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Comparative study of effect on compressive strength by partial replacement of PVC waste with natural coarse aggregate in concrete

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ABSTRACT

With the rising needs for resource materials and the environmental protection desires related with sustainable development, it has become essential to study all the possibilities of reusing and recycling industrial wastes and by-products, particularly in the field of civil engineering. This comparative study is done to investigate the effect on compression strength by partial replacement of PVC waste with natural coarse aggregate in concrete, non-biodegradable plastic aggregates made of polyvinylchloride (PVC) waste, obtained from scrapped PVC pipes. Concrete is a general mixture commonly used in current era for construction of different structures. Concrete cylindrical samples with partial replacement by volume of coarse aggregate with different percentages of shredded PVC waste were casted and then cured for 28 days. After completion of the curing period, concrete cylindrical specimens were tested for compression test. The results revealed that, Based on specific gravity of PVC, lightweight concrete is produced. The data trends shown that compressive strength test results of different percentages of PVC replacement were in contrast with control sample.

Keywords: Concrete, Light weight concrete, PVC waste, Concrete cylindrical samples, Compression strength.

INTRODUCTION

Accumulation of huge quantities of plastic wastes in landfills is becoming one of the major environmental problems, which lead to search for a proper Solid Waste Management System. The quantity of plastics consumed annually all over the world has been growing due to the performance properties of plastic materials in different applications. Polyvinyl chloride (PVC) is among the plastics which used in manufacturing of construction materials such as windows, doors and pipes and others. Data on massive quantities of PVC waste have been land filled is reported. [1]

For example, the quantity of PVC entering the municipal waste stream in Western Europe has been estimated to be about 2 million tons per year. [2]

And about 1737 tons per year are generated from only solid household waste in Tripoli-Libya. [3]

Plastic are normally utilized as a part of bundling, mechanical applications, private and business utilize, sustenance safeguarding, supply of food, medical purposes, sanitary fittings and for transfer of waste. As plastic comprise of various kinds, for example, Polythene, Polyethylene terephthalate (PET), Polyvinyl chloride (PVC), Low density plastic (LDP), High density plastic (HDP), etc. With such an immense number of uses, the yearly utilization of plastic has been expanding quickly. The high utilization and un-disposability of plastic are the elements which cause contamination in the common habitat and have adverse effects on plants, wildlife and human population. [4]

Pakistan annual consumption of plastic resins is over one million tons. The country consumes around 300,000 tons/year of polypropylene (PP) and 280,000 tons/year of polyethylene (PE), its almost entire demand is met by imports, as Pakistan has very small PP or PE production. The total PVC demand in Pakistan is estimated at 70,000 tonnes which is met through imports at a cost of $345 million per annum, such plastics are burned, harmful quantities of dioxins, a group of highly toxic chemicals are emitted. Some chlorinated plastic produce injurious chemicals which can then infiltrate into underground aquifer resulting in the contamination of drinking water. [4]

Countless ocean turtles, whales and other marine warm blooded creatures die every year from swallowing of discarded plastic (plastic packs, plastic containers and so on) for mistaken food. Also, when such plastics are singed, hurtful amounts of dioxins, a group of highly toxic chemicals are emitted. Dioxins are most harmful to the human life forms. As plastic waste is non-biodegradable, so it's reusing is relatively feasible option to reduce the harm initiated by its disposal. [4]

Concrete is for the most part thought to be a weak material in light of its low elasticity. This weak nature of cement can cause unexpected and appalling disappointment, particularly in the structures which are presented to seismic tremors, blasts and suddenly connected burdens.

The aim of this comparative study is to investigate the effect on compression strength due to partial replacement of shredded PVC waste with natural coarse aggregate in concrete.

Although Takenaka Corporation (1999) also advocated that PVC wastes can be treated to form secondary products used in concrete and the waste plastic could reduce the weight of normal concrete by 2–6%, little information is available on the effect of using PVC as aggregates in concrete. This paper reports on a systematic study on investigating the effect of replacing river sand by PVC granules on the fresh and hardened properties of lightweight aggregate concrete.

METHODOLOGY:

Local construction materials have been used in present study.

1) Rigid PVC waste

Rigid polyvinyl chloride waste which was widely used as a virgin in manufacturing of plastic pipes has been selected in this application. This waste was collected from Royal PVC Industry (Industrial state Peshawar). The waste was washed by water to remove dust, dried at room temperature, and then ground to particle size of about 4 mm. The density of the PVC waste was predetermined to be 1.36 g/cm^3.

2) Cement

Ordinary Portland cement had a strength class 42.5N according to the British standard BS EN 197 was purchased from cement shop available in local market and was used in all concrete mixtures.

3) Fine aggregate

The fine aggregate used in this work was natural sand which was obtained from local market (board bazar Peshawar).

4) Coarse aggregate

Natural coarse aggregate used throughout this study was natural stone crushed rock obtained from a local supplier (Bara crush depot). It was classified as number I which has maximum particle size of 1 inch down and bulk density of about 2.64 g/cm^3.

5) Experimental design

Experimental Engineering variables contained different percentages of rigid PVC aggregate ranged from 0% to 25% based on volume of the natural aggregate at constant other composition. These experimental variables indicated how the ratios of plastic aggregate affected the strength of concrete.

6) Casting of concrete cylindrical samples:

Concrete ratio was selected as 1:2.11:2.63 with 0.49 water cement ratio. Then cylindrical samples were prepared with replacement by volume of coarse aggregate with shredded PVC respectively for 28 days curing period and tested for compression (ASTM C39, 2016) by universal testing machine.

Comparative Results and Discussions

Table 1 concrete compressive strength containing PVC waste for 28 days curing period of different percentages studied by the past investigators

Reference	Type of PVC	PVC content	Property studied	Results for various contents
Safeer et al. (2018)	Scrapped PVC Pipes	5%,15%,25%	Compressive strength	5%= 3018.18psi 15%=2768.61psi 25%=2655.49psi
Azad A. Mohammed et al.	Scrapped PVC	5%,15%,25%	Compression	5%=6758.76psi 15%=5769.60psi

(2019)	sheets		strength	25%=5667.80psi
Najjar et al. (2013)	Ground plastic pipes	5%,15%,25%	Compression strength	5%=1991.26psi 15%=1706.80psi 25%=1493.45psi

As it can be seen from the results a gain in the compressive strengths of concrete as plastic is added. Based on specific gravity of PVC, lightweight concrete is produced. Compressive strength test results of 5%, 15% and 25% PVC replacement were in comparison with control sample. (Safeer et al. 2018) [4]

There is a small value of compressive strength and splitting tensile strength loss (not more than 8%) when the coarse aggregate of concrete is replaced by not more than 30% PVC aggregate. Replacement of sand with PVC aggregate is better to control the loss in compressive strength when high ratios of PVC aggregate are used. (Azad A. Mohammed et al. 2019) [5]

The load failure and the compressive strength of the concrete samples decreased slightly (less than 5%) when 5% of natural coarse aggregate volume was replaced by PVC waste in the concrete mixture. Even though the compressive strength of the concrete drops, the concrete material contains PVC waste can be used in certain applications were high strength are undesirable. (Najjar et al. 2013) [6]

And now we're gone to calculate the average results of the compressive strength that how much increase/decrease take place in the strength as same material is used in all three research studies of same proportion (5, 15 and 25%), as it is to be noted that only compressive strength test results are comparatively studied and the replacement of PVC content is done by volume with coarse/fine aggregate.

The following tables show the average values of compressive strength;

Table 2 shows the average comparative results of compressive strength test containing different PVC content percentages

Reference	PVC Content	Property Studied	Type of PVC	Results for various contents	Average Results
Safeer et al. (2018)	5%,15%,25%	Compressive strength	Scrapped PVC Pipes	5%= 3018.18psi 15%=2768.61psi 25%=2655.49psi	For **5%** $3018.18+6758.76+1991.26/3$ 3922.73psi
Azad A. Mohammed et al. (2019)	5%,15%,25%	Compressive strength	Scrapped PVC sheets	5%=6758.76psi 15%=5769.60psi 25%=5667.80psi	For **15%** $2768.61+5769.60+1706.80/3$ 3415.00psi
Najjar et al. (2013)	5%,15%,25%	Compressive strength	Ground plastic pipes	5%=1991.26psi 15%=1706.80psi 25%=1493.45psi	For **25%** $2655.49+5667.80+1493.45/3$ 3272.24psi

CONCLUSIONS

1. From the above comparative study it is cleared that based on specific gravity of PVC lightweight concrete is produced.

2. The average results of compressive strength test for 5%, 15 and 25% replacement are in comparison with the individual results.

3. The plastic aggregate consequent from PVC sheets fundamentally consists of different particles with respect the size and has a relatively good size distribution likened with the other plastics. This property will disturb the package of aggregate particles inside the concrete quantity and reduce the presence of faults and weak zones. Up to 25% of normal fine or coarse aggregate of concrete can be replaced with this type of plastic waste without scratching the concrete strength commendably.

4. This adverse effect seemed to be more prominent at high PVC content. However, the highest reduction did not exceed at 25% PVC replacement level.

5. However, PVC content replacement upto 25%, the average results of compressive strength are in judgment with control sample. No huge difference is revealed between individual results and average comparative results of the compressive strength test for 5%, 15%, and 25%.

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