

Wave Transit Time in Polymer-Mortar Composites

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Abstract: The time transmitted between two surfaces of Polymer-Mortar Composites is measured and evaluate the different in percentage of polymer and sand addition and also between two temperatures (at room temperature and when post cured at 50 °C) using two types of polymers, ultrasonic waves transmitted along direct path was investigated. Tests were conducted on plain concrete of dimensions 50 x 50 x 50 mm. Direct ultrasonic wave transmission tests were conducted between top and bottom surfaces of the cube. A test procedure, described in British standard BS1881 : part 203:1986. 2003 to determine wave velocities, was refined by defining the number and spacing of transducers.

Keywords: Polymer, Mortar, Composite, Wave Transit Time

1. Introduction

Ultrasonic testing of concrete is currently used for quality assessment in large concrete structures cast on site and in mass-produced prefabricated units. The intrinsic heterogeneity of concrete limits the carrier frequencies that can be used to 250 kHz and less (being 54 kHz the most common frequency) when probing distances are greater than 1m. It usually demands two ultrasonic transducers, one for pulse emission and the other for pulse reception. In practice, probes for ultrasonic testing of concrete are not much larger (50 mm) than the customary ones for metals. The contact face of a common cylindrical probe, whose diameter is of the order of magnitude of the wavelength, or even less, radiates besides longitudinal waves, also shear and surface waves of appreciable intensity. The radiation and reception beam patterns are much less collimated than in the case of metals, although still not entirely isotropic. In any case, the absence of any significant directional effect in the probes, as well as the multiple scattering of waves inside concrete, makes it possible, (in principle) to couple directly any two points on the surface of the specimen being tested. The fastest ultrasonic signal received in this way is then always a direct longitudinal wave pulse. This is followed by shear and surface wave-pulses, and by reflected longitudinal waves. For quality tests on concrete the longitudinal acoustic velocity is determined measuring the distance between probes and the time that the direct longitudinal pulse takes to go from the emitting to the receiving probe. A higher velocity usually means a better concrete quality (strength, durability and dimensional stability). Dry cracks in concrete members may be detected and their depth and inclination assessed by careful measuring time-versus distance relationships for longitudinal pulses. Cavities and micro-crack fields can be detected under suitable conditions.^[1]

The standard corrections and some of their limitations

The following correction is recommended by RILEM and British Standards for the situation depicted in fig. 1:

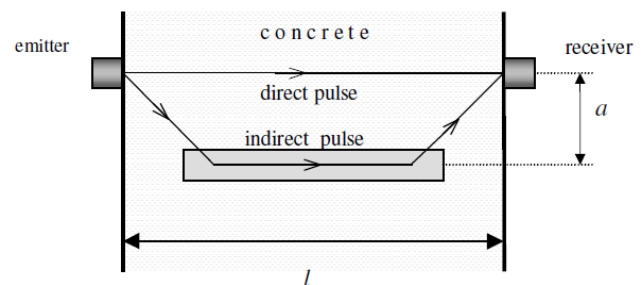


Figure 1: Direct and indirect paths for ultrasonic pulses in concrete. ^[2]

$$V=L/t$$

Where: L= path length (m) and t= transit time (micro sec.) so we can find the velocity of wave in the concrete in m/ μ sec.^[3]

2. Aims

In this work, measuring the wave transit time in polymer-mortar composites in different percentages and evaluate the best percentage.

3. Experimental Procedure

3.1. Materials

3.1.1 Cement

The cement that used is ordinary Portland cement. It is matched by the Iraqi Reference Guide indicative number (198) and the Ministry of Planning / Central Agency for Standardization and Quality Control Manual 198/1990. ^[4]

3.1.2 Natural Sand Aggregate

The fine aggregate used in study is according to the Iraqi specification No. 45 of 1984 for Cement under Iraqi specification^[4]

3.1.3 Polymer

Two epoxies were chosen to conduct the aim of this research, these epoxies are: 1. Resin group type Quickmast 105 (DCP) Company / Jordan. Specific gravity and viscosity of the epoxy resin were 1.04 and 1 poise respectively at 35°C. The ratio between resin and hardener for this epoxy is 3:1 by weight. Resin group type Repcon IR (Center

Construction Chemicals) Company / Saudi Arabia. Viscosity of the epoxy resin 2.2 poise at 24°C. The ratio between resin and hardener for this epoxy is 2:1 by weight.

3.2 Work Procedures

3.2.1 Mixes Proportions:

In order to achieve the scope of this study, the mixes were divided into sets for each polymer at room temperature and when post-curing for three hours at 50°C. Two sets of mixtures were prepared that consist of mortar and polymer to fabricate the polymer-mortar composite. The first set include mortar with ratio (1:1) (cement-sand) without water, while the other set include mortar with ratio (1:2) (cement-sand) without water. Each set was consist of different percentage of polymer (50:50, 40:60 and 30:70). The polymer was epoxy which is added to the mortar after mixing the resin with the hardener. The effect of curing was studied for both sets by preparing the two sets at room temperature (25°C) and others were post-cured at (50°C) for three hours. The details of these proportions and the details

of mixes are shown in table (1A), table (1B) and table (2) respectively.

Table 1A: Polymer- mortar Mixtures for Quickmast 105, [%]

Specimen No.	Mortar %	Epoxy %	Mixture %
1	1:1	1:3	50:50
2	1:1	1:3	40:60
3	1:1	1:3	30:70
4	1:2	1:3	50:50
5	1:2	1:3	40:60
6	1:2	1:3	30:70

Table 1B. Polymer- mortar Mixtures for Repcon IR, [%]

Specimen No.	Mortar %	Epoxy %	Mixture %
1	1:1	1:2	50:50
2	1:1	1:2	40:60
3	1:1	1:2	30:70
4	1:2	1:2	50:50
5	1:2	1:2	40:60
6	1:2	1:2	30:70

Table 2: The Details of Mixes

Polymer Type	Specimen No.	Weight in gram				
		Cement	Sand	Resin	Hardener	Total
Quickmast 105	1	150	150	225	75	600
Quickmast 105	2	180	180	180	60	600
Quickmast 105	3	210	210	135	45	600
Quickmast 105	4	200	100	225	75	600
Quickmast 105	5	120	240	180	60	600
Quickmast 105	6	140	280	135	45	600
Repcon IR	1	125	125	166.66	83.34	500
Repcon IR	2	150	150	133.33	66.67	500
Repcon IR	3	175	175	100	50	500
Repcon IR	4	83.334	166.67	166.66	83.34	500
Repcon IR	5	100	200	133.33	66.67	500
Repcon IR	6	116.67	233.34	100	50	500

3.2.2 Preparation, Mixing and Curing

The polymer- mortar with different proportions as given in tables (3A) and (3 B), was prepared by using electrical mixer (Automix, Controls Co. Italy) as in fig.2 , for each polymer the resin mixed with hardener for 2-5 minutes, then cement and sand were mixed for 5 minutes after complete homogenization the polymer- mortar were introduced in the mixture by mixing them for 10 minutes until achieving a homogeneous mix. After complete mixing, the polymer-mortar was poured in molds as in fig.(3) the molds were coated with mineral oil to prevent adhesion of polymer-mortar. Polymer- mortar casting was accomplished in three layers. Each layer was compacted by using a vibrating device (Viatest Co. German) as shown in fig.(4) for 1-1.5 minutes until no air bubbles emerged to the surface of the casting.



Figure 2: Electrical mixer (Automix, Controls Co. Italy)



Figure 3: The molds that are used for molding.

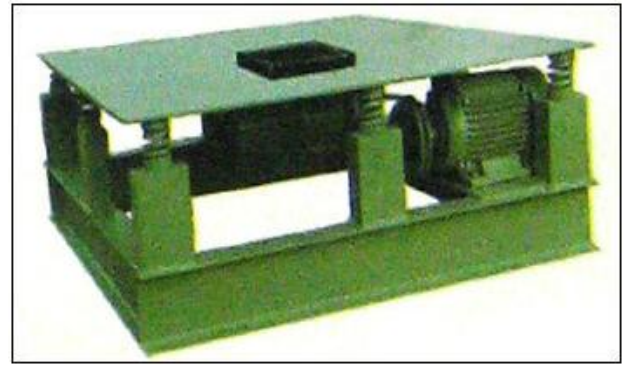


Figure 4: Vibrating table (Viatest Co. German).

The specimens were de-molded after curing at room temperature from casting, and left for 24 hours to complete curing, as shown in figure (5)



Figure 5: Some of specimens after de-molding

Ultrasonic Wave Transit Time Test

This test was carried out according to the British standard BS1881: part 203:1986,^[3] using the portable ultrasonic non-destructive indicating tester (PUNDIT Lab PROCEQ Co.) Switzerland, as shown in figure (6). Two transducers are fitted to the instrument cables, one acts as a transmitter for the ultrasonic pulses, and the second acts as the receiver. Both transducers are held against the surface of the specimen using coupling agent grease or petroleum jelly was applied between the tested surfaces of the specimen and

contact faces of the transducers to ensure good pulse transmittance. In this test, a pulse of longitudinal vibration with resonant frequencies of 54 kHz was produced by an electro-acoustical transducer and then converted into an electrical signal by receiver transducer. The transit time of the pulse is applied by an electronic timing circuit. The transducers can be used above and below a specimen member when looking for voids. The pulse velocity (V) in (m/sec.) was calculated as follows:



Figure 6: Portable ultrasonic non-destructive indicating tester (PUNDIT Lab PROCEQ Co.) Switzerland

4. Results and Discussions

The characteristic of polymer-mortar composite was experimentally determined for polymer-mortar composites tested at room temperature.

The ultrasonic test is a useful tool for assessing the uniformity of the polymer-mortar composites and detecting the transmitting time of waves. It gives useful information about cracks and the interior structure of polymer-mortar specimen. Results of the ultrasonic Wave Transit Time for all proportions at room temperature and when post-curing at 50°C are shown in figures (7,8,9,10,11,12,13 and 14).

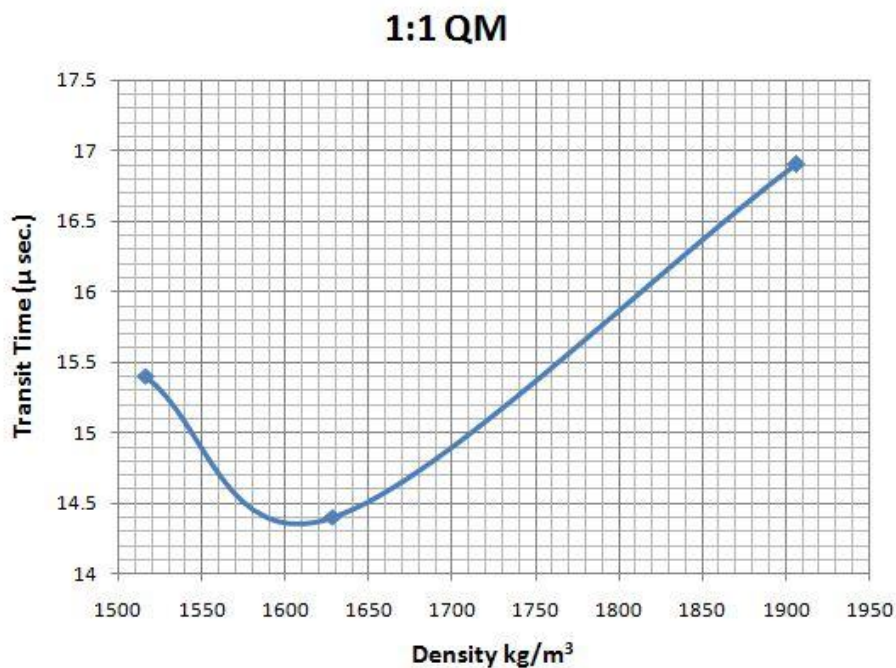


Figure 7: Ultrasonic Wave Transit Time of polymer-mortar composites using Quickmast 105 with 1:1 ratio at room temperature

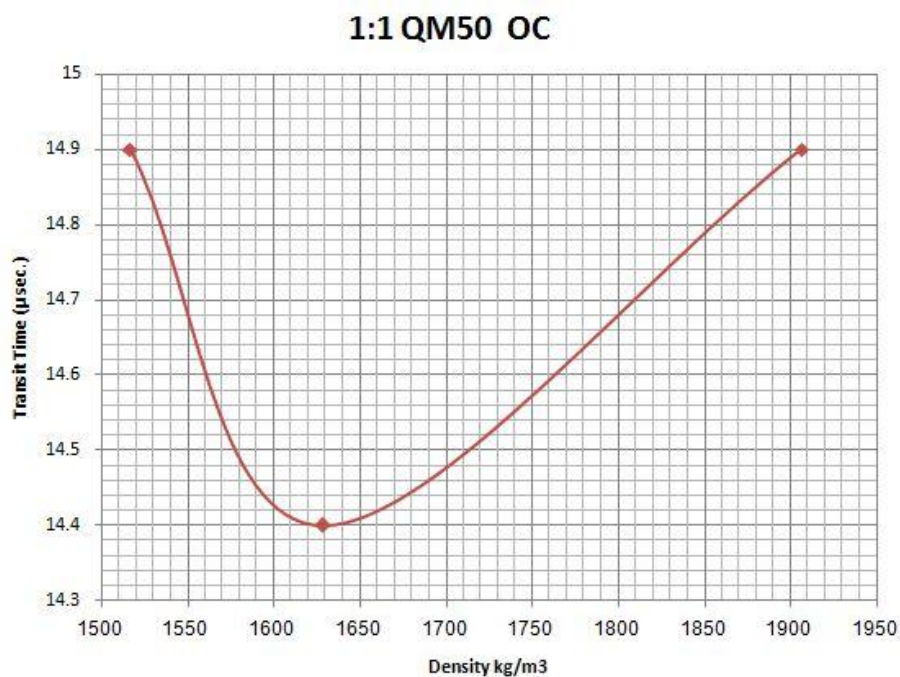


Figure 8: Ultrasonic Wave Transit Time of polymer-mortar composites using Quickmast 105 with 1:1 ratio when post-curing at 50°C

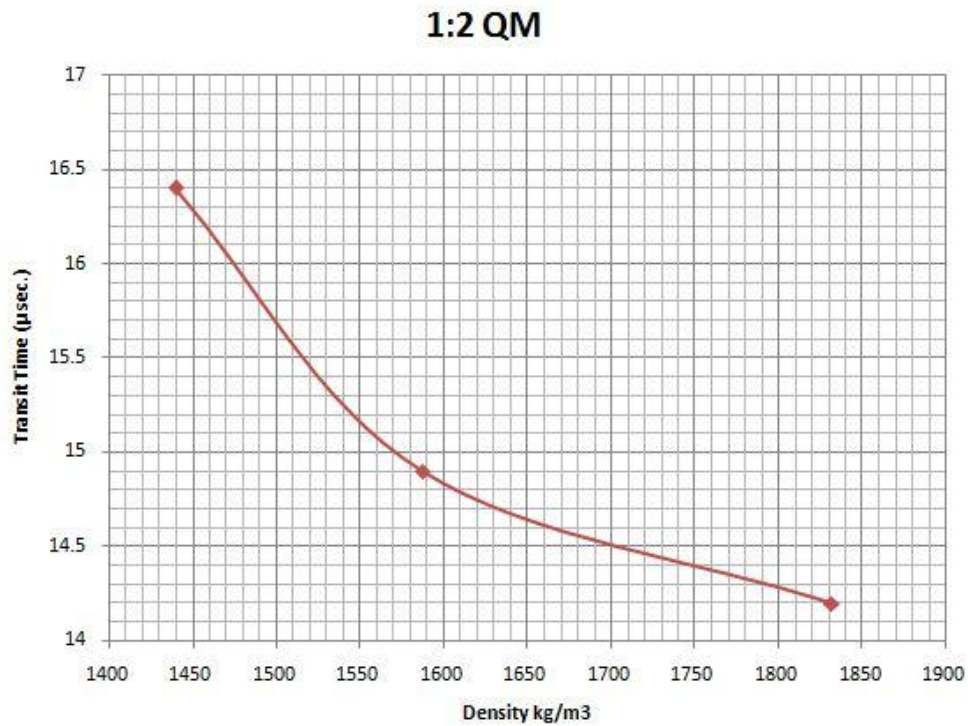


Figure 9: Ultrasonic Wave Transit Time of polymer-mortar composites using Quickmast 105 with 1:2 ratio at room temperature

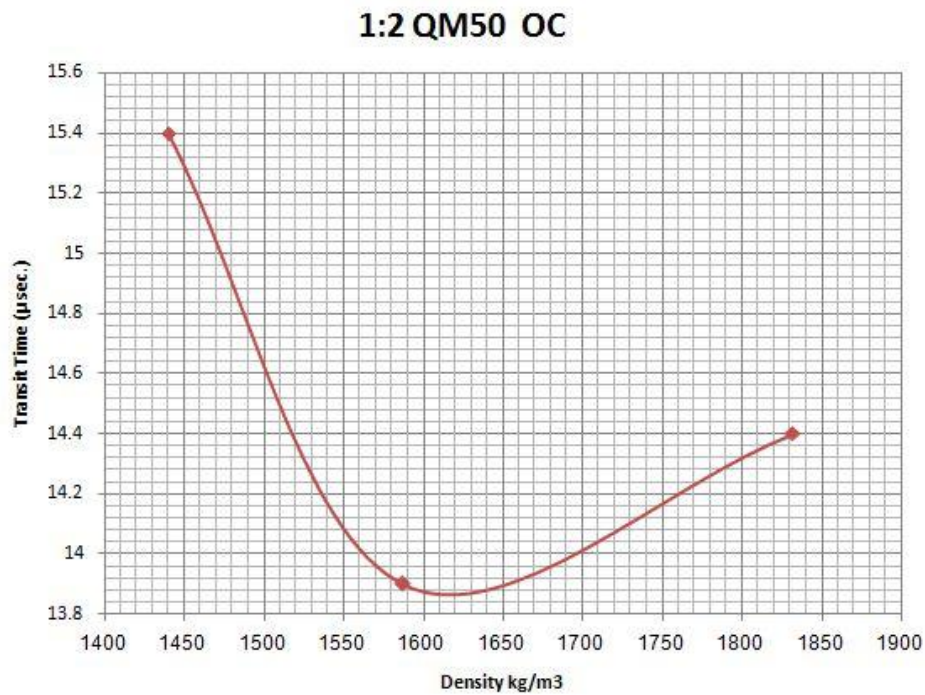


Figure 10: Ultrasonic Wave Transit Time of polymer-mortar composites using Quickmast 105 with 1:2 ratio when post-curing at 50°C



Figure 11: Ultrasonic Wave Transit Time of polymer-mortar composites using Repcon IR with 1:1 ratio at room temperature



Figure 12: Ultrasonic Wave Transit Time of polymer-mortar composites using Repcon IR with 1:1 ratio when post-curing at 50°C

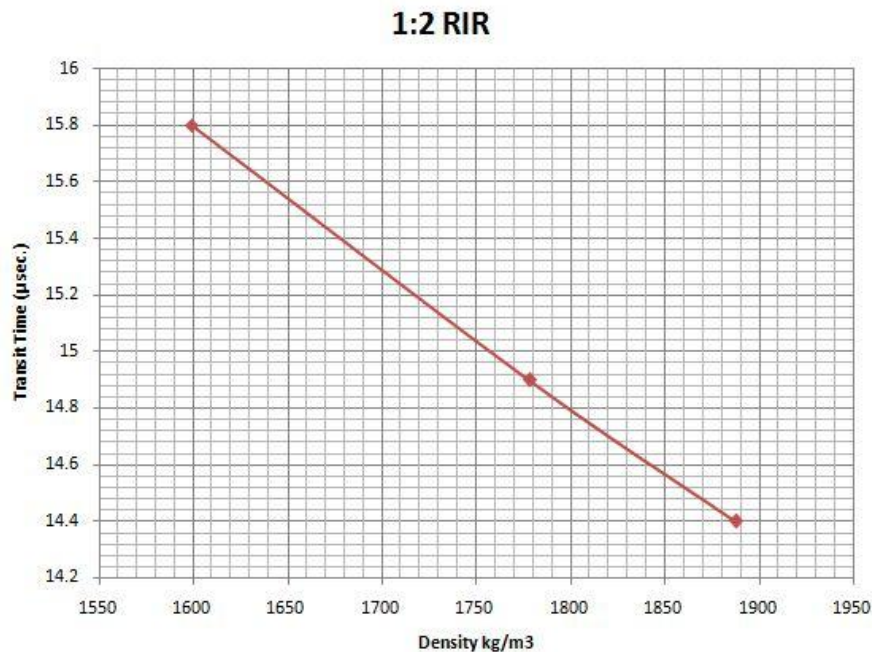


Figure 13: Ultrasonic Wave Transit Time of polymer-mortar composites using Repcon IR with 1:2 ratio at room temperature

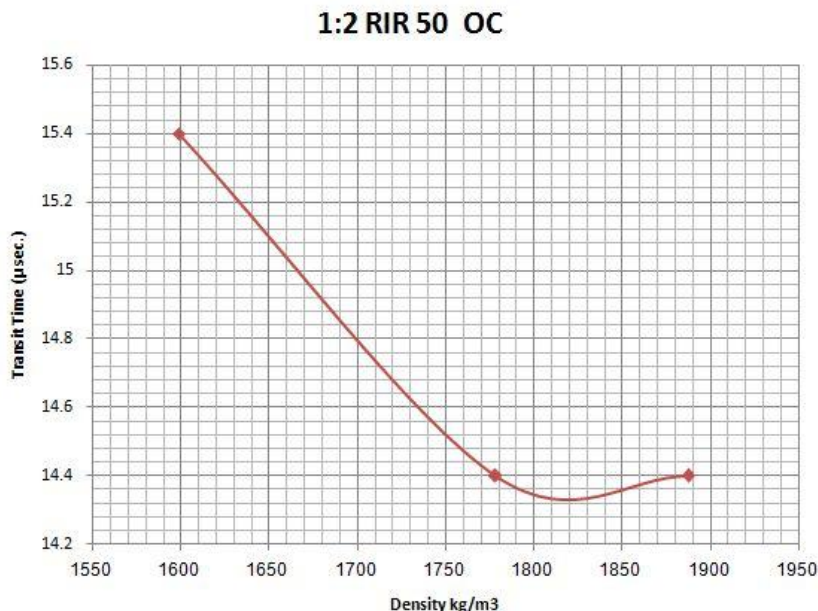


Figure 14: Ultrasonic Wave Transit Time of polymer-mortar composites using Repcon IR with 1:2 ratio when post-curing at 50°C

From the test results the following observations can be drawn:

All the specimens tested for ultrasonic pulse velocity ranges between 13.9 µsec. to 16.4µsec. which can be referred to the homogeneity of the composites.

- Polymer-mortar with high mortar content showed that an increase in wave transit time as compared with that of high polymer content. This behavior can be understood to the surface texture and high density of mortar.
- The increase in the wave transit time of polymer-mortar as a result of homogeneity and high density as well as the wave transit time in ceramic materials (cement and sand) is higher than polymeric materials so find that increasing the proportion of polymer less wave transit time.

- It clearly appears that the ultrasonic pulse velocity values of Quickmast 105 are higher than that of Repcon IR.
- Polymer-mortar composites with variations in proportions of cement to sand and also for polymer to mortar ratios give high wave transit time. This behavior can be understood to the voids contained in the specimen due to lack of penetration of the polymer in the mortar and also because of low density.
- The composite that gives the best results is due to good permeability of epoxy between mortar particles and minimize the voids in the composites.

5. Conclusion

The following main conclusion were achieved from this study

- The addition of polymer to mortar increases affects the behavior of concrete.
- Transit time could be affected with varying in polymer and sand percentages.

References

- [1] Roberto Suárez-Ántola, The meaning of transit times in NDT of reinforced concrete, Facultad de Ingeniería y Tecnologías, Universidad Católica del Uruguay.2007.
- [2] Naik,T., V.Malhotra and J.Popovics: “The ultrasonic pulse velocity method”, chapter 8 in V.Malhotra and N.Carino, Eds., “Handbook on Non Destructive Testing of Concrete”, CRC, Boca Raton, FL, 2004.
- [3] British standard BS1881 : part 203:1986. 2003.
- [4] Iraqi Reference Guide indicative (198) and the Ministry of Planning / Central Agency for Standardization and Quality Control Manual 198/1990.