REPLACEMENT OF FINE AGGREGATE

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ABSTRACT-Environmental concerns arising from the over-dredging of sand have led to restriction on its extraction across India, with direct economic impacts on concrete construction. A suitable environmentally friendly alternative to fine aggregate must be found to match the huge demand from concrete construction industry. In this work the fine aggregate is replaced by titanium-di-oxide, slag and PET bottle individually. This industry and plastic waste are rarely recycled. These materials degrade at extremely low rates meaning they persist in the environment is a long-term environmental concern. To tackle both the issues, it is proposed to process waste to create a partial replacement for fine sand in a concrete. A new concrete mixes are evaluated to study different composition & different replacement ratio, helps us to establish an appropriate choice of material to act as partial replacement of sand. The result shows that replacement of fine aggregate with volume of plastic decrease the unit weight of concrete, and there decreasing the compressive strength and tensile strength. The concrete incorporated copper slag and ferrous slag with 100% replacement ratio exhibit a slight bleeding and mechanical properties are constantly increasing. Then the replacement ratio of 80% was found to be effective. The photocatalytic concrete exhibits increasing mechanical strength and in control of pollution. Therefore, it was concluded that use plastic and industry waste provides some advantaged i.e. reduction in use of natural resources, disposal of wastes, prevention of environmental pollution, and energy saving.

Keywords—Recycled aggregate concrete – PET bottles – TIO2 – copper slag and ferrous slag - mechanical strength and durability.

I Introduction

The modern life style along with the new technologies caused more waste materials productions for which the disposing problem exist. Most of the waste materials are non-disposal and remain for hundreds and thousands of years in the environment. These non-biodegradable waste materials along with population growth have caused the environmental crisis all around the world. Many of them are stuffed in the dump place or they are outpoured in the dustbins illegally. Due to increase in production of day to day disposal goods, waste disposal management has become a major environmental issue in the world. Lack of proper waste disposal management causes environmental pollution and may cause detrimental effects on soil.

It is becoming increasingly important to manage and treat both the solid waste generated by industry and municipal waste. This waste ranges from the relatively inert glass bottle, excavated soil, demolition waste, to hazardous waste with high concentration of heavy metals and toxic organic compound. It plays a substantial role in concrete properties such as workability, strength, dimension stability and durability. The use of waste materials as aggregate in concrete preparation can consume vast amount of waste materials. This can solve problems of lack of aggregate mining and waste disposal. There is a growing interest in using waste materials as aggregate and considerable research undertaken to use different materials as aggregate substitutes. Among the material, we use PET bottle, TiO_2, copper slag and ferrous slag.

PET-polyethylene terephthalate (PET) bottles have taken the place of glass bottles as storing vessel of beverage due to its lightweight and ease of handling and storing. As the beverage consumption increases drastically, the production of PET bottles increased exponentially as it was reported that PET bottles were produced about 87,000 tons. Plastics based on polymers can be broadly classified into two categories, thermoplastic and thermosetting plastic. Thermoplastics, such as polyethylene (PE), polystyrene (PS), polypropylene (PP), polyethylene terephthalate (PET), and high density polyethylene (HDPE), can be melted through heating and hardened by cooling. On the other hand, thermosetting plastics cannot be melted or softened through heating. Polyethylene terephthalate (PET) is a semi crystalline polymer with high mechanical strength and toughness as well as hydrolytic, chemical and solvent resistance. It is widely used in packaging industries (i.e. pharmaceuticals and food products) and drinking bottles production. It is also used as precision moldings for office and domestic appliances, automobile parts and electronic devices in the manufacturing process. Because of the convenience of using PET bottles, the demand Is ever increasing. However, managing these large amounts of plastic wastes becomes a major concern for the environment. As such, it has become a significant issue of minimizing and/or reusing these waste products in various applications. These PET bottles are crushed compressed into bales. And this bales are send to recycling industry where they are shredded into small fragments. Application of waste PET bottles as various forms of filler materials in concrete have been explored, thus creating the opportunities for reusing these waste materials in concrete. Other options have been developed and adopted in reusing waste PET bottles as aggregates in mortars and concrete composites. The majority of these studies related to reusing waste PET bottles as a partial and/or full replacement of fine aggregate (sand) in both mortar and concrete Lightweight aggregate is an important material in reducing the unit weight of concrete complying with special concrete structures of large high-rise buildings. All of these studies concluded that the increase in volume replacement of PET aggregates showed a declining trend in the compressive strength of the concrete regardless the consistency of the water-cement ratio. The major advantage of using waste PET bottles as aggregates is the reduction of the self-weight of the concrete because of its low unit weight. This study will examine the physical and mechanical properties of concrete with melted waste PET bottles as fine aggregates.

TiO2- The use of titanium dioxide in the construction industry to improve the performance of different materials due to their self-cleaning and pollutant degrading capacities is continuously growing and extensively being applied. In fact, several applications such as soundproof walls, tunnels coverings or pavements in the road constructions field, tiles, wallpaper, windows, paints or coatings as interior furnishing materials and glass, plastics films, paints or panels as exterior protective envelopes are already being tested under real conditions and even commercially employed. TiO2 is well known for its pigment, the whiteness of which is incomparable with other materials. A great deal of attention as a “Photo catalyst” with various positive effects, such as purification, gas decomposition, brightness retention and self-cleaning, which can keep the buildings appearance clean without any maintenance. In this study, in order to clarify the basic properties of mortar and concrete using TiO2.

SLAG- Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially; the sustainable development for construction involves the use of non•conventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. So it is possible to utilize industrial by•products as well as other waste material in the production of normal concrete and high strength concrete when used as partial and/or full replacement of fine aggregate. Also, it has been demonstrated that many of the produced concrete (either normal or HSC) made with wastes and industrial resources possesses superior properties compared with the conventional concrete in terms of strength, performance and durability. CS is a by•product material produced from the process of manufacturing copper. It is totally inert material and its physical properties are similar to natural sand. FS is a by•product in the manufacture of pig iron and the amounts of iron and slag obtained are of the same order. The slag is a mixture of lime, silica, and alumina, the same proportion. The composition of FS is determined by that of the ores, fluxing stone and impurities in the coke charged into blast furnace. Currently, about 2600 tons of CS is produced per day and a total accumulation of around 1.5 million tons. This slag is currently being used for many purposes ranging from land•filling to grit blasting. These applications utilize only about 15% to 20% and the remaining dumped as a waste material and this causes environmental pollution. CS is a glassy granular material with high specific gravity. Particle sizes are of the order of sand and have a potential for use as fine aggregate in concrete. In order to reduce the accumulation of CS and also to provide an alternate material for sand. FS, although is an industrial by•product, exhibits well bonding properties. It permits very high replacement of sand and extends many advantages over conventional cement concrete. The utilization of FS as a sand replacement material is gaining importance due to its improved strength characteristics in concrete composites and also due to the economy achieved. The chemical composition of FS is similar to that of river sand. The performance of slag largely depends on the chemical composition, glass content and fineness of grinding. In India, we produce about 7.8 million tons of FS. All the FS is granulated by quenching the molten slag by high power water jet, making 100% glassy slag granules of 0.4 mm size. Indian FS has been recently evaluated. The use of slag leads to the enhancement of intrinsic properties of concrete in both fresh and hardened conditions. The major advantages are reduced heat of hydration, refinement of pore structures, and reduced permeability to the external agencies and increased resistance to chemical attack.

II Literature review

Frigione studied substitution of 5% of fine aggregate with the same weight of PET aggregates which are made from unwashed PET bottle wastes. The results show that unwashed PET with the 300 kg/m3 –400 kg/m3 cement content and 0.45–0.55 water to cement (w/c) ratios has approximately the same slump as the ordinary fresh concrete. In addition, compressive and tensile strength of this kind of concrete are slightly lower than the reference sample, while it has smaller modulus of elasticity; which is equivalent to more plasticity.

Albano et al. investigated the mechanical behavior of the PET waste particles in which, the volume substitution ratios were 10% and 20% and the average PET particle size were about 0.26 cm and 1.14 cm. The results show decrease in compressive strength, tensile strength and modulus of elasticity. Adding PET to the concrete mixture leads to decrease in concrete rigidity; which is useful when flexibility of the material is needed. According to non-destructive tests, adding PET particles to the concrete mixture results in reduction of slump, increase of water absorptions, and also reduction in propagation rate of ultrasonic pulse.

Akçaozoglu et al. examined the effect of PET waste particles as aggregate on two groups of mortars. One of them was entirely made of PET aggregates and the other one was made of both sand and PET aggregates. The results show that the unit weight, compressive strength and tensile–flexural strength of the mortars including PET aggregates are less than the mortars contain combination of both sand and PET aggregates. Both mortars had much lower unit weight, compressive strength and tensile–flexural strength compared with reference sample mortars.

Pawel sikora et al. In this study, the self-cleaning properties and strength development characteristics of mortar containing waste glass and nanomaterials (Nano silica – $NSiO_2$ and titanium dioxide – TiO_2) are analyzed in terms of waste glass content and the effectiveness of commercially available nanomaterials. Quartz sand is replaced with brown waste glass at ratios of 25%, 50% and 100% by weight. The photo-degradation of the Rhoda mine B test has been conducted to analyze the effect of titanium dioxide, Nano silica and waste glass presence in the cement mortar for its potential application in self-cleaning façades. Studies have shown that waste glass can act as a successful replacement for sand, especially when mixed partially with sand. Additionally, a positive influence of nanomaterials on the self-cleaning and mechanical properties was noted.

Mostafa Jalal et.al It was found that with the aim of energy saving and recycling of waste materials, addition of FA as a natural pozzolan can improve the rheological, mechanical and durability properties of concrete at higher ages. TiO_2nanoparticles as a partial replacement of cement up to 4 wt.% could accelerate C–S–H gel formation as a result of increased crystalline $Ca(OH)_2$ amount at the early age of hydration and hence improve the microstructure of concrete leading to improved durability-related properties and strength enhancement of the concrete

Luigi biolzi et.al The paper presents an investigation on the evolution of the mechanical and chemo-physical properties of a white high performance concrete exposed to the elevated temperature of 250, 500 and 750c. Based on the experiment, heat treatment to high temperature, profound and irreversible transformation in the materials must be considered in an analysis of residual properties in bending. Testing thermally damaged specimen of similar geometry, the experiments showed that the population of micro cracks evolves depending on thermal incompatibility of constituents and alterations in the material due to heating.

Caliskan and Behnood investigated the compressive strength of normal • strength concrete containing CS coarse aggregate and showed that the compressive strength of CS coarse aggregate concrete was marginally higher than that of limestone aggregate concrete.

Li and Zong also reported that concrete containing copper slag as fine aggregate exhibited similar mechanical properties as that containing conventional sand and coarse aggregates.

John and John have studied on the utilization of induction furnace steel slag/steel slag and inferred that the compressive strength of concrete containing induction furnace steel slag greater than 30% is found to be lower than control mix.

III Materials Used

Cement: OPC 53 grade

Fine aggregate: River sand

Plastic: PET bottle waste

Coarse aggregate: 12mm

Photocatalytic agent: TIO2

Slag: Copper slag and ferrous slag

IV Mix proportion

MATERIALS	MIX RATIO	CEMENT	FA	CA	WATER
PC	0%	3.427	5.9	5.34	1.62
PET	10%	1.85	0.246 2.952	2.8	1.05
	15%	1.85	0.369 2.829	2.8	1.05
	25%	1.85	0.615 2.583	2.8	1.05
TiO2	5%	3.427	0.295 5.60	5.34	1.62
	8%	3.427	0.472 5.42	5.34	1.62
	10%	3.427	0.59 5.31	5.34	1.62
SLAG	50%	3.427	2.95 1.475 1.475	5.34	1.62
	80%	3.427	1.18 2.36 2.36	5.34	1.62
	100%	3.427	0 2.95 2.95	5.34	1.62

For Cube

MATERIALS	MIX RATIO	CEMENT	FA	CA	WATER
PC	0%	2.913	5.019	4.543	1.272
PET	10%	2.913	0.5019 4.517	4.543	1.272
	15%	2.913	0.752 4.267	4.543	1.272
	25%	2.913	1.254 3.765	4.543	1.272
TiO2	5%	2.913	0.250 4.769	4.543	1.272
	8%	2.913	0.401 4.618	4.543	1.272
	10%	2.913	0.501 4.517	4.543	1.272
SLAG	50%	2.913	2.509 1.25 1.25	4.543	1.272
	80%	2.913	1.004 2.007	4.543	1.272

			2.007		
	100%	2.913	0	4.543	1.272
			2.5		
			2.5		

For Cylinder

V Experimental Method

The properties of natural aggregate, PET aggregate, TIO1, and slag were evaluated according to the procedure defined in various standard test methods.

The concrete mixes were al prepared using the same methods, which implies the use of exactly aggregate grading curve and concrete composition in terms of cement content, coarse aggregate and fine aggregate quantities and slump value. Three different classes of concrete mixes, three types of PET aggregate, TIO2 and slag. For each class the sub-class was prepared by replacing PET by 10%, 15%, 25%, TIO2 by 5%, 8%, 10% and slag by 50%, 80% and 100%.

The concrete mixes were prepared and cast using standard procedures. Slump and density were determined immediately after preparation of the mixes. They are then poured into predefined moulds and their air content was reduced by tamping. The specimen was kept in mould at ambient temperature for 24h to harden before being demoulded and transferred to a humidity chamber for curing for specific period. The 100* 100*100 mm3 cubic specimens were prepared for compressive strength determination; cylindrical specimen 150mm long and 100mm in diameter were prepared for splitting tensile strength.

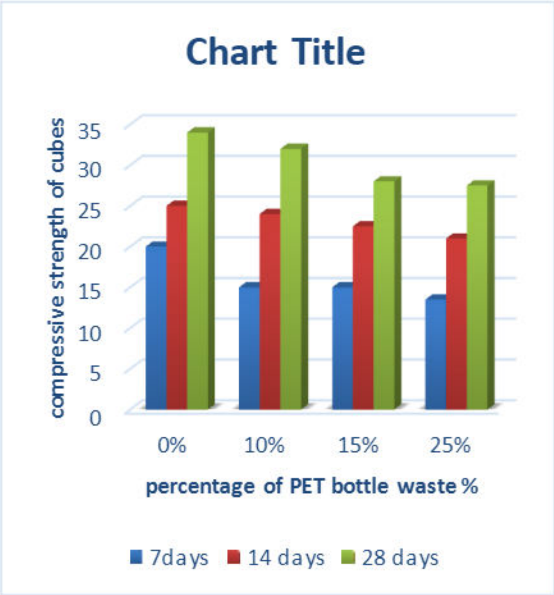
The test method determines the properties of harden concrete. The compressive strength of harden concrete was determined after 7, 14 and 28 days of curing with the use of compression testing machine. Split tensile strength of specimen was determined with the same machine. Durability test was determined by using HCL and NA2SO4.

Compressive strength of concrete

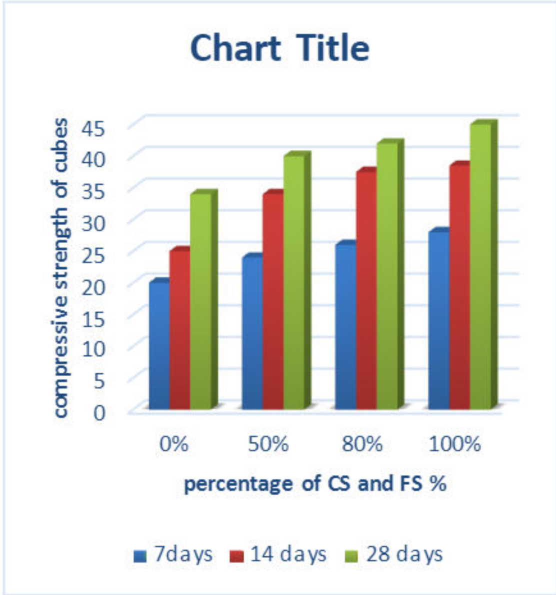
Split – tensile strength

VI Result and discussion

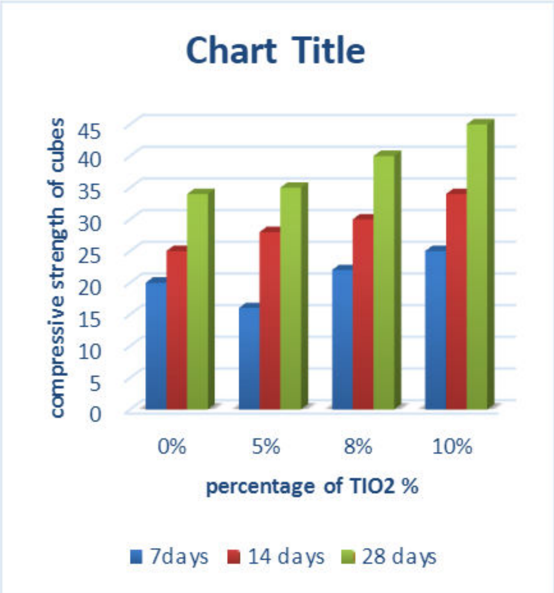
Compressive strength: Compressive strength is defined as force per unit area and given by P/A N/mm2. The chart represents variety of compressive strength of specimen.



Replacement of fine aggregate with pet bottle waste

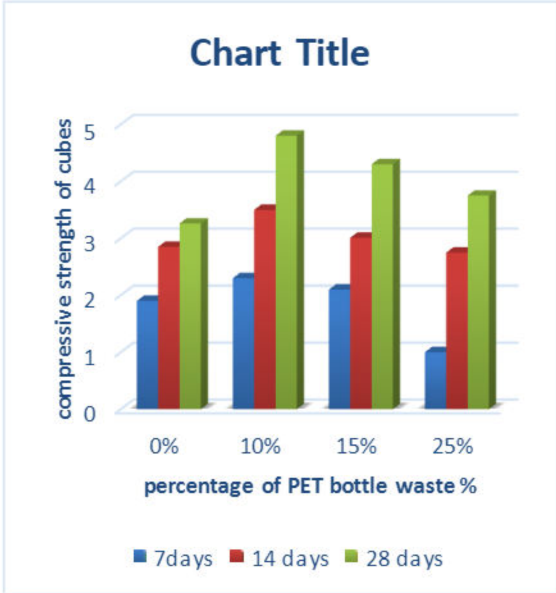


Replacement of fine aggregate with copper slag and ferrous slag

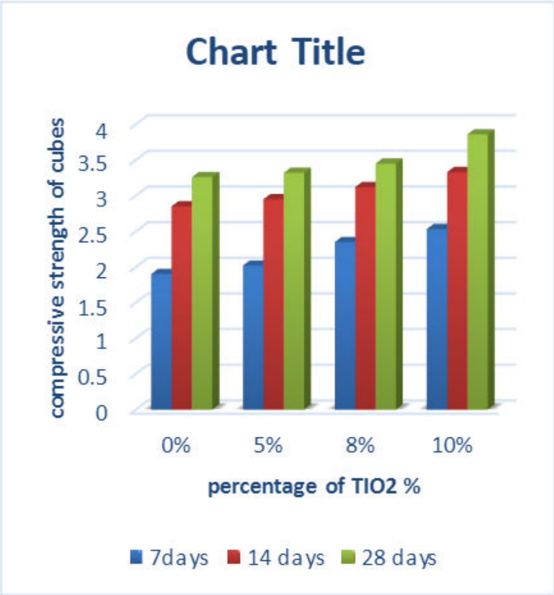


Replacement of fine aggregate with titanium – di – oxide

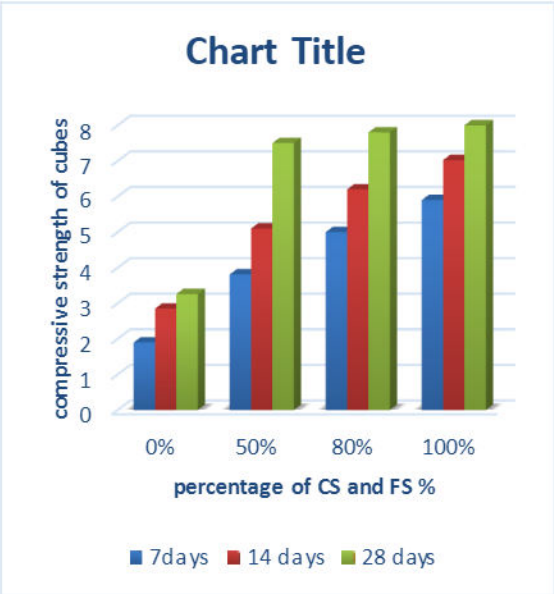
Split – tensile strength: The cylindrical specimen is subjected to testing after 7, 14 and 28 days.



Replacement of fine aggregate with pet bottle waste



Replacement of fine aggregate with titanium – di – oxide



Replacement of fine aggregate with copper slag and ferrous slag

VII Conclusion

The results of this study have led us to reach the following conclusions.

PET:

1. Solid PET waste reduces the unit weight of the concrete.
2. It offered much better workability than the regular concrete aggregate while using same w/c ratio. This provides the opportunity to work with low w/c ratio and get the desired concrete strength.
3. The mechanical properties tend to increase up to 10% of replacement ratio and diminish for 15% and continues as before for 25% substitution. It is concluding that strength decrease with increasing PET ratio.

Tio2:

1. 10% of substitution of TiO2 exhibits greater resistance to brightness degradation.
2. When replacing fine aggregate with TiO2 an increase in compressive strength and split tensile strength is inferred.
3. It has little influence in workability due to its fineness.

Slag:

1. CS and FS concrete show increase in density upto 20% therefore, it increases the unit weight of concrete.
2. The highest compressive strength obtained was 46.5 MPa (100% replacement) and the corresponding strength of controlled concrete was 32.2 MPa.
3. With higher level of replacement 100% the unit weight of concrete increases and there was a slight blending tendency. So it is recommended that replacement of FS and SC shows effective result.

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