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Production of Lightweight Concrete Blocks Using Industrial Plastic Waste

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Abstract—*The visibility of plastic waste volume is increasing because of its accumulation in recent decades and its negative impact on the surrounding environment and human health, the industrial Plastic waste is third major constitute at municipal and industrial waste in cities. This paper investigates the effects of adding different proportions of EVA waste (10%, 25%, 40%, 55% and 70% of weight of coarse aggregate) resulting from cutting the industrial EVA waste (from local footwear industry) as constituent of hollow blocks and evaluate the efficiency on concrete blocks for trying to produce a hollow blocks concrete with high strength and lightweight. An experimental study was carried out to test for compressive strength, weight and water absorption. Tests are conducted for finding the strength of the concrete in 28 days strength. Finally, the results are compared with the normal conventional concrete block. The optimum % of EVA waste was found 70% was reducing the weight 19.4% and reducing the compressive strength28%respectivly. Based on results it recommended to use EVA waste for nonstructural loads members as partitions.*

Keywords—EVA waste, Fine aggregate (F.A), Coarse aggregate (C.A), Concrete light weight, hollow block

1. INTRODUCTION

EVA is a co-polymer made from two different monomers: 1.Ethylene monomer. 2. Vinyl acetate monomer.

In a foam state, EVA has properties 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 influences polymer properties. Higher vinyl acetate content tends to make the polymer softer and more rubbery, while lower vinyl acetate content tends to make the polymer harder and more crystalline, Figure1. illustrates the molecular formula of EVA [1][2].

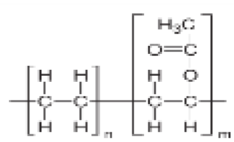

Fig1. *EVA molecular formula*

The EVA foam made from the conventional process has acellular structure that contains cell which are mostly closed cells (90%closed cell and 10% open cells) [3],[4].

with EVA content should be used as insulating materials and suitable for walls against strong solar radiation [5].

2. EXMATERIALS USED:

The materials used in this work are OPC, EVA waste, fine and course Aggregates, the tests carried out on 0.5 water-cement ratio. firstly cement ,fine and course aggregate were manually mixed in ratio (1:2:4) for 5 minutes, then the water added ,and all materials mixed according to1881 British method .This pure mix without EVA waste is consider as control sample. EVA waste was obtained by collected from local footwear industry (shahata industry) like runner shoes as shown in figure (2)

Fig2. *Fractions of EVA aggregate from(2mm-15mm) after cutting*

The percentage replacements of course aggregates by industrial EVA waste, this are calculated by using the specific gravity of EVA aggregates, in place of specific gravity of course aggregates were 10%, 25%, 40%, 55% and 70%.
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.[7]

2.1 General properties of EVA waste aggregates

The EVA waste has properties, such as impact strength, puncture resistance, excellent clarity, heat seal properties, and flexibility colour lumps. The following tests were done to determine the properties of EVA in Table 1

Table 1: Properties of EVA Waste Aggregates

S.NO	Characteristics	Value
1	Specific gravity(ASTM D792)	0.5
2	Total water absorption (%)(ASTM D570)	1.03
3	Sieve 4 (%) (ASTM D1921- Sieve Analysis)	23.37
4	Break strength (*MN/m*^{2}) (ASTM D638-Tensile Test)	2.2
5	Minimum breaking load (*N*)	8.9
6	Maximum load (*N*)	217

2.2Cement:

The cement used was Ordinary Portland cement (OPC) conforming to British Standards No. 12 of 1996 with a specific gravity of 3.15. Initial and final setting times of the cement were 170 min and 242 min, respectively.

2.3Fine Aggregate:

The sand used for experimental program was locally procured and conforming to zone II. 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 Indian Standard Specification IS: 383-1970. The bulk density of sand was found out to be 1.6 g/cm3 and the specific gravity was found to be 2.6.

2.4Coarse Aggregate:

The natural broken stone (coarse aggregate) used for the study was of 5-15mm size maximum. It is conforming to IS: 383-1970. It was retrieved from a local coarse. The shape and quality of aggregate was uniform throughout the project work [8].

3. EXPERMENTAL WORK

3.1 Concrete Blocks

3.1.1Classification of concrete Hollow blocks (SSMO: 2011/3947)

Hollow block(open or closed cavity) is a block having on ore more large holes or cavities which either pass through the block open cavity or do not pass through the block closed cavity and having the solid material between 50to75 percent of total volume of the block calculated from overall dimensions (IS2185:2015),The external dimensions of the units should respect modular co-ordination size principles [14][15]. In Sudan the current co-ordinations sizes of blocks are shown in table 2

Table2: Dimension of Concrete Blocks according to SSMO:2011/3947

Length, *mm*	**Width, *mm***	**Height, *mm***
400	200	100
400	200	120
400	250	120
400	200	200
390	190	190
400	150	100
400	200	150

Usually the current thickness - e - of blocks is multiple of ±20 mm, the hollow blocks shall conform to the following grades and minimum average compressive strengths as shown in table 3.

Table 3: Compression Strength of Concrete Blocks According *to ASTM-C140-75*

Type	**Minimum Compression strength C.S(N/mm^2) at28days**			
	Load bearing units		**Nonload bearing units**	
	Average C.S for units	**Test of one unit**	**Average sC.S for units**	**Test of one unit**
Hollow Block	7	5.5	3.2	2.6
Solid Block	12	10	4.0	3.5

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3.2Mixes for EVA Concrete Hollow Blocks

Concrete hollow block have standard mix according to ASTM C 140-08a and SSMO 2011/4918 [52],i.e.1:7:7 (cement :sand :aggregates) was used for pure concrete hollow blocks. Batching was by weight and constant 0.5 w/c ratio was used, the concrete mixture was done manually on smooth concrete pavement. The coarse aggregates and fine aggregates were mixed thoroughly.[11] To this mixture cement was added .these were mixed to uniform color .then water was added carefully. For forming of EVA concrete block repeated the above mix design with different proportions of EVA aggregates as replacement for coarse aggregates to ensure homogeneity. Thirty Hollow concrete blocks of size (400mm×200mm×200mm) were used produced in locally factory,(ALOMDAH) by hydraulic concrete blocks machine as shown in fig 3, the concrete blocks produced on six batch depend on percentage of EVA aggregate any batching had produced five blocks as shown in fig3.7, twenty five blocks for replacement 10%-25% - 40% - 55% - 70% EVA, and five blocks without replacement i.e. 0 % EVA to serve the control .the mix proportions are presented in Table 4.

Fig3.*Hydraulic concrete bocks machine*

Fig4. *Batch from Hollow Concrete blocks*

Fig5. *Concrete Hollow Blocks Used in This Work*

Table 4: Mixes proportions for Concrete Hollow Blocks according ASTM C 140-08a and SSMO 2011/4918 by Mass.

	Mass of Quantities(*kg*)					
Samples	**EVA%**	**EVA Agg,kg**	**Coarse agg, kg**	**Fine agg, kg**	**Water, kg**	**Cement kg**
S_{01-05}	0	0	44.00	44.00	3.00	6.00
S_{11-15}	10	0.88	39.60	44.00	3.00	6.00
S_{21-25}	25	2.20	33.00	44.00	3.00	6.00
S_{31-35}	40	3.50	26.40	44.00	3.00	6.00
S_{41-45}	55	4.90	19.80	44.00	3.00	6.00
S_{51-55}	70	7.20	13.20	44.00	3.00	6.00

3.3 Results of Experiments of Hollow BlocksConcrete mixes with industrial EVA waste

The results of Hollow blocks concrete tests conducted by adding different *proportions of industrial EVA waste considered are 10%, 25%, 40%, 55%, 70% in the mix.*

3.4Water Absorption Results of Hollow concrete Blocks:

Table 5 presented the results of water absorption at 28 days for the average density of different propositions of hollow concrete blocks. Samples S1, S2, S3, S4, S5 and S6. There were three samples for each test and the average results were taken

Table 5: Average water absorption Test for Hollow concrete mixtures, S1, S2, S3, S4, S5 and S6 at 28 days age [9] [10][11]

Mixes	**Average Water Absorption (%)**
	28 ***days***
Concrete mix with zero EVA, S_1	5.40
Concrete mix with 10% EVA, S_2	5.50

Concrete mix with 25% EVA, S_3	5.60
Concrete mix with 40% EVA, S_4	6.40
Concrete mix with 55% EVA, S_5	7.20
Concrete mix with 70% EVA, S_6	7.40

3.5 Compressive strength Results of Hollow concrete Blocks

The individual hollow concrete blocks were tested for compression under Compressive Testing Machine as shown in fig 6[12].

Fig 6. *Compressive Testing Machine* **Fig 7.** *Crack in Hollow Concrete Block*

The compression strength values were obtained from applied load by (*kN*) from compression machine on net area of sample from hollow concrete blocks (rips) mm^2, average compressive strength for each mixtures by unit (*mPa* or N/mm^2) which shown in fig 6 and fig 4.10, and compared and are represented in tables 4.30to 4.35.The average compressive or crushing strength for hollow concrete blocks of size (400x200x200). There were four samples for each test and the results would be taken as the average of these four blocks, after 28 *days*[13].

$$\textbf{Net area of Block (Rips)} = (400\times200)-(2\times140\times120)-(140\times40)= 40800\ mm^2 \qquad (1)$$

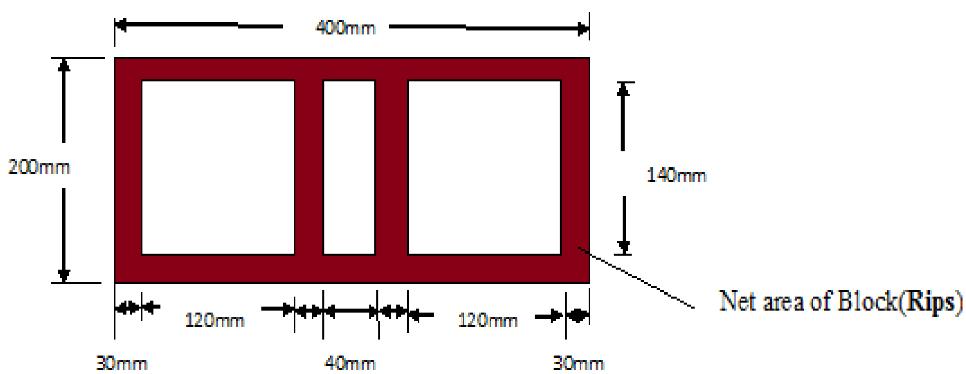

Fig 8. *Plan of Hollow Concrete Blocks Explain the Net Area*

Table 6: Compressive Strength Test For Sample With 0%EVA Waste (Blank)

Samples	Load (*kN*)	Net Area Rips (mm^2)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)	Age
S_{01}	60		1.47	**1.50**	

S_{02}	60	40800	1.47		28 days
S_{03}	55		1.35		
S_{04}	70		1.72		

Table 7: Compressive Strength Test for sample with 10%EVA waste

Samples	Load (*kN*)	Net Area Rips (*mm²*)	Compressive strength (*N/mm²*)	Average compressive strength (*N/mm²*)	Age
S_{11}	40		1.00		
S_{12}	60	40800	1.47	**1.29**	28 days
S_{13}	60		1.47		
S_{14}	50		1.23		

Table 8: Compressive Strength Test For Sample With 25%EVA Waste

Samples	Load (*kN*)	Net Area Rips (*mm²*)	Compressive strength (*N/mm²*)	Average compressive strength (*N/mm²*)	Age
S_{21}	50		1.23		
S_{22}	55	40800	1.35	**1.26**	28 days
S_{23}	55		1.35		
S_{24}	45		1.10		

Table 9: Compressive Strength Test for sample with 40%EVA waste

Samples	Load (*kN*)	Net Area Rips (*mm²*)	Compressive strength (*N/mm²*)	Average compressive strength(*N/mm²*)	Age
S_{31}	55		1.35		
S_{32}	50	40800	1.23	**1.20**	28 days
S_{33}	40		1.00		
S_{34}	50		1.23		

Table 10: Compressive Strength Test for sample with 55%EVA waste

Samples	Load (*kN*)	Net Area Rips (*mm²*)	Compressive strength (*N/mm²*)	Average compressive strength (*N/mm²*)	Age
S_{41}	45		1. 10		
S_{42}	45	40800	1.10	**1.17**	28 days
S_{43}	50		1.23		
S_{44}	50		1.23		

Table 11: Compressive Strength Test for sample with 70%EVA waste

Samples	Load (*kN*)	Net Area Rips (*mm²*)	Compressive strength (*N/mm²*)	Average compressive strength (*N/mm²*)	Age
S_{51}	45		1. 10		
S_{52}	45	40800	1.10	**1.08**	28 days
S_{53}	45		1.10		
S_{54}	42		1.03		

Table12: Compressive Strength for all samples of hollow concrete block at 28 days

Mixes	Average Compressive Strength for (N/mm^2)
	28days
Concrete mix with zero EVA	1.50
Concrete mix with 10% EVA	1.29
Concrete mix with 25% EVA	1.26
Concrete mix with 40% EVA	1.20
Concrete mix with 55% EVA	1.17
Concrete mix with 70% EVA	1.08

4.Average weight Results of Hollow concrete Blocks

The average weight of at 28days after curing concrete hollow blocks is presented in table 13, and fig 8 show that all blocks with 70% EVA waste replacement have lowest weight than that of control mix (blank,0% EVA), it also clears that percentage of EVA waste replacement increase the weight of blocks decreases.

Table 13: Average weight for Block concrete mixtures for samples S_1, S_2, S_3, S_4, S_5 and S_6 at 28 days age

Mixes	Average Weight (*kg*)
	28 *days*
Concrete mix with zero EVA, S_1	19.10
Concrete mix with 10% EVA, S_2	18.3
Concrete mix with 25% EVA, S_3	17.85
Concrete mix with 40% EVA, S_4	16.53
Concrete mix with 55% EVA, S_5	15.93
Concrete mix with 70% EVA, S_6	15.40

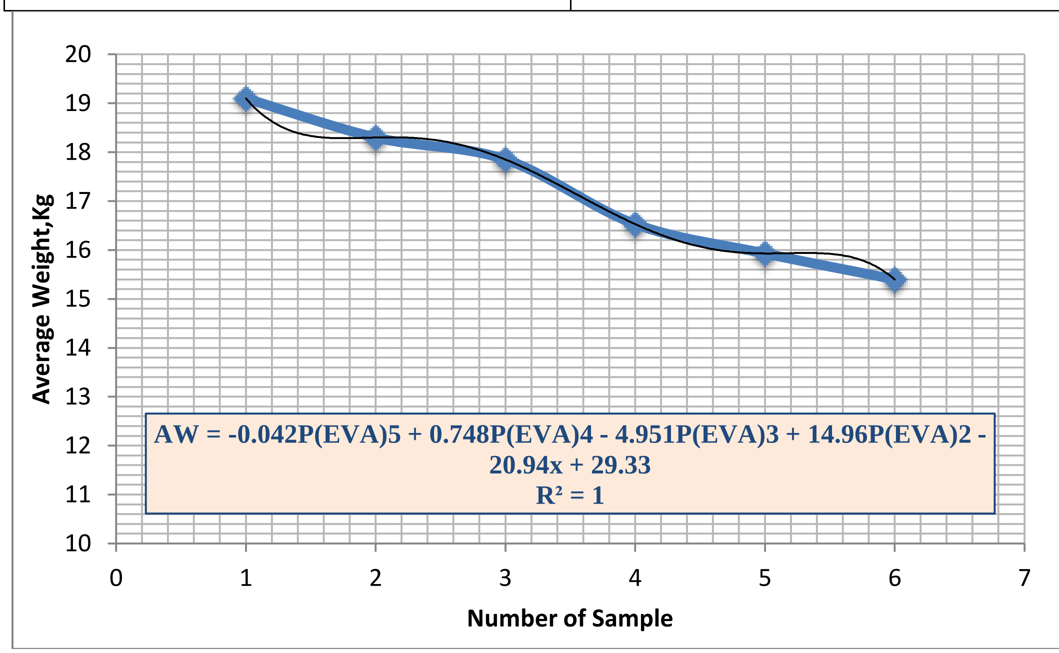

Fig 8.*Average Compressive Strength For Concrete Blocks Mixes*

I. Discussion Of The Results

The results obtained from the different tests are summarized as following:

1. Compressive strength of **hollow concrete blocks** at the age of 28 days decreased with increasing amounts of EVA waste Fig. 6&7.
2. The density of Block decreased with increasing amounts of EVA waste Fig 4.
3. The weight of Blocks decreased with increasing amounts of EVA waste Fig 5.
4. Increased percentage of water absorption with increased amounts of EVA waste in blocks as table 12.

II. Conclusions

In this study the EVA waste was used as additive to investigate its effect on Concrete blocks through the measure of workability for fresh concrete and compressive strength for blocks concrete in 28 days. Based on the results it can be concluded that:

- For hollow blocks concrete the percentage of water absorption decreased with increased amounts of EVA waste
- For hollow concrete blocks when add **10%** from EVA waste after 28day give us good strength compare with blank sample and when add **70%** from EVA waste gave low value of compressive strength. The values of Compressive strength for concrete decreased with increasing the percentage of EVA waste replacement in the mixes**1.5** to**1.08** M pa(N/mm^2)

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5.Recommendations

Based on the result of the study performed in this research, two types of the following recommendations are made:
Used of industrial EVA waste as replacement of aggregate is better for non loads structure members for examples, tiles and interlock

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