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STUDY ON PERMEABILITY, SOUND INSULATION FOR LIGHT WEIGHT CONCRETE MIXTURE WITH INDUSTRIAL EVA WASTE

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ABSTRACT
This paper aims to study the permeability and evaluate the concrete structure ,sound insulation property and quality control for proportional additions of EVA waste as constituent of lightweight concrete with different densities .This study also intended to present a proposed empirical formula to determine the sound insulation of concrete cubes by using **UPV**, Samples of various proportions (10%, 25%, 40%, 55%, and 70%) of EVA waste in the mix and a control sample,(0%) were cured in water tanks for 28days. The sound insulation of concrete area calculated according to a proposed empirical formula made in this work . It was found that permeability decrease with increase in replacement percentage of EVA waste compared with the normal conventional concrete, Results showed that using10% EVA gave the lowest permeability and the best performance, Results of sound insulation showed transmission losses increased with decreased the average weight per area unit for concrete mixtures. Accordingly it was concluded that there is an indirect relationships between the amount of the EVA in the mix and the sound insulation of the product. Same relation was noticed against compressive strength.

KEYWORDS: Ultrasonic Pulse Velocity, Industrial Waste, lightweight Concrete, Sound Insulation, Ethylene Vinyl Acetate

I. INTRODUCTION
Concrete is the name given to a mixture of particles of stone bound together with cement. Because the major part of concrete is of particles of broken stones and sand, it is termed the aggregate. the material which binds the aggregates is cement and this is described as the matrix[1][9].

According to I.Y.elgady et al(2016)), had shown using EVA waste as the constituent of light weight concrete mixtures for construction application ,Recycled lightweight concrete made from footwear industry waste concluded use of ethylene/vinyl acetate copolymer (EVA) in mortar and concrete production as additive to investigate its effect on fresh and hardened concrete through the measure of workability for fresh concrete and compressive strength for fresh and hardened concrete in 7 &28 days.Based on the results it can be concluded that:

- For fresh concrete the value of slump decreased with increased amounts of EVA waste.
- For hard concrete the value of average compressive strength concrete decreased with increased amounts of EVA waste . The best performance for lightweight concrete mixtures at 7days , 15M Pa& and 20.5 M Pa for 28 days respectively when used 10% of EVA waste .[4].

P. Khamput et al (2014) studied physical, mechanical, and thermal insulation properties of light weight concrete block products mixed with ethylene vinyl acetate plastic scrap (EVA) from shoe factories, and they concluded the least density of light weight concrete block mixed with waste of ethylene vinyl acetate plastic products is 640 kg/m^3. The appropriate mixtures of light weight concrete block mixed with EVA plastic scrap can reach the required values from the standard of TIS 58-2533 and can be used as a thermal insulation wall.[2].
The sound isolation in single walls is fundamentally function of the known mass law. Several studies in different countries allow to say that masonry made with lightweight concrete units, if conveniently plastered to be airtight, has a better behavior than the suggested by the mass law (Short and Kinniburgh 1978, Cormon 1973).

Sound absorption is a different property and is related with the decreasing of sound reflection from a surface. Most lightweight concrete surfaces, if unplastered, have a quite good sound absorption [3].
According to ASTM C597-97 UPV test can be considered as one of most promising methods for evaluation the concrete structures, once it makes possible an examination of the material homogeneity estimate the mechanical properties, the compressive strength and the modulus of elasticity, The UPV results can be used for, permeability ,diagnosis, prognosis and quality control. The method is based on the propagation of a high frequency sound wave which passes through the material. The speed of the wave varies in function of the density and elastic properties of the material, [1][6].

II. MATERIALS AND METHODS

Materials Used

In this study two types of coarse aggregate were used as constituent in concrete : natural aggregate comes from granite rock have maximum size between 5mm,and 15mm, industrial aggregate EVA waste were obtained and collected from local footwear industry, EVA waste were cut into piece of different length between (2mm-15mm) by using cutter machine , High performance concrete was designed by using British curing method. Trail control mixes (S_1) for 28 days with replacement of coarse aggregate by industrial EVA waste in concrete with and then mixed by different proportions S_{2}-10%, S_3 25%, S_{4}-40%, S_{5}- 55% and S_6-70%.with concrete .[4] [5].

Fig. 1ultrasonic pulse test

Mix Design:

Mix design was done according to BS1881 method**.** The percentage replacements of aggregates by industrial EVA waste were 10%, 25%, 40%,55%and 70%. 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 6 proportions as shown in Table 1.

Mix Design Method

British method of mix design was used for mix design for concrete cubes test .concrete specimens with various percentages of EVA waste were prepared .The details of various mix proportions for different replacement levels of Aggregate by EVA waste at 7 and 28 days was be found at references[1][4].
The aggregate dry density used was 2470 kg/m^3,and the maximum aggregate size use in all mixes was 15mm .using standard cubes moulds (100*100*100)mm, 6 cubes representing each ratio, were casted and tested at age 28 days.

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Fig. 2: Sample of concrete mix with industrial EVA

Fig. 3 UPV test at different proportions of concrete with EVA

Permability , Ultrasonic pulse velocity test(UPV)

The idea is to project the sound inside a material and measure time, the time taken by the pulse travel through the concrete is measured by electrical timing- unit with an accuracy of ±0.1 microsecond and ,knowing the length of path travelled through the concrete. the pulse velocity can be calculated.According to rules:velocity comes from divided length of sample on time pulse transmission

table 1, show the higher of elastic modulus ,density and integrity of mortar,the higher is the pulse velocity.in this study UPV is used as nondestructive testing parameters such as transducer frequency and specimen geometry on cement mortar . this table used as guide line for results of pulse velocities .to know mortar quality. [6].

Table 1: Genral guide lines for mortar quality based on UPV

Mortar Quality	Pulse velocity(km/sec)
Very good to excellent	>4.0
Good to excellent	3.5-4.0
Satisfactory but loss of integrity	3.0-3.5
Poor and loss of integrity exit	<3.0

III. RESULTS AND DISCUSSION

The results of hardened concrete tests conducted by adding different ratios of Industrial EVA waste, examples of this result of the permeability and sound insulation are done by UPV test and shown in table 2 and depicted graphically in Figures 4. firstly the permeability of lightweight concrete(concrete mixtures) is determined on 28 days for each sample S_1, S_2, S_3, S_4, S_5 and S_6. There were three samples for each test and the average results was taken.

Before determine the permeability and sound insulation , pulse velocity must be calculated as follow:

$$V=L/T \quad (1)$$

V= the pulse Velocity, *Km/µ sec*, L=thickness of sample (Path length), *Km*,(10cm=10-4*Km*), T= time of pulse transmission, micro second ,10^{-6}*Sec*

Table 2,presented the mean UPV of cubical specimens. All of these specimens were tested at 28days. according to ASTM C597-97 ,and standard table1, mixes quality for blank 0% EVA waste was very good to excellent ,the quality for 10% EVA waste was good to very good ,that means the quality reduced when increased the EVA waste replacement presented from 10% to 70% as shown in table 2

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Table 2: Average Pulse velocity for concrete mixtures for samples S_1, S_2, S_3, S_4, S_5 and S_6 at 28 days age .

Mixes	Average Pulse Velocity (*Km/sec*) 28days
Concrete mix with zero EVA	4.1
Concrete mix with 10% EVA	3.68
Concrete mix with 25% EVA	3.33
Concrete mix with 40% EVA	2.92
Concrete mix with 55% EVA	2.89
Concrete mix with 70% EVA	2.42

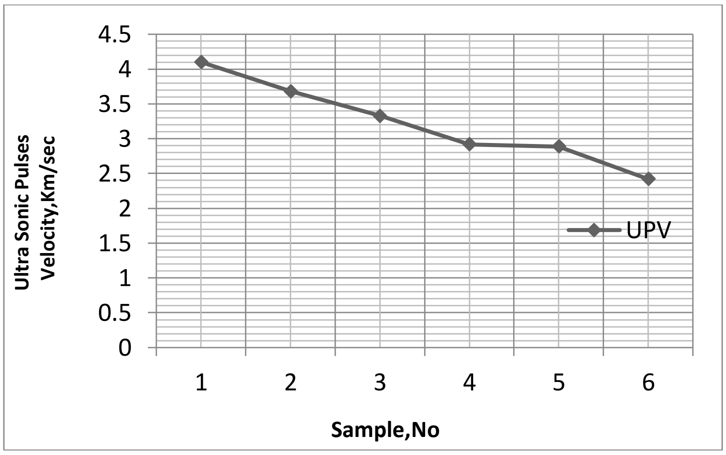

Fig 4: Average ultrasonic pulses velocity for concrete mixtures at 28 days

Relation between Ultrasonic Pulse velocity and Density

The test results of ultrasonic pulse velocity and density of concrete cubes with propositions of EVA waste showed direct relation as seen in Table 3 and Figure5 ,that meansUPV increased with increase the amount of EVA waste as replacement of natural coarse aggregate which effect in densities .

Table 3: Relation between ultrasonic pulses velocity UPV and density for concrete mixtures , samples S_1, S_2, S_3, S_4, S_5 and S_6 at 28 days age

Mix	Ultrasonic Pulses velocity (UPV) *Km/sec*	Density, ρ *Kg/m^3*
Concrete mix with zero EVA, S_1	4.1	2540
Concrete mix with 10% EVA, S_2	3.68	2490
Concrete mix with 25% EVA, S_3	3.33	2410
Concrete mix with 40% EVA, S_4	2.92	2120
Concrete mix with 55% EVA, S_5	2.89	2090
Concrete mix with 70% EVA, S_6	2.42	1940

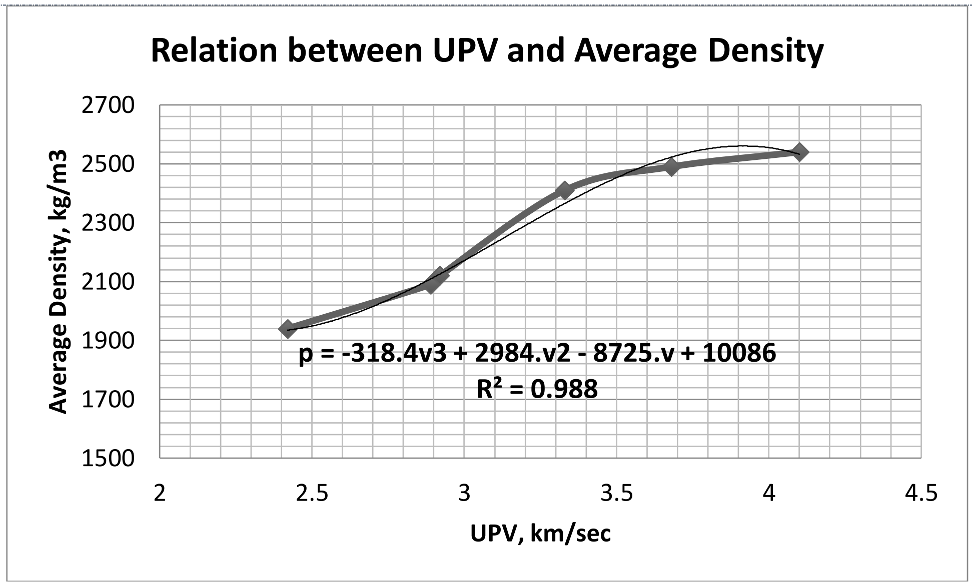

Fig5: Relation between Average densities and ultra sonic pulses velocity of concrete mixtures at 28 days

The experimental equation was derived from results between the density for different values from EVA waste of concrete with UPV to get a new density of concrete of known UPV, as follow:

$$\rho=-318.4V^3+2984\ V^2-8725\ V+10086 \quad (2)$$

- This empirical formula done by using Microsoft Excel. it is **(Polynomial equation-third Order)**
- ρ,Density of concrete(kg/m^3) .
- V,Ultrasonic pulse velocity(Km/sec).

Relation between Ultrasonic Pulse velocity and Compressive strength

The results which obtained from this relation between compressive and average pulse velocity for light weight concrete as seen in below table 4 and fig 6. the UPV increases when increase the percentage of EVA waste. that means density was decreased, another experimental equation was derived from result table between C.S and UPV to give compression strength of known UPV for light weight concrete.
The value of compressive strength when add 10 from EVA waste after 28day give us good strength and UPV compare with blank sample and when add 70% from EVA waste gave the lowest value.

Table 4: Relation between ultrasonic pulses velocity UPV and Compressive strength for concrete mixtures , samples S_1, S_2, S_3, S_4, S_5 and S_6 at 28 days age

Mix	Ultrasonic Pulses velocity (UPV) *Km/sec*	Compressive strength *N/mm²* at **28** days age
Concrete mix with zero EVA, S_1	4.1	27
Concrete mix with 10% EVA, S_2	3.68	20.5
Concrete mix with 25% EVA, S_3	3.33	10.3
Concrete mix with 40% EVA, S_4	2.92	5.84
Concrete mix with 55% EVA, S_5	2.89	5.02
Concrete mix with 70% EVA, S_6	2.42	2.68

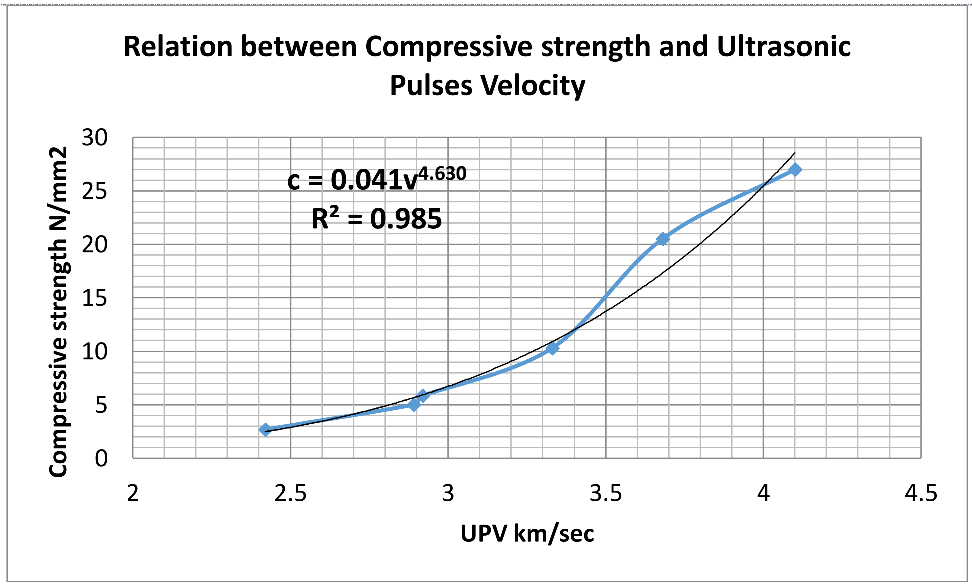

Fig 6: Relation between ultra sonic pulses velocity and Compressive strength for concrete mixtures

$$C=0.041V^{4.630} \quad (3)$$

this empirical formula done by using Microsoft Excel. it is **(Power equation) .**
This formula takes into consideration pulse velocity :

- **V**,Ultrasonic pulse velocity(Km/sec) to get:
- **C.S**,compressive strength.(*MPa*).at 28 days

*this equation used to studiedmechanical property of light weight concrete or for casting the values of **C.S** on different densities as shown in table4.*

New formula to determine the sound insulation(Transmission losses) **of light weight concrete**
one aim of this work study of sound insulation property of light weight concrete samples with different densities. Experimental tests on concrete samples were made by using the ultrasonic instrument(UPV), the sound insulation of concrete specimens in this work calculated according to a proposed empirical formula for Transmission losses **(TL)done by(Harris, C.M., and Yousif .K**[7][8]**.**

$$TL = 20 \log (f \times m) - 48 \text{------}(4)\text{(Harris equation)}$$

This formula takes into consideration pulse velocity, wall width in this case used specimen face , and frequency as follow:

TL= Transmission losses,dB
f =Frequency, 54KHz
m =W/A Mass per Area unit ,Kg/m^2
A= Area=$0.1^2 m^2$

This formula is supported on a statistical criteria. The results are evaluated and compared with the values that computed using the most well-known formula, the comparison show compatibility of the results.

Table 5: Transmission losses TL and Average Weight per Area unit ,m for concrete mixtures ,samples S1, S2, S3, S4, S5 and S6 at 28 days age

Mix	Transmission Losses (TL), dB	Average Weight/Area (m),*Kg/m^2*
Concrete mix with zero EVA, S_1	94.74	254
Concrete mix with 10% EVA, S_2	94.57	249
Concrete mix with 25% EVA, S_3	94.29	241

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Concrete mix with 40% EVA, S_4	93.17	212
Concrete mix with 55% EVA, S_5	93.05	209
Concrete mix with 70% EVA, S_6	92. 40	194

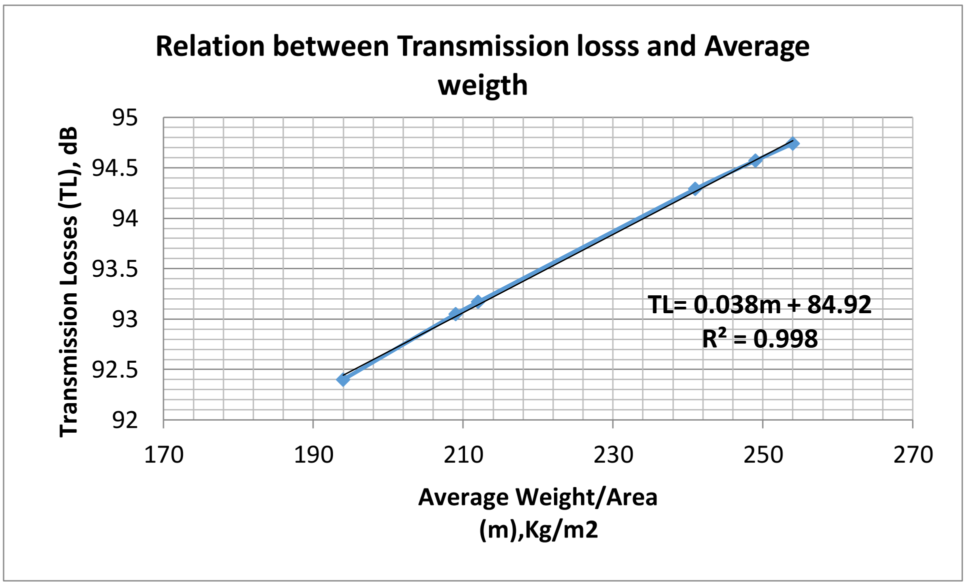

Fig 7: Transmission losses and Average Weight per area unit for concrete mixtures at 28 days

$$TL=0.038m+84.92\text{--}(5)(I.Y)$$

This empirical formula done by using Microsoft Excel.itis **(Linear equation) .**
Transmission losses increased with decreased theaverage weight per areaunit for concrete mixtures as shown in table5 and figure7,The results are evaluated and compared with the values of control mix(0% of EVAwaste) that computed using the most well-known formula, the comparison show compatibility of the results. inverse relation between the average weight divided on area to transmission losses from equation

The results obtained from the UPV test are summarized as following:

1. Permeability of concrete from UPV test at the age 28 days increased with decreasing the amount of EVA waste.
2. Compressive strength of concrete at the age 28 days decreased with increasing amounts of EVA waste and decreased the UPV.
3. The density of concrete decreased with increasing UPV .
4. The weight of concrete decreased with increasing the amounts of EVA waste.
5. transmission losses decreased with increasing the amount of EVA waste.
6. transmission losses increased with increased the average weight per area unit for concrete mixtures, direct relation.

IV. CONCLUSION

this study explain how to use the solids wastes of shoes industry (industrial EVA waste) as aggregate for production of light weight concrete. Also EVA waste used to investigate its effect on hardened concrete through the measure of permeability and compressive strength ,transmission losses sound for hardened lightweight concrete in 28 days. Based on the results it can be concluded that:

- For hard concrete the value of average ultrasonic pulse velocity decreased with increased amounts of EVA waste
- also the value of UPV decreased with increased compressive strength of EVA waste ,the highest value of UPV m 3.68 Km/sec gave 20.5MPa,the lowest value 2.42Km/sec,gave 2.48 M Pa for 28 days.
- the transmission losses increased with increased the average weight per area unit for concrete mixtures, direct relation.thehightest value 94.74dB at 254kg/m2.that means when increased the area increase the insulated sound.

V. RECOMMENDATIONS

Based on the result of the study performed in this research, two types of the following recommendations are made:

- Use of industrial EVA waste as replacement of aggregate is better for non loads structure members for examples light weight blocks ,tiles and interlock.
- Use other types of EVA waste with othe propotions as solid or liquid in fresh concrete with optimum values to obtained good workability and high compressive strength. with reduce the accumulation of it .
- Use a light weight blocks that content different ratio from EVA waste to helped in keeping the interior sound insulation, when the out side was noise is raised, there are many examples for used LWCB as sound insulation as follow: Studio, Halls of universities, conference hall ,meeting room,schools,..etc
- Study the use of EVA waste as substitute for sand in concrete mix.
- The EVA waste can be used in thermal and water insulation .
- Use EVA waste in installations exposed radiation.

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