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IMPROVING SOME OF PHYSICAL PROPERTIES OF CEMENT MORTAR BY THE ADDITION OF GLASS FIBERS

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Abstract: Glass fibers reinforced mortar is a modern composite material in the field of construction. This composite consists of cementitious matrix includes cement, sand and water and reinforcement which is represented by glass fibers. This study aims to show the effect of addition random dispersed glass fibers and layers glass fibers on water absorption, velocity of ultrasound wave passing through the reinforced mortar and acoustic impedance of mortar. Mixtures of 1:2 cement/sand ratio and 0.5 water/cement ratio were prepared to make the mortar. Two series of mortars reinforced by glass fibers (random and layers) were prepared. Each series were reinforced with different percentage (0.54, 0.76, 1.1 and 1.42)wt.%. Glass fibers reinforced mortar exhibits better properties than plain mortar. The increasing in glass fibers addition caused an improvement on mortar by reduction of water absorption, ultrasound wave velocity and acoustic impedance. The addition of glass fibers layers showed better properties than random addition after curing for 7 and 28 days.

Keywords: *Random glass fibers, Glass fibers layers, water absorption, acoustic impedance.*

تحسين بعض الخواص الفيزيائية للملاط بإضافة الياف الزجاج

الخلاصة: الملاط المدعم بألياف الزجاج هي مادة مركبة حديثة في مجال الإنشاءات. تتألف هذه المادة المركبة من مادة الأساس الإسمنتية ومادة التقوية. تتكون مادة الأساس الإسمنتية من الإسمنت والرمل والماء كما تمثلت مادة التقوية بألياف الزجاج. تهدف هذه الرسالة لإظهار تأثير اضافة الياف الزجاج العشوائية وطبقات الياف الزجاج على امتصاصية الماء و سرعة الموجة فوق الصوتية النافذة خلال الملاط المدعم بألياف الزجاج بالإضافة الى دراسة الممانعة الصوتية. تم تحضير خلطات من الملاط بنسبة خلط وزنية (١:٢ اسمنت- رمل) ونسبة الماء الى الإسمنت (٠,٥). كما تم تحضير سلسلتين من الملاط المدعم بألياف الزجاج (عشوائية و طبقات). تم اضافة نسب وزنية مختلفة من الياف الزجاج لكلا السلسلتين (٠,٥٤، ٠,٧٦، ١,١، ١,٤٢)%. المونة المدعمة بألياف الزجاج اظهرت خواص افضل منها في الحالة الغير مدعمة. الزيادة في اضافة الياف الزجاج اظهرت تحسينا في خواص المونة من خلال تقليل كل من قابلية امتصاص الماء و سرعة الموجة فوق الصوتية والممانعة الصوتية.

1. Introduction

Cement mortar without any fibers addition will promote the cracks as a result of dry and plastic shrinkage or other reasons of volume changes. The development of these cracks causes elastic deformation of cement mortar. Glass fibers addition reduces the water bleeding of mortar.[1,2]

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Glass fibers reinforced mortar is considered a new building material which has superior properties than ordinary mortar.[3] The Addition of glass fibers to cement mortar is one of adopted methods to improve the properties, performance and durability of mortar. This addition constructs a cohesive structure overcomes the property of dimensional instability due to the influence of external conditions because of the fragility of the mortar. Also glass fibers addition producing structure with properties better than normal mortar, among these properties are reduced permeability, water proof and improved thermal and acoustic insulation properties.[4]

The possibility of using a glass fiber reinforced concrete system was recognized by Russians in the 1940s.[5] Academic studies have continued to develop this addition and recently become widely used for many construction applications such as facades, balconies, fountains, ceilings and architectural units.

Pshtiwan N. Shakor and Pimplikar, 2011, studied the effect of short length glass fibers on compressive strength and flexural strength of concrete cubes of (10×10)cm. and (15×15)cm. compared with concrete cubes free from glass fibers. Based on results obtained the best results was by addition glass fibers of 1.5% of cementitious weight and the further addition weakened the bond strength of materials. [6]

Mohammed K. Abd, 2013, investigated the effect of glass fibers on the workability, compressive strength, splitting tensile strength and modulus of rupture of fresh and hardened self-compacting concrete. Four mixes were used with mix proportion of (1:1.75:2), water/cement ratio was 0.4, super plasticizer of 5% of cement content, limestone powder of 100Kg /m3 , and glass fibers (0,1,3,5)% of mixes volume. The workability was determined by using V-funnel and L-box tests. The higher addition of glass fibers showed reduction in workability and increasing in compressive strength after curing for 7 and 28 days. [7]

Rasha S. Mahdi, 2014, the effect of glass fibers on compressive strength, flexural strength and surface hardness by using Schmidt hummer on mortar were studied. Three mixes were used with glass fibers of (1, 1.5 and 2)% by weight of cement. The best results for compressive and flexural strength was by addition of 1% glass fibers. Schmidt hummer was estimated the surface hardness of mortar after using glass fibers it showed reduction in rebound number compared with plain mortar. [8]

2. Aims

This work aims to study some physical properties of cement mortar such water absorption and acoustic impedance after the addition of glass fibers in layer and random manner, as well as studying the effect of curing for 7 and 28 days on these composites.

3. Experimental Procedure

3.1. *Materials*

3.1.1. Cement

Sulfate-resistant Portland cement of (Tasluja) Al-Jissir trade mark from Lafarge cement factory was used. In order to avoid the humidity effect on cement properties it

was stored in a dry place. Several chemical and physical tests was carried out in NCCLR (National center for construction labs. & researches) to verify its specification, the cement was identical to the Iraqi standard specification No.5/1984. "Table 1" and "Table 2" shows the chemical composition and physical properties of the cement, respectively.

Table 1. Chemical composition and properties of cement

Chemical composition & properties		
Tests	Results%	Limits of Iraqi standard specification No.5/1984
SiO_2	19.74	———
Al_2O_3	4.28	———
Fe_2O_3	5.04	———
CaO	64.13	———
MgO	2.92	≤ 5%
SO_3	2.36	≤ 2.5%
C_3A	2.82	≤ 3.5%
Lime Saturation Factor (L.S.F)	0.98	≤ (1.022-0.66)%
Insoluble residue (I.R)	0.96	≤ 1.5%
Loss on ignition (L.O.I)	3.92	≤ 4%

Table 2. Physical properties of the cement

Physical properties	Results	limits
Fineness (m/kg) (blain's method)	358	≥ 250
Setting time (hr. : min) (Vicat's method)		
-Initial setting	2 : 15	≥ 45 min.
-Final setting	4 : 15	———
Soundness (Autoclave)	-0.1	≤ 0.8
Compressive strength (MPa)		
-3 days	19.5	15
-7days	25.5	23

3.1.2. Sand

A sand from Al-Ukhaidir region was used as fine aggregate with specific gravity of (2.58) and fineness modulus of (2.17). A sieve analysis was carried out in (NCCLR) to know the grading of the fine aggregate according to the Iraqi standard specification No.45/1984. "Table 3" shows the results of sieve analysis process and "Fig.1" shows the upper and lower limits of Iraqi specification and the used sand.

Table 3. The results of sieve analysis process.

Sieve aperture	Passed %	Limits of third area %
10 mm	100	100
4.75 mm	99.9	90-100
2.36 mm	92.4	85-100
1.18 mm	82.3	75-100
600 micron	63	60-79
300 micron	32.5	12-40
150 micron	12.6	0-10
Parentage of salts%	4.8	5

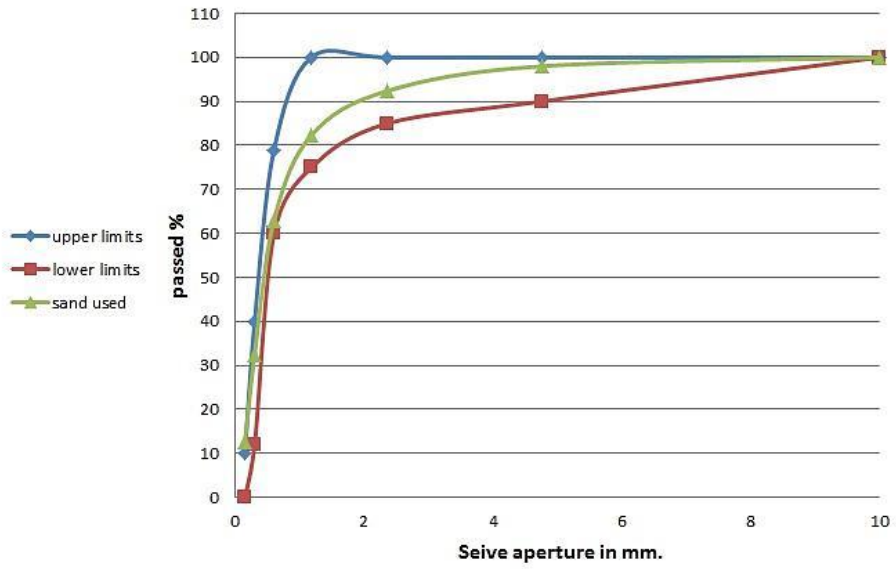

Figure 1. The upper and lower limits of Iraqi specification and the used sand.

3.1.3. Glass fibers

A chopped strand mats glass fibers of China Beihai trade mark with 2.58 g/cm^3 density was used. It was of thickness (2mm) and fiber length (3cm). It was cut into two shapes layers and random fibers as shown in "Fig. 2".

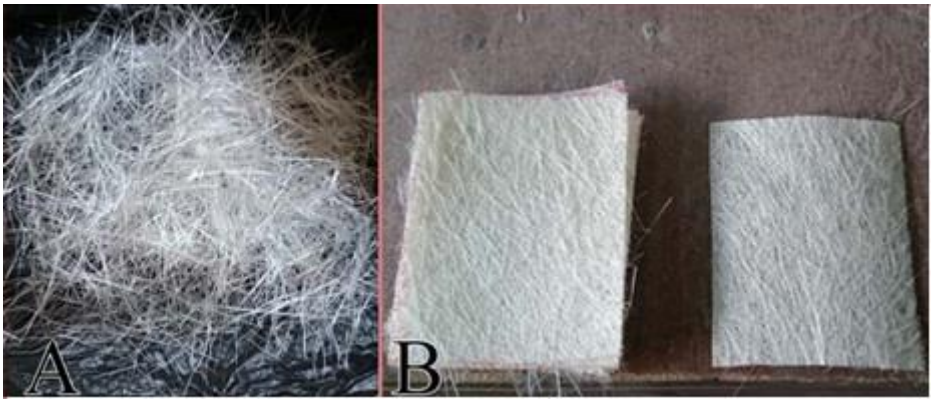

Figure 2. A: Random glass fibers, B: Glass fibers layers.

3.1.4. Water

Water is an essential element of mortar due to its rule in chemical reaction with cement.[9] A tap water was used for mixing process and distilled water for curing process.

3.2. Experimental work

Mixtures of 1:2 cement/sand ratio and 0.5 water/cement ratio were prepared for making mortar. Two series of mortars reinforced by glass fibers were prepared. The first series were reinforced with glass fibers in a layers form and the second in a random

form. Each series (layer and random) were reinforced with different percentage (0.54, 0.76, 1.1 and 1.42) % by weight. Table(4) shows the mix design proportions.

Table 4. Mix design proportions

Specimens	Cement Kg/m^3	Sand (Kg/m^3)	Water (L/m^3)	Glass fibers Wt.%
control mortar	627.9	1255.7	313.93	0
Glass fibers mortar	627.9	1255.7	313.93	0.54
	627.9	1255.7	313.93	0.76
	627.9	1255.7	313.93	1.1
	627.9	1255.7	313.93	1.42

The glass fibers layers were prepared by cutting a glass fibers mat into square layers of (15×15)cm. dimensions. The glass fibers were weighed before mixing as shown in "Fig. 3(a)". For achieving a homogenous mixing of the materials, sand, cement, water, and glass fibers were mixed together by hand for about two minutes.

The water was added to the mixture and mixed for four minutes according to ASTM C305.[10] "Fig.3(b)" Showing the preparation of glass fiber mortar. After the mixing process the reinforced mortar was poured in cast iron molds of (15×15×15)cm. dimensions. When the specimens were solidified they de-molded and cured at temperature (20∓5)°C for 7 and 28 days at controlled room of (50∓5)% humidity as it shown in "Fig. 4".

Figure 3. (a) Glass fibers weighing, (b) preparation of glass fibers mortar.

Figure 4. Curing at (a) controlled temperature and (b) controlled humidity

4. Testing

4.1. Water absorption

According to ASTM C642-97,[11] the water absorption was determined by drying the specimens in oven with temperature of (100-110) °C for 24 hours, cooled in room temperature and weighed. The specimens were immersed in water at (20∓5°C) for 7 and 28 days. The specimens were weighed after their surfaces were dried by towel. The water absorption was calculated according to equation (1).[11]

$$\text{Water absorption } \% = \frac{\text{Weight after immersion (Kg)} - \text{Dry weight (Kg)}}{\text{Dry weight (Kg)}} \times 100 \quad (1)$$

4.2. Ultrasonic Test

According to ASTM C597-02,[12] a portable ultrasonic non-destructive indicating tester of (PROCEQ) Switzerland making was used. Ultrasonic pulse velocity test (UPV) was measured by determine the transmitting time of ultrasonic waves through the specimens. "Fig. 5" shows the ultrasonic apparatus. The transit time velocity was calculated according to equation (2).

$$\text{Velocity(m/sec.)} = \frac{\text{Distance between Opposite faces (m)}}{\text{Transit time (sec.)}} \quad (2)$$

Figure 5. Ultrasonic test

4.3 Acoustic Impedance (Z) measurement

A measures of the opposition that a system presents to the acoustic flow resulting of an acoustic pressure applied to the system is known as acoustic impedance with units of ($Kg/s.m^2$), it can be computed from equation (3).[13 & 14]

$$\text{Acoustic impedance } (Kg/s.m^2) = \text{Velocity } (m/s) \times \text{Density } (Kg/m^3) \quad (3)$$

5. Results and Discussion

5.1. Water absorption

The water absorption of mortar specimens were measured after (7 and 28) days of curing. The addition of glass fibers (random and layers) decreases the water absorption compared with control specimens due to the water proof property of glass fibers.[15] "Fig. 6" & "Fig. 7" show the effect of random glass fibers and layer glass fibers respectively. Layers glass fibers addition shows better results than random addition. "Fig. 8" shows a comparison between the effect of glass fibers on water absorption at 7 and 28 days of curing.

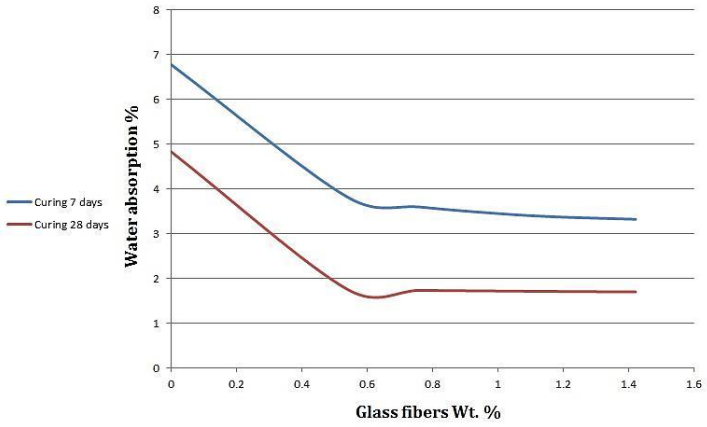

Figure 6. Effect of random glass fibers addition on the water absorption of mortar

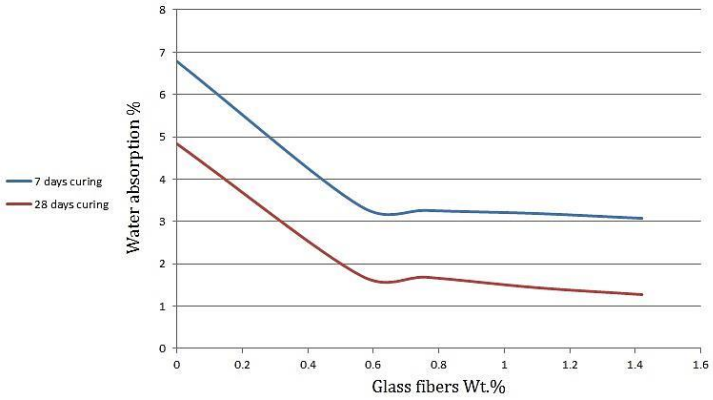

Figure 7. Effect of glass fiber layers addition on the water absorption of mortar

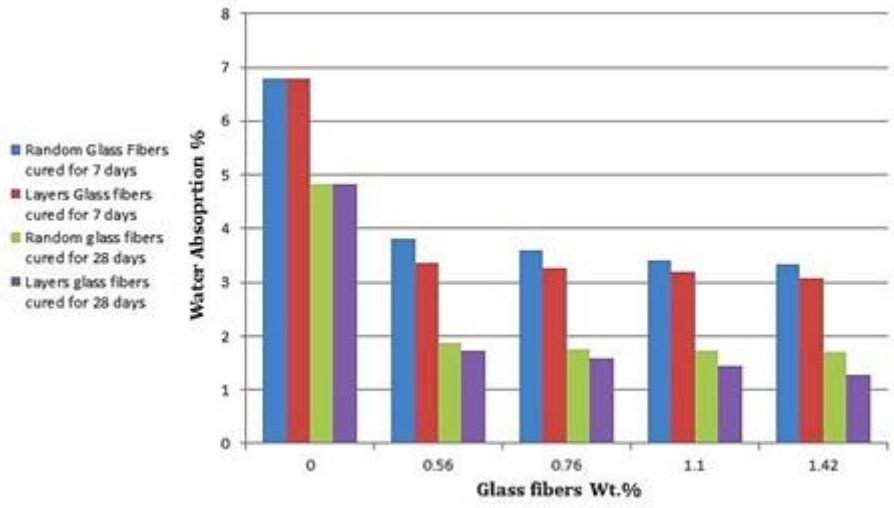

Figure 8. a comparison between the effect of glass fibers on water absorption at 7 and 28 days of curing mortar

5.2. Ultrasonic test

The transmitted time of ultrasound wave gives an indication about the homogeneity of the interior structure and cracks of the specimens. The addition of glass fibers (random and layers) was showed a reduction in ultrasound wave's velocity compared with control specimens after curing for 7 and 28 days as shown in "Fig. 9" and "Fig. 10", respectively. The reason of this reduction in ultrasound velocity belongs to the fact that the glass fibers are good acoustic insulator Therefore they act as an obstacles to disperse the sound wave.[16] The effect of glass fibers (random and layers) addition on the sound wave's velocity after curing for 7 and 28 days is showed by the comparison in "Fig. 11".

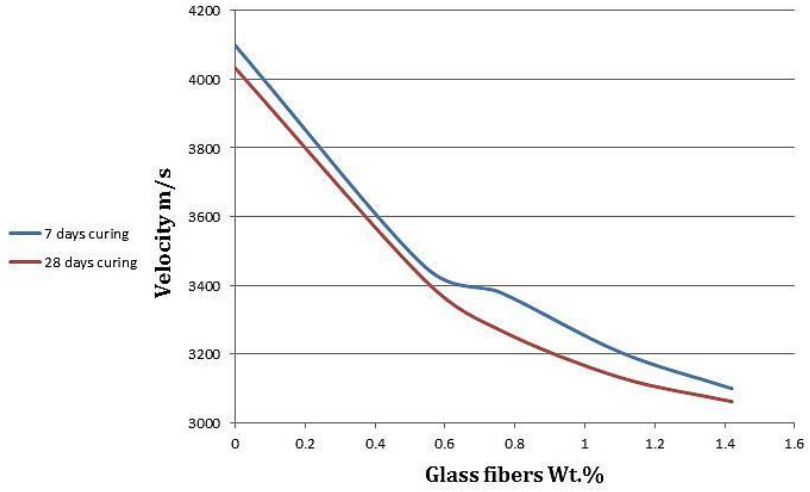

Figure 9. Effect of random glass fibers addition to mortar on velocity

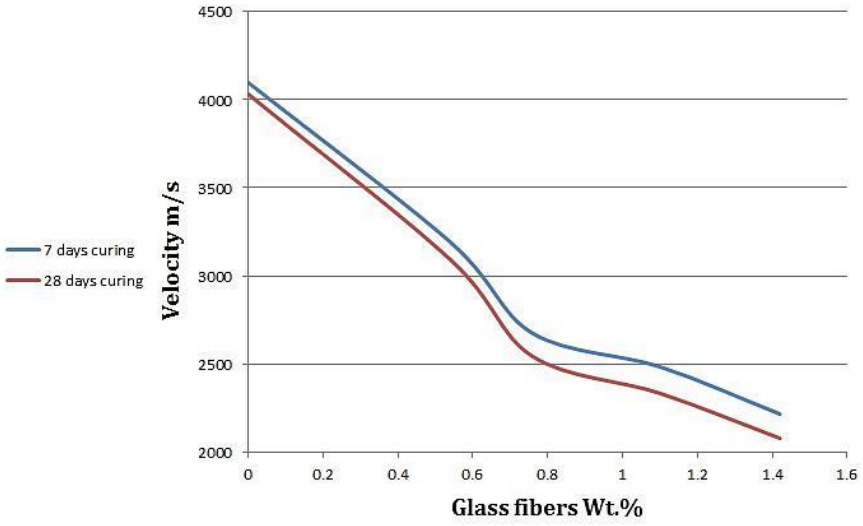

Figure 10. Effect of glass fibers layers addition to mortar on velocity

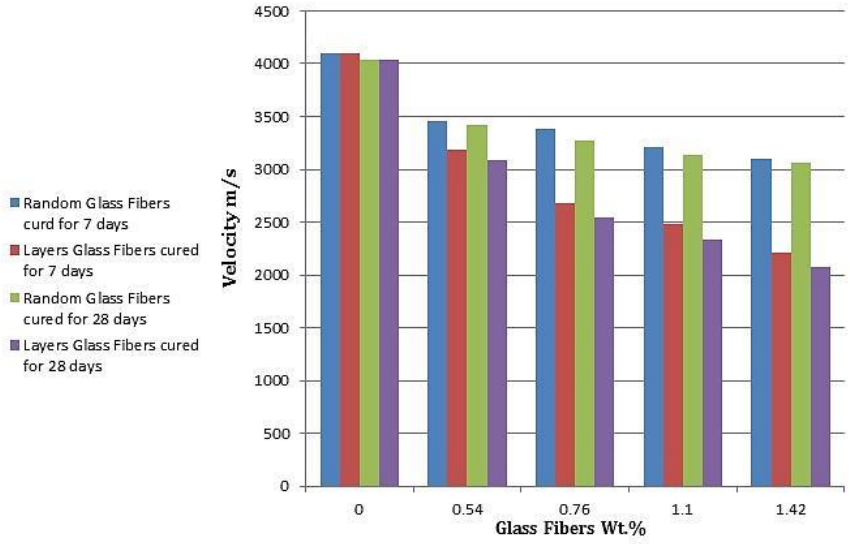

Figure 11. A comparison between the effect of glass fibers (random and layers) addition on the ultrasound wave's velocity after curing for 7 and 28 days

5.3. Acoustic Impedance

The addition of glass fibers (random & layers) to the mortar specimens showed a decreasing in acoustic impedance as shown in "Fig. 12" and "Fig. 13", respectively. The layers glass fibers addition caused better reduction in velocity than random addition. The comparison in "Fig. 14" shows the effect of glass fibers (random and layers) addition on the acoustic impedance after 7 and 28 days of curing.

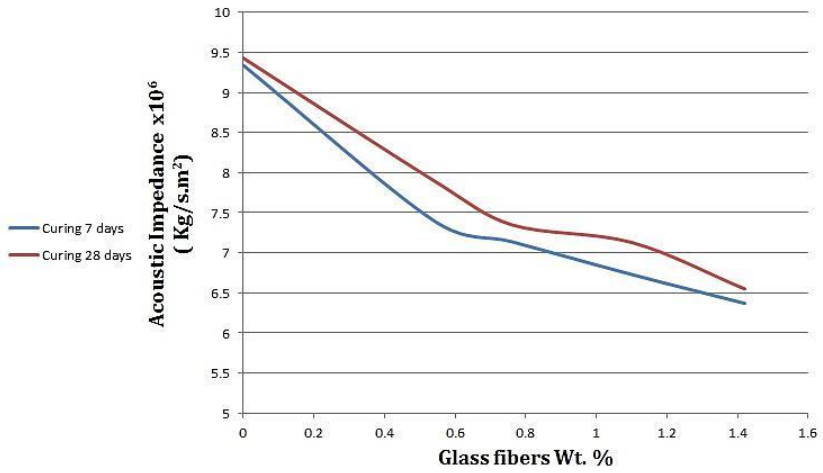

Figure 12. Effect of random glass fibers addition on acoustic impedance

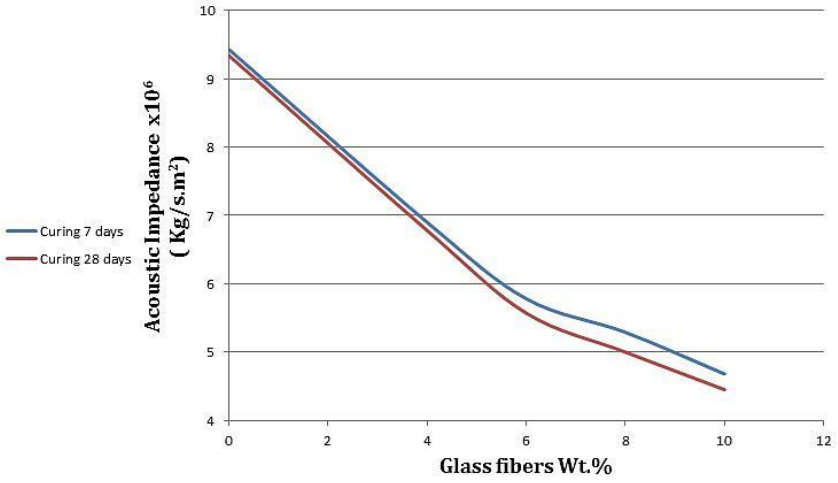

Figure 13. Effect of glass fibers layers addition on acoustic impedance

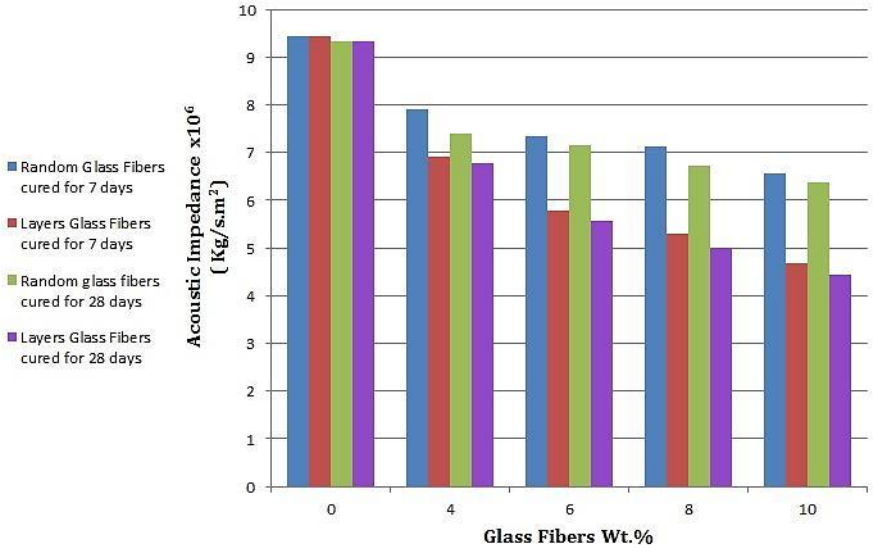

Figure 14. A comparison between the effect of GF (random and layers) addition on the acoustic impedance after 7 and 28 days of curing

6. Conclusions

The addition of glass fibers (random and layers) to cement mortar causes a reduction in the water absorption, ultrasound velocity and acoustic impedance compared with control specimens after curing for 7 and 28 days. The best results was achieved by addition of 1.42 wt.% glass fibers. The addition of glass fibers layers showed better results than random addition. The curing process has noticeable effect for all tests. The curing for 28 days showed better results than 7 days.

7. References

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