Effect of Using EVA as Partial Replacement for Coarse Aggregates on Concrete Properties

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ABSTRACT Ethylene-vinyl acetate (EVA), is the copolymer of ethylene and vinyl acetate. The weight percent of vinyl acetate usually varies from 10 to 40%, with the residuum being ethylene, also EVA is an elastomeric polymer that makes materials which are (rubber-like) in fineness and flexibility. In this study, EVA waste was used in the concrete mix instead of different percentages of coarse aggregates (5%, 8%, 10%, 12%) by volume. The concrete slump test was performed to measure the workability of freshly made concrete. The compression test was performed on all samples at 7 and 28 days. The results were compared with the standard mixture. It was concluded that EVA was a suitable material to replace coarse aggregates. Accordingly, the results of these experiments indicate that not only EVA can be noticed as aggregate in concrete, but also it will have more advantages in lightweight concrete than normal concrete. Using of EVA concrete shows decrease in slump for further replacement without compromising on strength. The best replacing ratio was 5% of aggregate.

Keywords: EVA, Coarse Aggregates, Lightweight Concrete, Slump, Compressive Strength.

1. INTRODUCTION

The use of plastic materials has been growing all over the world in packing, automotive and manufacturing applications. This results in a great generation of urban and manufacturing waste that can be stored or discarded. Due to the low density of plastics, storage or organization in landfills implies the availability of large surface areas. The elimination of plastics can be done by incineration, although, as the production of plastics involves the use of potentially harmful chemicals, the ashes produced may not always be passable in a landfill because of their potentiality to cause groundwater and soil pollution due to leachate carrying heavy metals. These problems have increased the use of recycled thermoplastics such as polyethylene, polypropylene and polyamide, which can be melted for recycling in the plastic industry. Moreover, the thermosetting plastic, such as (EVA) used by the footwear industry, cannot be melted through heat [1].

One way to using recycled plastics is their incorporation into (LWC). When selecting suitable combinations of filler and binder thus formed building material can be used not only in new construction, but also in reconstruction and renovation of existing buildings [2].

(EVA) is a co-polymer made from two different monomers: Ethylene monomer and Vinyl acetate monomer. In a foam state, EVA has characteristics like rubber, making it useful where cushioning is important such as in midsoles, sock liners, and unit soles in footwear.

In EVA, the relative amount of vinyl acetate to ethylene effects polymer characteristics.

Higher vinyl acetate content resort to make the polymer smoother and more rubbery, while lower vinyl acetate content tends to make the polymer harder and more crystalline, Fig.1. illustrate the molecular formula of EVA [3].

This material is bright and has good properties as an inhibitor, See Fig.2. low heat and high durability, it is easy to work on, conductive and

weld-proof, and has high body and flexibility and high load resistance Impact, high viscosity, anti-effort in cracks, high partial weight, non-leakage Water, radiation resistance, and UV. The more the content of vinyl acetate changes, the less Crystals of different properties of polymeric ethylene acetate are based mainly on content or percentage. In the lower level of vinyl acetate, the vinyl acetate has a heat-related skin with properties Similar to low density polyethylene ASTM 40-960 depending on 150 kg/m³ minimum density Clear, bright materials, Well-durable, Resistance of stresses to cracks, Lightweight, High viscosity, High partial weight, Easy to form, Leak proof and High resistance to UV radiation and radiation [4].

Fig.1.The molecular formula of EVA

Fig.2.EVA Sample

The low density of the mixture is achieved due to the use of lightweight aggregates which produces specific characteristics such as low density, ranging from 300 kg/m³ to 1800 kg/m³ and compressive strength, ranging from 0.3 N/mm² to 40 N/mm².

The coarse and fine aggregates are considered lightweight when their density is less than 1120 kg/m³ and greater than 880 kg/m³, respectively [5].

It is known that such wastes have great potential to be used as (LWC), in substitution of natural aggregates in the production of alternative

products. It is a waste with low density, large deformation capacity, and good vocal and thermal properties, stable, inert and non-susceptible to mushroom [6].

The use of (LWC) permits greater design flexibility and essential cost savings, reducing dead load, improved cyclic loading structural response, longer spans, thinner sections, smaller size structural members, less reinforcing steel, and lower foundation costs ,although, to produce artificial (LWC) is necessary high consumption of energy.

Plastics waste, as EVA has been used with relative success to produces concrete, (LWC) and components of construction.

The use of these materials as aggregate to production of concrete has economical and ecological impact due large amount of waste made annually [7].

The purpose of this study is to evaluate the performance of concrete with (EVA) recycled aggregate replacing conventional coarse aggregate in the production of lightweight concrete.

Previous study [8] Displayed that it is possible to use polymer waste in a new product with efficient acoustic and thermal performance compared to conventional lightweight subfloors.

Study [9] analyzed the efficiency of micronized EVA composite subfloors in test specimens of 3, 5 and 7 cm thickness and three polymer addition contents. Samples with 50% micronized EVA displayed better impact insulation efficiency with $\Delta L'_{nT, w} 23 \text{ dB}$.

Research [10] proposes the use of EVA waste and rice husk in subfloors to lessen impact noise, substituting natural fine aggregates in the contents of 25, 50 and 75%. The results displaced that the use of both natural and artificial waste can represent gains in the efficiency of effect noise acoustic insulation for subfloors when used in larger proportions.

In research [11], piassava fibers were used as reinforcement of (LWC) containing 4% and 6% of EVA, with the goal of improving the flexural strength of the material. The experimental results demonstrate that the addition of EVA decreases

the density and flexural strength of the concrete in proportion to the amount of addition, but a recovery resistance is got when the piassava fibers are added in amounts of 1 to 2% by volume.

The test results were carried out in previous study [12] showed that the average compressive strength at 28 days of the original EVA block was 1.2 N/mm², whereas the block EVAr₇₀ was 2.2 N/mm² and the block EVAr₅₀ was 1.7 N/mm². Thence, there was an 83% increase in the compressive strength on the block EVAr₇₀ and 44% on the block EVAr₅₀. It was also observed there was no significant difference among the weights of all the blocks produced. Thus, it appears that the EVAr aggregate impacted more in the compressive strength than in the mass of the blocks. So, the recyclability of the EVA block appears viable.

Previous study [13] specified that mixes prepared with aggregates that are basic in nature, i.e. with higher calcium content, show better bonding with both neat bitumen and EVA-modified bitumen compared with acidic aggregates, i.e. aggregates with higher silica content.

2. MATERIAL AND METHODS

2.1 Cement

The cement used was Ordinary Portland cement (42.5 Grade) produced by Sakhr Al Sudan Company conforming to BS EN 197-1 [14]. The characterization of the cement used is shown in table I.

2.2 Fine Aggregates (FA)

The sand used for experimental program was locally. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm. The fine aggregates were tested as per British Standard Specification BS EN 12620:2002. The specific gravity was found to be 2.47, water

2.3 Coarse Aggregates (CA)

The natural coarse aggregate used for this study was of 20 mm maximum size. It is conforming to BS EN 12620:2002. Specific gravity was found to be 2.65, water Absorption 0.7% and voids ratio 35.21%. It was retrieved from a local coarse.

2.4 EVA Aggregates

EVA coarse aggregate used for this study was of 9.5 mm maximum size characterized by small color particles (Fig.2.) which are obtained from cutting off expanded sheet waste used to produce insoles and innersoles of shoes. Specific gravity was found to be 0.45.

2.3 Mix Design

Mix design is done as per BS 8500-2 method [15]. The blends used in this research were designed to achieve a specific compressive strength of 30 N/mm² in 28 days. Eva material has been added as a function of the aggregate displacement volume and the specific weight of the Eva material, the calculation was done as follows:

Eva weight = density of Eva x volume of aggregate displaced. In order to study the mechanical properties of EVA waste concrete, five mix proportions were made.

The percentage replacements of aggregates by industrial EVA waste were 5%, 8%, 10% and 12%. This was done to determine the proportion that would give the most favorable result. The 0% replacement was to serve as control for other sample which is finally used for the comparison. The mix proportions studied for the EVA waste concrete are totally 5 proportions as shown in Table II.

Mix Design Method

5 concrete mixes were prepared with various percentages of EVA waste. The details of various mix proportions for different replacement levels of Aggregate by EVA waste.

The aggregate dry density used was 1668.43 kg/m³ and the maximum aggregate size use in all mixes was 20 mm using standard cubes moulds (150*150*150)mm, 6 cubes representing each ratio, were casted and tested at age 7 and 28 days.

TABLE I: CHARACTERIZATION OF THE CEMENT

Properties	Results
Initial setting time	140 min
Final setting time	245 min
Compressive Strength	42.31 N/mm ²

Absorption 1.8%.

TABLE II: MIX PROPORTIONS

Mix	0%	5%	8%	10%	12%
Free water (kg/m ³)	195	195	195	195	195
Cement (kg/m ³)	405	405	405	405	405
FA (kg/m ³)	840	840	840	840	840
CA (kg/m ³)	950	902.5	873.75	855	837.5
EVA (kg/m ³)	-	14.4	25.31	28.69	39.94

3. RESULTS AND DISCUSSION

3.1 Slump

Slump test was carried out on the five mixes. It was realized that the slump decreases when increasing the percentage ratio of the EVA waste in the mix as shown in Fig.3.

3.2 Density

In table III and Fig.4. Observe the values of average density for different propositions from EVA waste, the lowest density values belong to concrete with the highest replacement level of EVA. The mixtures 12% EVA can be classified as lightweight concrete.

Fig.3. Slump

TABLE III: RESULTS OF AVERAGE DENSITY AT 7 AND 28 DAYS

Mix	7days density (kg/m ³)	Change percentage (%)	28days density (kg/m ³)	Change percentage (%)
0%	2429.62	-	2436.53	-
5%	2378.96	2.08	2396.5	1.64
8%	2326.1	4.26	2333.5	4.22
10%	2322.45	4.41	2321.3	4.72
12%	2264.29	6.8	2277.09	6.53

3.3 Compressive Strength

The compressive strength test was carried out on 15cm cubic specimens, Table IV and Table V gives the results of compressive strength at 7 days and 28 days. Fig.5, Fig.6. and Fig.7. shows compressive strengths comparison of all concrete mixes.

Fig.4. Relation between percentage of EVA and Average Density of concrete at ages of 7 and 28 days

According to these results, compressive strength of EVA aggregate concretes is lower than natural aggregate concretes as can be seen in Fig.5, which can be due to the lower density of EVA concretes.

TABLE IV: RESULTS OF AVERAGE COMPRESSIVE STRENGTH AT 7 DAYS

Mix	7 days Compressive Strength (N/mm ²)	Change percentage (%)
0%	34.76	-
5%	31.94	8.11%
8%	25.94	25.37%
10%	25.74	25.94%
12%	25.20	27.5%

TABLE V: RESULTS OF AVERAGE COMPRESSIVE STRENGTH AT 28 DAYS

Mix	28 days Compressive Strength (N/mm ²)	Change percentage (%)
0%	46.57	-
5%	42.05	9.7%
8%	33.87	27.27%
10%	32.43	30.36%
12%	31.7	31.93%

4. CONCLUSIONS

This paper demonstrates that it is possible to use solid wastes of the footwear industry and the construction industry as aggregate for the production of conventional and lightweight concrete. Based on the results, the following conclusions can be drawn:

1. The density of recycled concrete was reduced. The lowest density values belong to concrete with the highest replacement level of EVA.
2. It was observed that the workability was reduced by increasing the amount of the EVA in the concrete mixes; the highest value of workability was achieved at 8% EVA concrete mix.

Fig.5. compressive strength at 7 days

Fig.6. compressive strength at 28 days

Fig.7. compressive strength at 7 and 28 days

3. Results of the experiments which are carried out on hardened concrete, indicate that 5% EVA concrete mix achieved higher values of compressive strength compared to other replacement ratio where it was 9.7% less resistant than the standard mix and it was the most suitable ratio for use.

4. It was observed that all EVA replacement ratios (5%, 8%, 10%, 12%) achieved the compressive strength higher than characteristic compressive strength which is equal to 30 N/mm² in 28 days.

5. Recycling EVA as aggregate in concrete not only improves mechanical properties of concrete,

but also helps the surrounding environment to be protected against its severe deposit problems.

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