EFFECT OF TREATMENT LIMESTONE IN LIGHT WEIGHT SELF-COMPACTING MORTAR ON FERROCEMENT PANELS IN FLEXURE

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ABSTRACT

The present work investigated the possibility of using limestone as a fine aggregate, after treating with sodium hypochlorite (NaOCL), in improving the properties of light weight self-compacting cement mortar (LWSCM). In this paper, three different mortars were fabricated, one of them contained limestone, the second one had NaOCL-treated lime stone, and the third was a normal mortar with fine sand which kept as reference. In addition, a total of nine ferrocement panels containing NaOCL were fabricated, they were tested under effect of four-point loading in order to study their mechanical properties. The effect of sodium hypochlorite on some physical and mechanical properties of mortar in both states fresh and hardened was also investigated. Compressive strength of (LWSCM) was examined at three commonly selected ages: 3, 7 and 28 days. Results showed that, the treated limestone improves the compressive strength compared to cement mortar containing untreated limestone and normal fine sand. Additionally, the treating of lime stone by the sodium hypochlorite enhances the fresh mortar properties such as mini slump flow test and flow time, besides the mechanical properties of hardened mortar including specific gravity, flexural strength, and compressive strength. Finally, the panels of treated-limestone mortars experienced the largest ultimate load and stiffness of all panels.

Keywords: Self-Compact Mortar, Sodium Hypochlorite, Limestone, Light Weight, ferrocement.

تأثير الحجر الكلسي المعالج في المونة الخفيفة الوزن و الذاتية الرص على لوحات السمنت المسلحة بالانثناء

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الخلاصة:

هذا البحث يهدف الى امكانية استخدام حجر الكلس كركام ناعم , بعد معالجتة بهايبوكلورات الصوديوم (NaOCL) ,في تحسين خصائص المونة الخفيفية الوزن ذاتية الرص(LWSCM) . في هذا البحث تم أعداد ثلاث خلطات مختلفة, واحدة منها حاوية على الحجر الكلسي والثانية على الحجر الكلسي المعالج والثالثة على الرمل الناعم كمونة مرجعية. بالاضافة الى تسع من الالواح السمنتيه المسلحة والتي اختبرت تحت تاثير اربع نقاط تحميل لدراسة الخصائص الميكانيكية . كذلك تم دراسة تاثير هايبوكلورات الصوديوم على بعض الخصائص الفيزيائية والميكانيكية للمونة الطرية والمتصلبة. تم فحص مقاومة الانضغاط لل (LWSCM) باعمار 3,7و28 يوم . اظهرت النتائج ان حجر الكلس المعالج زاد من مقاومة الانضغاط بالمقارنة مع حجر الكلس غير المعالج

والركام الناعم الاعتيادي .بالاضافة الى ذلك معالجة حجر الكلس يعزز من خصائص الخلطة الطريه مثل قابلية التشغيل وزمن الانسياب فضلا عن الخصائص الميكانيكية للخلطة الصلبة بما في ذالك الوزن النوعي ,مقاومة الانثناء ومقاومة الانضغاط .واخير الالواح بمونة حجر الكلسي المعالج شهدت تحمل وصلابة اعلى من كل الالواح.

1. INTRODUCTION

Lightweight concrete with a self-compacting characteristic (SCLC) is a developed type of self-compacting concrete (SCC), or alternatively termed self-compacting mortar (SCM), which performed without any external vibration (Zhimin et al,2009) .

Different types of evaluation and testing methods identical to those used for SCC were used to study the properties of the new product, SCLC. One of the extensively studied property was the workability of SCC by numerous studies in Europe and North America (Ding et al,2008). Khayat et al.(2004) reported that resisting material segregation and deformation also can be evaluated, in a certain extent, by L-box, U-box, and J-ring tests while they was testing the flow-ability of self-compacting cement mortar (SCC).

Safi et al.(2015) studied the ability of replacing sand as fine aggregate by recycled plastic waste in the self-compacting mortars and its influence on characteristics such as density and mechanical properties. The results showed that there is a positive enhancement in the characteristics in term of the density. The mortars with plastic waste added by 50 per cent produced lighter mortar and exhibited better mechanical strength suitable for lightweight materials than other ratio of plastic waste. According to the results of Safi et al.(2015) study, a lowering between 15% and 33% occurred for mortar including 20–50% plastic waste (case 28 days of hydration).Similarly, Felekoğlu et al. (2005) research studied the fresh state mechanical achievement by selecting the adequate quantity and kind of limestone powder (LS). To compare the effect of adding crushed materials on the mortar’s primary properties self-compactability, strength and viscosity, a series of few various testing methods such as viscosity value measurements, mini-slump, V-funnel tests, and fluidity tests may accordingly designed. For example, for a specified workability of cement-powder mortar containing plasticizer a set of duly selected tests can be used to find the suitable kind of materials and optimum mixing ratio.

Celik et al. (2014) produced concrete with improved workability, higher compressive strength at age of 28 day (39 MPa), excellent result of 57 MPa for one year strength, and dramatic and decreasing in the porosity of produced concrete by replacing 45% by size of ordinary Portland cement (OPC) with 30% and 15%.of fine ash , limestone powder respectively.

Petit and Wirquin, (2010) studied the plastic viscosity and yield stress of SCC mortars containing limestone filler and peak-range water-reduction admixture (HRWRA) under applied pressure when tested by cylindrical-shear-paddles-equipped Marsh cone. Test results of their work exhibited that when subjecting pressure on the mixture, the mixture segregated. They found that other factors rather than pressure such as mixture density, the height from which the mortar is poured and the value of plastic viscosity were only affecting the yield stress.

Many research improved the properties of (SCM) for hardened and fresh mortars such as mechanical performance and workability. Rao et al .(2015) studied the mechanical characteristics of mixtures containing nano-materials (SiO_2 and TiO_2) to upgrade the achievement of self-compacting early age and its effect on the produced concrete characteristics during utilization. The results showed that adding nano materials into mortars used in rehabilitation and reform works has great potential however it needs optimization. Similarly, Khotbehsara et al .(2015) studied hardened and fresh characteristics of self-compacting mortar including nano-CuO (NC) and fly ash (FA) for numerous different ratios. The results indicated considerable advancement in the mechanical characteristics of the specimens containing CuO nanoparticles and FA as a replacement for cement.

From SEM micrographs, the increase in strength and durability of samples of SCMs including nanoparticles can be related to the changes in structure as they showed more packed pore structure.

Mortar with Self-curing property can be produced by adding hydration enhancing additives. Polyethylene glycol and liquid paraffin wax are considered as very effective options to improve the self-hydration characteristics of the SCM. These chemical treat mortars internally leading to enhance hydration and the formation of gel C-S-H (Madduru et al,2016). Şahmaran et al. (2006) estimated the effectiveness of chemical admixtures and additives in various mineral to produce SCM .They added four mineral additives to the tested mixtures: kaolinite, grinded brick, fly ash, and finely grinded limestone and three kinds of super-plasticizers (SP). Properties of fresh mortars were examined by using mini V-funnel test and mini slump flow tests and the properties, at two primary ages 28 days and 56 days, of the hardened mortars were tested by ultrasonic pulse velocity. The properties of both fresh and hardened state were improved significantly as a result of using of limestone and fly ash powder .

This paper aims to experimentally produce lightweight self-compacting concrete mortar LWSCM by using the treated limestone to strengthen the material that is added to the mix and in same time have low density.

2 . EXPERIMENTAL WORKS

Nine ferrocement panels were fabricated to evaluate the flexural behavior. The panels were divided into three groups. The first group was cast with normal light weight self-compacting mortar. In the second group of panels light weight self-compacting mortar (LWSCM) containing limestone was used. The last group was casted with (LWSCM) containing treatment limestone. The panel's dimensions were 350 x 125 x 30 mm ,and the details of reinforcement were showed in **Figure**(1) .The meshes reinforcement composed of 1.05 mm diameter wires welded together at right angle to form a 13mm square openings. The panels were tested as simply supported under 4- point bending as showed in **Figure** (2).Additionally, Cement mortar cubes of 50 mm side length and prisms with dimensions of 40 x 40 x 160 mm were used to estimate the modulus of elasticity and compressive strength of produced concrete, respectively. The prisms were cast and cured, according to ASTM C109 (ASTM-199) and ASTM C348(ASTM-1997) ,to investigate the modulus of rupture.

2.1. Employed Materials

Cement: - the tested cement was ordinary Portland cement that complies to the Iraqi specification No. 5/1984. **Table** (1) shows its chemical properties.

Limestone :- locally naturally available lightweight aggregate of limestone was used as fine aggregate, Keeping in mind the difference in the grading for the fine aggregate and grading must conform to the ASTM C330 (ASTM ,2004), requirements as given in the **Table** (2).

Fine Aggregate: - Graded fine aggregate from Tuz city(Iraqi Specification, No.45. (1984)).The chemical and physical properties as shown in **Table** (3).

Alkaline solution:-Sodium hypochlorite (NaOCL) 1 M pH = 12 were used to treat limestone powder.

2.2. Treatment Of Limestone

The limestone treatment was achieved by immersing the limestone in alkaline solution NaOCL (sodium hypochlorite) for 24 hours, and then washed it very well. Finally, the treated limestone was put inside an oven for three hours to dry it.

2.3. Mixing

The mix design method used in this study was according to EFNARC (2002) .Several trial mixes were done at the beginning in order to get the optimum admixture dosage and the required mechanical performances of LWSCM.

The normal light-weight self-compacting mortar was fabricated by mixing 710 kg/m3 cement, 1210 kg/m3 fine aggregates, and 4.26 kg/m3 SP (0.6% of cement mass). The percentage of water to cement was constant value equal 0.28.
The same quantities above were used in casting the mortars having limestone and treated limestone. Except they had 1037 kg/m3 limestone and 1095 kg/m3 treated limestone, respectively.

3. TEST METHODS FOR FRESH MORTAR

The fabrication of all specimens was done in according to "ASTM C 192/C 192M-02 (1998), Standard Practice for making and curing concrete test samples in the laboratory".

3.1. Mini Slump Test

The mini-slump test is one of the fresh mortar tests that use a cone-shaped mold to measure the spread of mortar inside the mold. The test is conducted by filling the mortar inside a truncated cone with larger diameter of 100 and the smaller diameter 70 mm, and 60 mm of height placed on a non-absorbing smooth plate (Mehdipoura et al,2011). Then the cone is lifted and the value of two measurements of perpendicular diameters are averaged to calculate the final diameter of the fresh mortar sample as shown in **Figure** (3).

3.2. Mini V-Funnel Test

The test is conducted by measure the flow time of one liter of mortar through the funnel small opening. The mortar viscosity, which may be linked with the soft state properties of the mortar such as cohesiveness, pump ability and workability, is measured by this test (Mehdipoura et al,2011). The device used in this test is shown in **Figure** (3).

4 . RESULTS AND DISCUSSION

4.1 . Fluidity

The obtained results of mini-slump test are shown in **Figure** (4). As expected, the control mix achieved the highest slump flow values. The self-compacting mortars with treated and no treated limestone recorded mini-slump values smaller than that of corresponding normal light-weight self-compacting mortar by about 10.2% and 9%, respectively. This may be attributed to the decrease in the momentum of limestone due to the low mass of lime.

4.2. Mini V-Funnel Test

The results of mini V-funnel test are shown in **Figure** (5). The flow time of mortars containing treated and no treated limestone were 23.2% and 31.3% larger than that recorded to mortar without limestone, respectively. Because of the reduction in the viscosity due to the smooth limestone surface, also the treatment using sodium hypochlorite smoothened significantly the surface of limestone because of interaction with lime (Alsharie et al ,2015).

4.3. Density

The hardened 28 days oven dry density of all types of mortar mixtures are presented in **Figure** (6).Since the density of limestone is low, the 28 days dry density of SCM containing limestone reduced by 11.3% comparing with the control mixtures, this result conforms to the requirement of ACI 213-R-03,(2003). However, the reduction in the density in mortar with treated limestone reached 10.9%.Comparing with SCM.

4.4. Compressive Strength

Compressive strength results of SCM samples at age of 3, 7 and 28 day are shown in **Figure** (7) in accordance with ASTM C109 (ASTM,1998).Results showed that the mix containing limestone decreased the compressive strength comparing with the SCM by 18.9., 19.7 and 7.1% at an age of 3, 7 and 28 days, respectively. In contrary, compressive strength of SCM containing treated limestone at an age of 3, 7 and 28 days increased by 5.1, 5.7 and 11.1%, respectively, compared with SCM, because the roughness of limestone particles increased due to treatment . Finally, the compressive strength of SCM with treated limestone was larger than those of same mortars having no treated limestone by 24, 25.4 and 18.2% at ages of 3, 7 and 28 days, respectively.

4.5. Ultrasonic Pulse Velocity

Figure (8) shows the test result of UPV test (Ultrasonic Pulse Velocity) for SCM samples at an age of 3, 7 and 28 days. Results showed that the mix containing limestone reduced the velocity about 1.1, 2.3 and 7.8% compared to the SCM at age of 3, 7 and 28 days, respectively. However, the velocity of SCM containing treated limestone at age of 3, 7 and 28 days increased by 11.2, 9.35 and 7.2%, respectively compared to self-compacting mortar. Since the NaOCL treating increased the hardness of limestone particle and hence made it more homogeneous from sand.

4.7. Hammer Test

Figure (9) shows the hammer test results. this method gives results for compressive strength comparable to results of Ultrasonic test, where the hammer result of mortar having limestone reduced by 27.1, 19.1 and 4.8% at an age of 3, 7 and 28 days, respectively, when comparing the limestone mix with control mix, and the ratio increased by 4.5, 6.4 and 11.6% at an age of 3, 7 and 28 days, respectively, when comparing the treated limestone mix with control mix.

4.8. Modulus Of Rupture

The flexural strength of prisms was calculated at age 28 day in accordance to ASTM C348 (ASTM,1997). **Figure** (10) shows that the flexural strength of the mixes containing limestone and treated limestone dropped to about 42.5 and 37.3%, compared to control mix, respectively.

4.9. Flexural Strength

Flexural strength of ferrocement panels was evaluated using universal testing machine with capacity of 500 kN. The panels of ferrocement samples were subjected to a direct four-point loading and supported as simply, as shown in **Figure** (11). The load was applied gradually till the panel failure. At each load increment, the central deflection was recorded using dial gauge of 0.01mm accuracy. **Figure** (12) shows the ultimate load capacity for the panels, noted that the mix SCM containing normal limestone gave ultimate load less than the reference mix about 4.9%, because the compressive strength of reference mix was hiegher than that of limestone mortar. Treating the limestone using alkaline solution led to considerable enhancement in the panel ultimate load. The failure load of treated-limestone panels were 10.7% and 15.6% above than those of normal and limestone panels, respectively. As shown in **Figure** (13) ,the ductility of panels were improved when using treated or no treated limestone in their construction. For a certain load, the central deflection of normal panels was smaller than those of corresponding mortar having either treated or no treated limestone.

5. CONCLUSIONS

1. Treating the Limestone with NaOCL improved both the fresh and hardened SCM properties compared to non-treated limestone and control mixture for fresh mortar.
2. Using NaOCL in treating the limestone improved Flexural strength and ductility of ferrocement panels.

3. The flow time of treated and non-treated limestone increased about 23.2% and 31.3% respectively. And its fluidity augmented decreased about 10.2%, and 9% respectively, compared with control mix.
4. The 3, 7, and 28 days compressive strength of treated limestone mortars were higher than those of normal mortars. However, the limestone mortars gave the lowest compressive strength.
5. Density reduced for non-treated limestone and treated limestone compared with control mix about11.3%, and 10.9%, respectively.
6. The ultimate load capacity of treated limestone panels was improved by about 10.7% comparing to normal one.

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Table (1): Chemical properties composition of cement.

Oxides composition	Content %	I.Q.S. N0.5:1984%
Silica, SiO_2	13.4	-
Alumina, Al_2O_3	4.6	-
Iron oxide, Fe_2O_3	----	-
Magnesia, MgO	---	< 4
Sulfate, SO_3	1.1	< 3
Loss on Ignition, (L.O.I)	0.95	<1.5

Oxides composition	Content %	I.Q.S. N0.5:1984%
Insoluble material	1.05	<1.5
Lim Saturation Factor, (L.S.F)	0.9	1.02_0.66
Silica, SiO_2	13.4	-

Table (2): Grading of lightweight fine aggregate.

Sieve size	Cumulative passing %	ASTM C330 Limits %
9.5-mm (3⁄8-in.)	100	100
4.75-mm (No. 4)	90.38	85-100
1.18-mm (No. 16)	66.83	40-80
300-µm (No. 50)	15.89	10-35
150-µm (No. 100)	6.09	5-25

Table (3): Grading of fine aggregate.

Sieve size	Cumulative passing %	I.Q.S.45:1984 Limits Zone (2)%
9.5-mm (3⁄8-in.)	100	100
4.75-mm (No. 4)	91.34	100-90
2.36-mm (No. 8)	83.8	100-75
1.18-mm (No. 16)	67.73	90-55
600-µm (No. 30)	40.3	59-35
300-µm (No. 50)	12.45	30-8
150-µm (No. 100)	0	10-0

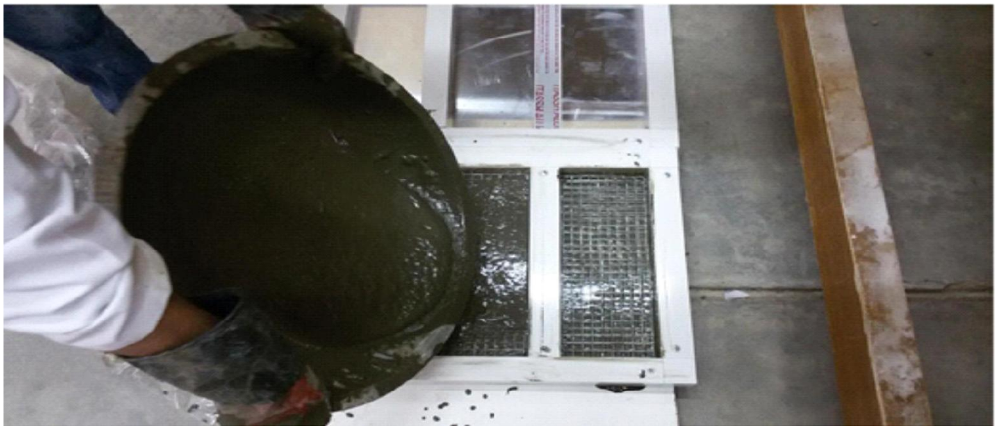

Figure (1): Casting of the ferrocement panels.

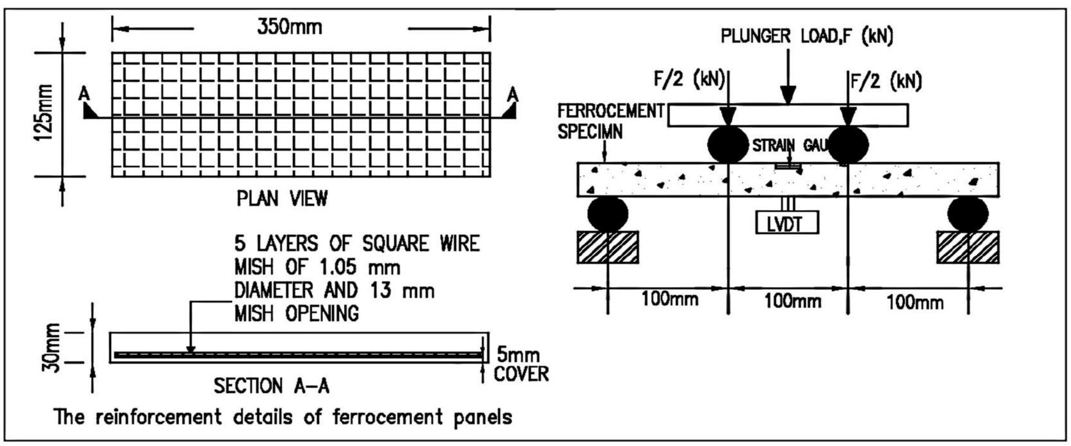

Figure (2): Details of ferrocement panels and test.

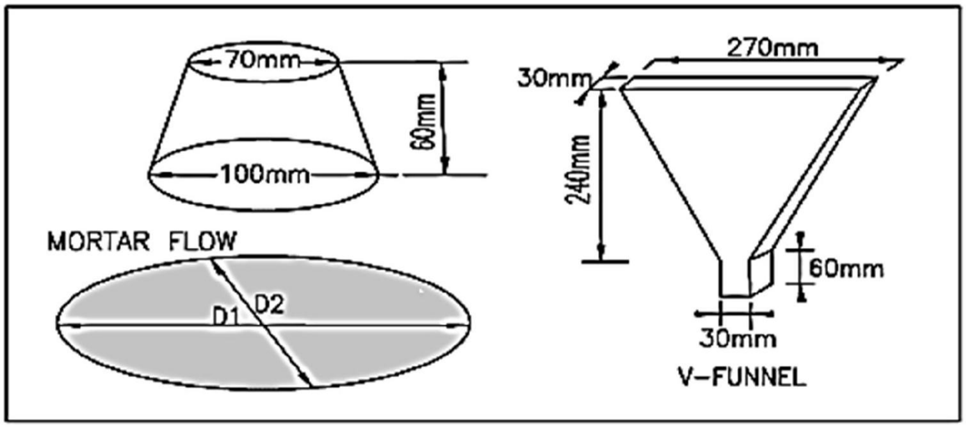

Figure (3): Dimensions of mini-slump and mini V-funnel.

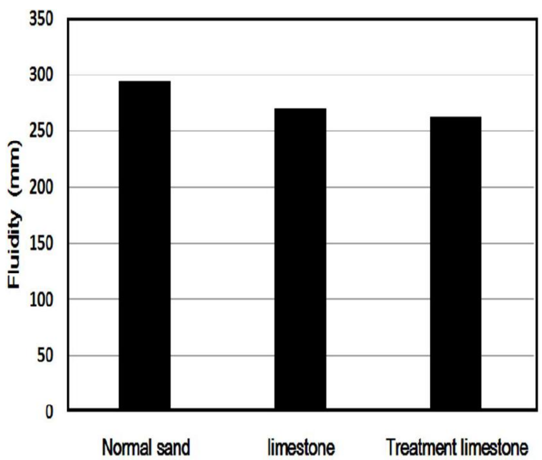

Figure (4): The relationship between mix and the fluidity.

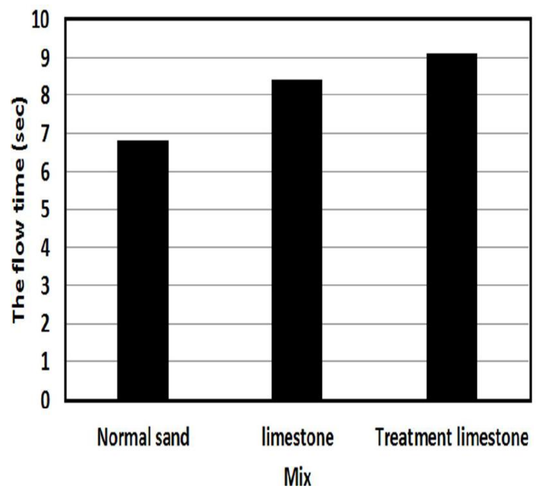

Figure (5): The relationship between mix and the flow time.

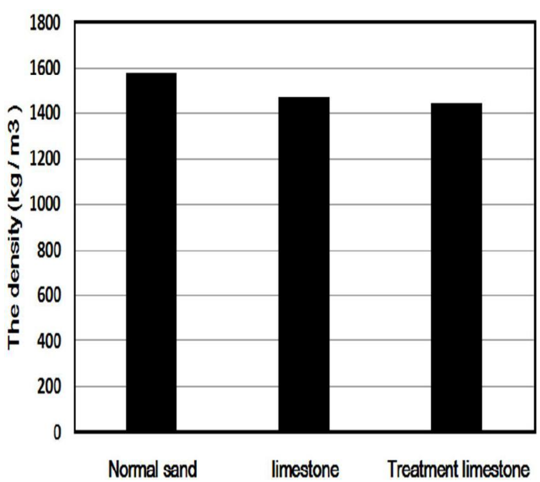

Figure (6): The relationship between mix and the density.

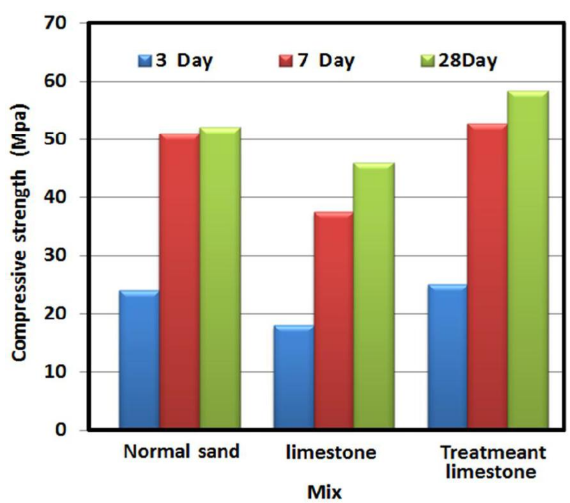

Figure (7): The relationship between mix and compressive strength.

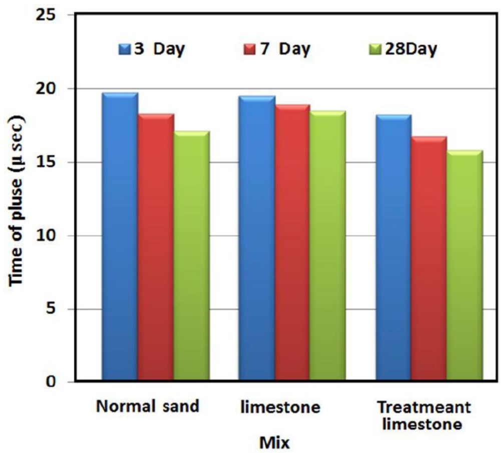

Figure (8): The relationship between mix and ultrasonic pulse velocity.

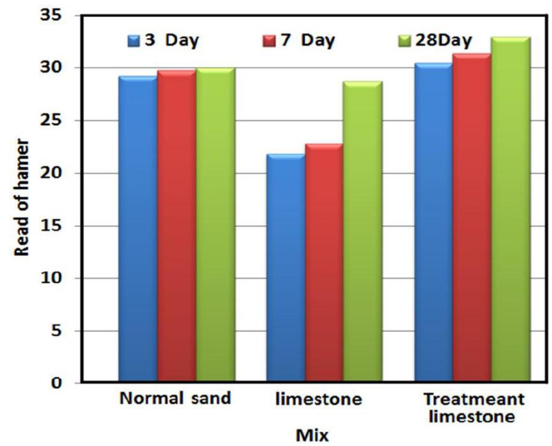

Figure (9): The relationship between mix and read of hummer.

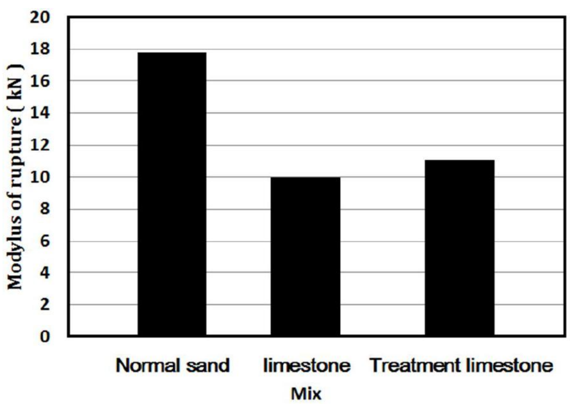

Figure (10): The relationship between mix and modulus of rupture for prism.

Figure (11): Test set-up.

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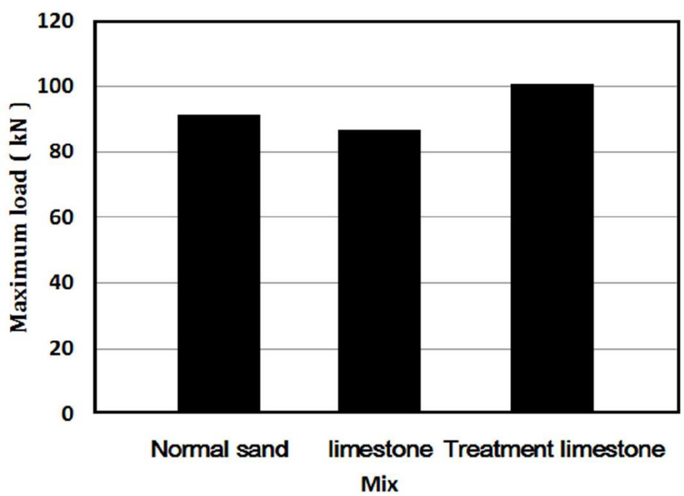

Figure (12): The relationship between mix and maximum load.

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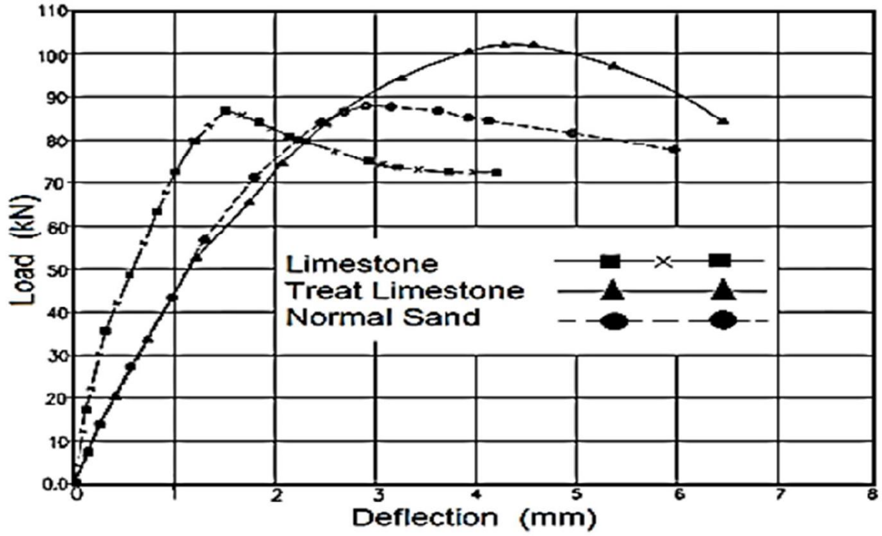

Figure (13) : Curve of load application versus displacement in the test.