2011, the number compost unit is 162 and vermi compost unit is 24 in number in Tamilnadu and it ranks first all over India in municipal solid waste processing facilities [2]. In this study an attempt is made to utilize homogeneous compost obtained from municipal solid waste is used for fine aggregate in building construction. The different percentage such as 5%, 10%, 15% and 20% replacement of compost with fine aggregate is made and compressive strength study is made. The concrete is exposed to elevated temperature mainly because the replaced material is organic in nature.The behavior of compost based concrete specimen at an elevated temperature is necessary for this study. The weight loss and compressive strength loss in concrete cube at an elevated temperature is studied.

Methodology

Collection of materials

The materials namely cement, fine aggregate, coarse aggregate, compost and water is used in this study. The basic properties are tested in the laboratory. The specific gravity of the cement is 2.22. The fine aggregate used here is manufactured sand (M Sand). It is obtained from local stone crushing factory. The compost is obtained from local solid waste decomposing plant. Coarse aggregate is obtained from stone crushing factory. The size of the stone used here is passing 22.5mm and retaining in 20 mm sieve. Table 2 shows the physical properties of materials used in the study.

Table 2 Characteristics properties of raw materials used for this study

S.No	Test	Coarse aggregate	Fine aggregate	Compost
1	Specific gravity	3.116	2.33	1.76
2	Fineness Modulus	2.985	4.56	1.77
3	Water absorption (%)	0.81	4.35	2.26

Mix Design

Mix design is an important procedure to attain the maximum strength. Based on the value obtained from the material property tests the mix design was calculated as per IS codal provision of 10262 for M30 grade concrete. Table 3 shows the mix proportion of replacement of compost in conventional concrete.

Mixing and casting

Improper mixing leads to low strength and less durable concrete. First the dry materials like cement, fine aggregate, coarse aggregate and compost mixed thoroughly the water has been added and mixed for another 2-3 minutes. Like mixing, casting also an important, the concrete should be placed into the mould before the initial setting. The concrete cube size of 100mm × 100mm × 100 mm are casted to find out the compressive strength tests.

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Table 3 Mix ratio of conventional concrete with compost

Percentage of compost %	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Compost (kg/m^3)
0%	478.95	529.52	1101.65	0
5%	478.95	503.07	1101.65	26.45
10%	478.95	476.62	1101.65	52.9
15%	478.95	454.17	1101.65	75.35
20%	478.95	423.72	1101.65	105.8

Curing

Curing is supplying water to the concrete for a certain period at different interval. Curing influences the hydration process which improves the strength. There are different methods of curing can be adopted based on the requirement. Water curing is adopted in this work. For normal concrete the water curing is done for 28 days and the tests carried out after 28 days of curing period.

Experiment for hardened concrete

The compressive strength of the specimen is tested by Compression Testing Machine. To find the temperature resistance, the cubes are kept in oven at different temperature (200°C, 400°C, 600°C and 800°C) with duration of 2 hours. After that the specimen is kept at room temperature to cool down and their compressive strength and weight loss is tested.

Results and discussion

Effect of percentage replacement on compressive strength

Table 4 shows the compressive strength of CC and CVC specimen. It is found that the compressive strength concrete is 30.5 N/mm^2 at 5% replacement of compost whereas control specimen shows 29 N/mm^2. It is almost 2 N/mm^2 more than control specimen. The reason could be compost may fill the minute pores which is present between fine aggregate and coarse aggregates. However 10%, 15% and 20% CVC specimen shows 19.8, 16.8 and 18.2 N/mm^2 respectively. The possible reason could be there is minimum binding between aggregates; compost and cement may decrease the compressive strength.[20] found the cementitious material like metakaolin, ground granulated blast furnace slag (GGBS), fly ash and silica fume can increase the binding between composite materials in concrete.

Table 4 Compressive strength results

S.No	% Replacement	Compressive strength (N/mm^2)
1	0	29.0
2	5	30.5
3	10	19.8
4	15	16.8
5	20	18.2

Effect of compressive strength loss and weight loss at an elevated temperature

To improve the serviceability of building, the building material should be tested whether it resists fire during accidents. It is decided that compost based specimen and conventional concrete specimen are subjected to an elevated temperature. The CC specimen and 5% replaced CVC specimen which gives maximum compressive strength are subjected to an elevated temperature of 200 °C, 400 °C, 600°C and 800°C temperature is shown in Table 5 and Fig.1. It is found that the compressive strength reduction at 200 °C in control specimen and CVC specimen are 5.3% and 10% respectively. The compressive strength reduction at 400°C in CC and CVC specimen are 6.11% and 11% respectively. The compressive strength reduction at 600°C in CC and CVC are 15% and 23.2% respectively. The compressive strength reduction at 800 °C in CC and CVC specimen are 24% and 58.2% respectively. It is found that at all higher temperature the compressive strength reduction is obtained in both CC and CVC specimen. Arioz O (2007) observed the strength of the concrete decreased when the temperature is increased. The reason could be difference in thermal expansion between aggregates and binder, decomposition of cement paste, degradation and phase decomposition of aggregate [22,23]. At higher temperature the physical, chemical and mechanical properties of concrete is affected [22,23]. At higher temperature the bond between aggregates and cement may broken and loss of compressive strength may occur. Demerial B 2010 found above 600°C degeneration of CSH (Calcium Silicate Hydrate) gel increases amount of air voids and formation of more pore structure in the specimen thereby decreases the transmission of sound and the value of ultrasonic pulse velocity while experiment is conducted.

It is noted that the compressive strength lost is more in CVC specimen than CC specimen. The loss is almost double in CVC specimen than CC particularly at 200 °C and 800°C. In compost based specimen, at an elevated temperature of 800° C, the volatile organic compounds may evaporate thereby increases more spaces. Another reason could be the weight lost in more in CVC specimen than CC specimen causing decrease in strength (Table 6).

Table 5. Reduction of compressive strength at an elevated temperature

Temperature (°C)	Loss of compressive strength (%)	
	CC	CVC
200	5.30	10.00
400	6.11	11.00
600	15.00	23.20
800	24.00	58.20

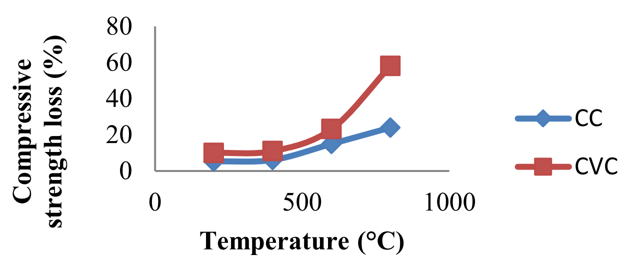

Fig.1. Loss of compressive strength in CC and CVC specimen

Study of weight lost at an elevated temperature
Table 6 and Figure 2 shows the weight lost in CC and CVC specimen at different temperature. From table 6, the weight lost of CC specimen at 200°C is 2.45%. After that, the CC specimen is exposed to 400°C, 600°C and 800°C the weight lost is 3.09, 3.3 and 4.55% respectively. The CVC specimen gives 6.11 % weight lost at 200°C. After exposed to 400°C, 600°C and 800°C the weight lost is 6.5, 6.5 and 7.1% respectively. There is no abrupt change is weight lost is observed beyond 200°C. From Fig. 2, the weight loss is more in CVC specimen than CC specimen. In CVC specimen the weight lost is almost 3% higher than CC specimen at all temperature. [22] found when the concrete is subjected to an elevated temperature; the weight is significantly reduced in conventional concrete after 800°C.

Table 6.Weight loss at an elevated temperature

Temperature (°C)	Weight loss (%)	
	CC	CVC
200	2.45	6.1
400	3.09	6.5
600	3.3	6.5
800	4.55	7.1

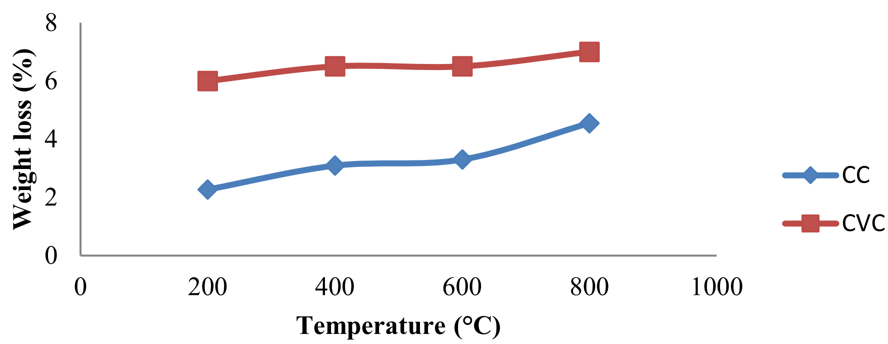

Fig.2 Weight loss in CC and CVC specimen

Tuffail M and Gentcturk B 2017 found free water will expel at 105°C. The dehydration of hydrous calcium aluminium sulfate mineral will occur at the temperature of 80 to 150°C. At 150°C to 170°C, gypsm will be degraded. The degradation of CSH will takes place beyond 400°C. The second phase of CSH decomposes at 600°C to 800 °C forming β-C_2S. The breakdown of CSH is fully occurring at the temperature of 900°C. The dangerous and crucial temperature for concrete is from 400°C to 900°C. In the particular temperature range, the concrete almost lost its strength.

Conclusion
In this study the following conclusion are arrived

1. The compressive strength of concrete and compost based specimen are 29 N/mm^{2}and 30.5 N/mm^2 respectively. Result shows 5% replacement compost in concrete shows encouraging results.
2. At higher temperature the decrease of compressive strength in CC and CVC specimen is observed. Also in CVC specimen, the loss is double than CC. This may be due to escaping

of volatile organic compounds at higher temperature. Another reason could be thermal effect create cracks in concrete by breaking the bond between composite material in concrete thus results reduction in compressive strength. To increase the binding properties between aggregate, cement and compost, pozzolanic material like GGBS, Fly ash, Metakaolin or silica fume can be added for improving the strength.

3. The weight lost of CC and CVC occurred at an elevated temperature. Weight loss is 3% more in CVC than CC.

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