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Using Ultrasonic Wave to Study Modulus of Elasticity, Shear Modulus and Poissons's Ratio of Polymer Concrete.

Meethaq M. Abed[1*]
1. Karbelaa Technical Institute, Foundation of Technical Education, Iraq.
* E-mail: mee1sa2012@gmail.com

Abstract
The main aim of this study is assess the modulus of elasticity , shear modulus and Poissons's ratio of polymer concrete (PC).Polymer concrete is a composite material realized with resin and aggregates.The Unsaturated polyester composite resin was used for binding the aggregates. The silica foam and glass fibers were introduced in the composition as filler.Some mechanical properties of polymer concrete have been investigated, by non-destructive method. The experimental results of ultrasonic wave at 26 KHz test were correlated with, modulus of elasticity, shear modulus and Poissons's ratio. The fiber percentage and silica foam was constant, the unsaturated polyester resin and the Silica sand dosages were varied.The results showed that by increase the percentage of sand aggregate (%W) in all groups the Poissons's ratio,Pulse Velocity,Modulus of Elasticity and Shear Modulus are increased.
Keywords: Shear Modulus, Polymer Concrete, Modulus of Elasticity, Poissons's ratio,Ultrasonic wave.

1. Introduction

The work in this investigation was planned in order to obtain further information about the effect of addition of Silica sand to the Unsaturated polyester resin on the some mechanical properties of PC such as modulus of elasticity, shear modulus and Poissons's ratio .PC has been used for decades in engineering construction like machine foundations, in the building industry for façade products and sanitary parts, in electrical engineering for isolation devices and especially in the chemical industry for all types of ducts due to favorable properties, especially its corrosion resistance as well as its strength and elasticity [Lang G. 2005].PC is a composite material in which resin is used as binder for aggregates such as Sand or gravel instead of Portland cement [Castello X, Estefen S. 2008]. PC is an inert product that can be cast in almost any shape [Zou G.P, Taheri F. 2006]. Due to its rapid setting, high strength properties and ability to withstand a corrosive environment. It is increasingly being used as an alternate to cement concrete in many applications, construction and repair of structures, highway pavements, bridge decks, waste water pipes and decorative construction panels[Garas Victor Y, Vipulanandan C.1998]. However, the growing need for durable materials to replace portland concrete, particularly with regards to chemical strength properties, has not been translated into widespread usage of PC.The most likely reasons behind this are a lack of information on the properties of PC, the technology employed in its production and its higher cost. The major cost component in these materials is the resin used in their production [E.B. Mano,1991].The importance in assessing the modulus of elasticity of the PC compositions in this study stems from the fact that this property is one of the most important characteristics of these materials. There are also polymers with low modulus of elasticity values (classified as thermoplastics) which, if used in PC compositions, can result in low modulus of elasticity values in the final product. However, as the polyester resins used in the production of PC are dissolved in a styrene monomer, cross-linking occurs during polymerization and a tridimensional reticulate structure (a thermoset) results. This thermosetting polymer is insoluble, infusible and displays improved mechanical properties when compared with thermoplastics. These characteristics require the use of different technologies in the mode of application of these polymers[Jane P. Gorninski, Denise C. Dal Molin, Claudio S. Kazmierczak. 2004].Typical properties of polymer concrete are given in Table (1-1).The three compositions in this study used fixed concentrations.This concentrations are (85,65,55,40,25%) unsaturated polyester resin of all specimens group and (15,35,45,60,75%) sand as a aggregate in group-1 and (4%) silica foam as a filler with (11,34,41,56,71%) sand in group-2 and (1%) fiber glass with (4%) silica foam and (10,25,40,55,70%) sand in group-3.This filler is used between aggregate and silica foam and also in different concentrations to provide a more comprehensive assessment of the effect of silica foam on the elasticity modulus of PC compounds.

2.EXPERIMENTAL PORGRAM

2.1. Materials

2.1.1 Resin

Unsaturated polyester resin (UPS) was used as the matrix in the preparation of composite material polymeric and manufactured by the (Industrial Chemical of resins Co. LTD) in Saudi Arabia. This resin transforms from liquid to solid state by adding (Hardener) and this hardener is manufactured by the company itself and it is a (Methyl Ethyl Keton Peroxide) coded (MEKP) and be in the form of a transparent liquid. It is added to the unsaturated polyester resin 1% percent at room temperature, and in order to increase the speed of hardening, catalyzer materials on interaction is used as a catalyst (Catalyst) called accelerators.Cobalt Napthenate which are mixed directly with the resin and manufactured by the same company.

2.1.2 Aggregate

Aggregate used in PC with gradation of 0-2mm,2-8mm and 8-16mm. In this research,we used it between 0-2mm.Silica sand is the main component of the polymer Concrete used in this study. It is brought from (General Company for Mechanical Industries in Al-Eskandria).

2.1.3 Filler

Silica foam is used as filler in order to achieve chemical resistance, impact and erosion strength and to increase bonding between matrix and reinforcement phase. Silica foam was brought from "Nippon AEROSIL CO. LTD JAPAN, NFPA, NO.77-1984".

2.1.4 Fibers

In this research glass fibers used from type (E-Glass) as strengthening phase in the form of choppy glass fibers, average diameter of filament for this choppy glass fibers is (4–6 µm) and with length is (10-15 mm).These fibers provided by (Mowding LTD**.** UK)English Company.

2.2 Moulds for Plate

The moulds used for casting of the specimens comprised of a square steel frame measureing 50*50*50 mm by ASTM C579 – 01 Method –B **(**see fig.1).

2.3. Samples Design

By rule of mixture, design of mixtures for all groups are showed in the following manner:-

GROUP-1**:** Samples for studying the effect of silica sand particles volume fraction with particle size rang (300µm ≥ p.s > 74µm).

GROUP-2**:** The effect of particle size and volume fraction for silica sand particles on UPS matrix with added 4% silica foam (0.02-0.5 µm) for all samples.

GROUP-3: Samples with different volume fractions of silica sand and adding percent of silica foam is 4% at (0.02-0.5 µm) and fiber glass 1%. Samples these groups are designed as shown in table (1-2).

2.3 Method

The test of static modulus of elasticity, shear modulus and Poissons's ratio was performed using ultrasonic pulse velocity test (U.P.V) to find longitudinal and transverse velocity (V_L , V_T) respectively.To find the values of static modulus of elasticity, shear modulus and Poissons's ratio we used equations (1,2,3):

Poissons's Ratio (v) $$v = (1-2(V_T/V_L)^2) / (2-2(V_T/V_L)^2) \quad \text{........(1)}$$

Static Modulus of Elasticity (KN/mm^2) $$E = V_L^2\, \rho\, (1+ v)\, (1-2 v) / (1- v) \quad \text{.........(2)}$$

Shear Modulus (KN/mm^2) $$G = V_T^2\, \rho \quad \text{....................................(3)}$$

3.Results and discussion

The results obtained in the ultrasonic wave test are presented and discussed in this section.

3.1 Non–Destructive Test(Ultrasonic Pulse Velocity test (U.P.V))

The cubes samples were tested using non-destructive methods namely ultrasonic pulse velocity test. The Ultrasonic pulse velocity was measured by an ultrasonic concrete tester (CSI), type cc – 4 at 26 KHz.The test method is prescribed by BS. 1881 : part 203 : 1986 specifications (see Fig 2).

Fig.3 shows effect of Fillers on Pulse velocity for all concentrations.The results summarized in Fig.3 show that high pulse velocity values were obtained in group-2 because adding silica foam as filler which leads to chemical bond between sand and binder. As a result, increasing of pulse velocity.When adding fiber glass (group-2) we showed slightly low in values because the fiber glass hinders formation of chemical bond.

3.2 Poissons's ratio

Fig.4 shows variation of Poissons's ratio with Pulse velocity for all concentrations.The results summarized in Fig.4 show that Poissons's ratio values increase with increasing pulse velocity for all groups.In this figure,The maximum value Poissons's ratio is 0.2 nearly of all groups.This value decrease to reach -0.2 in group-1, -0.55 in group-2 and -1 in group-3.This decline of values indicates that the decreasing of adhesion properties between strengthening and matrix phases.

3.3 Modulus of Elasticity

Fig.5 shows variation of Modulus of Elasticity with percentage of fillers for all concentrations. The results summarized in Fig.5 show that Modulus of Elasticity values increase with increasing percentage of fillers for all groups.In this figure,the maximum values of Modulus of Elasticity are (0.0023, 0.0025 (KN/mm^2)) nearly of group-2 and group-3 respectively while the value of Modulus of Elasticity is (0.0015 (KN/mm^2)) of group-1.In general,increasing percentage of fillers leads to increase of Modulus of Elasticity because load distribution on the fillers particles and matrix.

3.4 Shear Modulus

Fig.6 shows variation of Shear Modulus with percentage of fillers for all concentrations.The results summarized in Fig.6 show that Shear Modulus values increase with increasing percentage of fillers for all groups.In this figure,the maximum value Shear Modulus is ($0.11*10^{-5}$ (KN/mm^2)) nearly of group-2 while the value of Shear Modulus is ($0.3*10^{-6}$,$0.62*10^{-6}$ (KN/mm^2)) of group-1and group-3 respectively.In general,increasing fillers leads to increase of Shear Modulus because transformation of the stress from matrix to particales.

5. Conclusion

There was an increase in Pulse Velocity as concentrations of percentage of fillers increased and an increase in Poissons's ratio as pulse velocity increased.The maximum value of Poissons's ratio is 0.2 and then decreasing values to -1 and -0.55 in group-2 and group-1 respectively.High modulus of elasticity values were obtained and the peak value was 0.0025 (KN/mm^2).These values are approach to those observed in group-2.High shear modulus values were obtained and the peak value was $0.11*10^{-5}$(KN/mm^2) and then decreasing values to ($0.3*10^{-6}$,$0.62*10^{-6}$ (KN/mm^2)) in group-1 and group-3 respectively.

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Figure 1. Moulds and Specimens

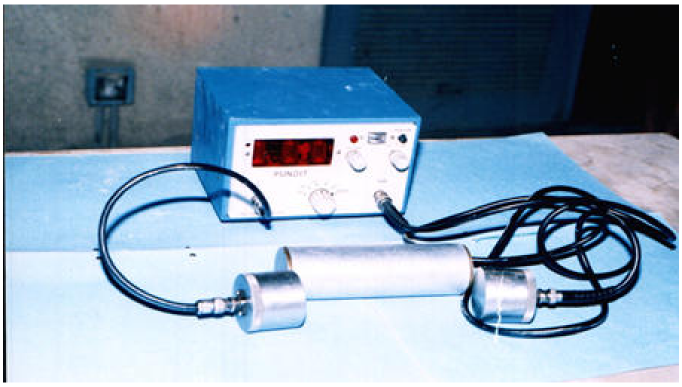

Fig.(2): Ultrasonic Pulse Velocity device.

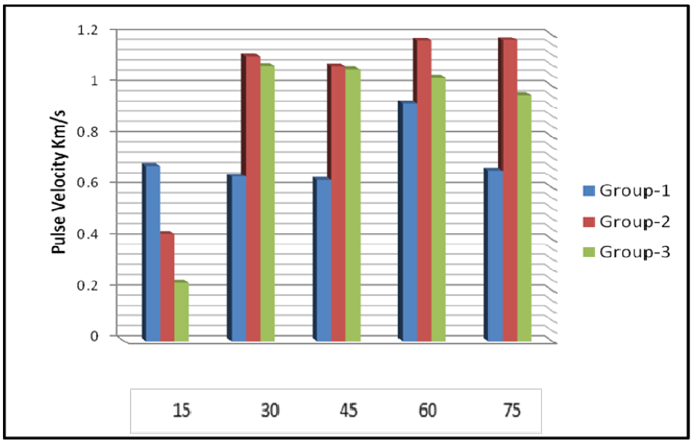

Figure 3: Effect of Fillers on Pulse velocity for all groups.

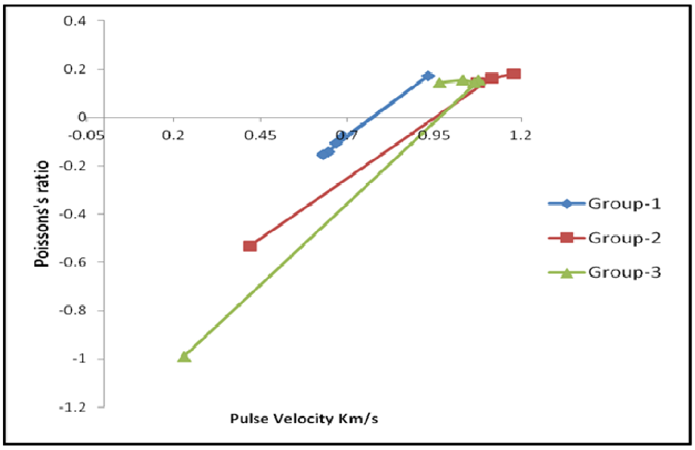

Figure 4: Variation of Poissons's ratio with Pulse velocity for all groups.

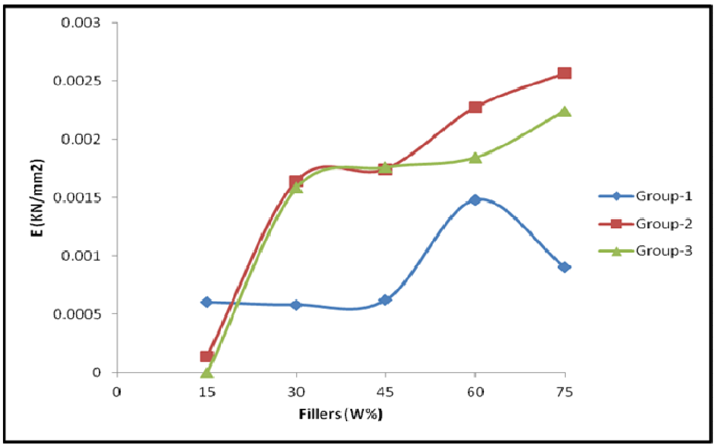

Figure 5: Variation of Modulus of Elasticity with Fillers for all groups.

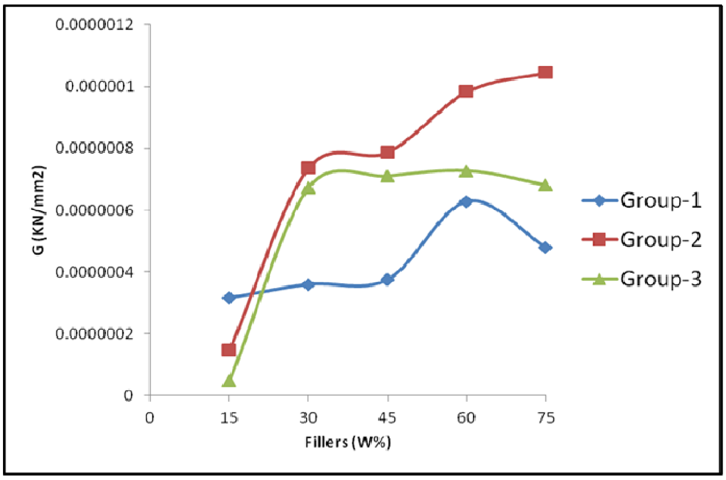

Fig 9: Variation of Shear Modulus with Fillers for all groups.

Table 1-1: Physical Properties of some of Polymer Concrete[Walter O. Oyawa. 2005].

Fill material description	Fill material label	Young's modulus E_{fill} (KN/mm^2)	Poisson's ratio υ_f	Ultimate strength (N/mm^2)	Shortening strain at peak strength (%)	Bulk-K and shear-G moduli (KN/mm^2)	
						K	G
Latex mortar	LCM	15.2	0.222	21.1	0.7272	9.11	6.22
Polymer concrete-1	E1A	12.9	0.316	52.0	0.7208	11.7	4.90
Polymer concrete-2	E2A	3.0	0.480	19.0	4.845	25.0	1.01
Normal concrete	CN	29.6	0.171	26.0	0.4035	15.0	12.6

Table (1-2):Samples design.

Material / NO	UPS (%W)	**Group-1** Silica sand (%W)	**Group-2** Silica sand+4% Silica foam (%W)	**Group-3** Silica sand+4% Silica foam+1%fiber glass (%W)
1	**85**	**15**	**11**	**10**
2	**65**	**30**	**26**	**25**
3	**55**	**45**	**41**	**40**
4	**40**	**60**	**56**	**55**
5	**25**	**75**	**71**	**70**