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The Influence of Clay Bricks Dust Incorporation on the Self-Curing of Cement Mortar

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ABSTRACT

Self- curing is the potential of lightweight aggregate to absorption great amount of water thru mixing which prominently can moves to the paste during hydration process. Self- curing empowers a water to be distributes more evenly act out the cross section. Whereas, the external curing water is only able to penetrate several millimetres into concrete with low water cement ratio. Brick dust accumulates in the demolish site creates serious environmental contamination. This study investigates the effect of brick dust recovered from construction site on the Properties of mortar cured in three curing conditions. Mortar in this study produced using BD as cement additive with (2, 4, 6, and 8) % by weight of cement. BD was used as cement replacement (1, 2, 3, and 4) % by weight of cement. Three curing conditions were experienced in this study to identify whether BD can be used as self- curing agent. Compressive strength, Fresh and hardened density, water absorption, and modulus of rupture were tested. The results of compressive strength and modulus of rupture were decreased when BD used as cement additive and as cement replacement increase. However, they were higher for mortars cured in air conditions than those cured in water and partially water curing. Water absorption, was increased with the increase of (BD) when used as cement additive and replacement. It was indicated BD could be used as self- curing agent and could replace cement at specific ratios which will achieve economical profits and reduce environmental pollution.

Key words: brick dust, compressive strength, water absorption, modulus of rupture, self- curing.

تأثير غبار الطابوق الطيني على الانضاج الذاتي لمونة السمنت

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الخلاصة

الانضاج الذاتي يعبر عن قدرة الركام الخفيف الوزن على امتصاص كمية كبيرة من الماء خلال عملية الخلط وحدوث الاماهة، الانضاج الذاتي يمكن الماء من ان يتوزع بانتضام خلال مقطع الخرسانة ، في حين ان الانضاج الخارجي يتغلل الماء مليمترات قليلة داخل الخرسانة خصوصا عندما تكون نسبة الماء الى الاسمنت منخفضة. تراكم غبار الطابوق سواء في اماكن البناء او الهدم يخلق مشاكل بيئية خطيرة.هذه الدراسة تبحث في تاثير غبار الطابوق على خصائص المونة.

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تم اضافة غبار الطابوق الى مونة السمنت كنسبة من وزن السمنت وبنسب (2، 4، 6، 8) % الى جانب ذلك تم اضافة غبار الطابوق الى المونة كاستبدال وزني من وزن السمنت المستخدم وبنسب (1، 2، 3، 4) % . تم تطبيق ثلاث طرق للانضاج لتقييم استخدام مسحوق الطابوق الطيني كعامل انضاج ذاتي.

بينت النتاج ان قيم مقاومة الانضغاط ومعاير الكسر تقل بزيادة نسبة غبار الطابوق كاضافة او استبدال وزني من السمنت. على اية حال هذه القيم كانت اعلى من قيم النماذج سواء تم انضاجها بشكل جزئي بالماء او كليا بالهواء في حين ان امتصاص النماذج للماء يزداد بزيادة نسبة غبار الطابوق كاضافة او استبدال من وزن السمنت. بناءا على ذلك فان غبار الطابوق يمكن ان يستخدم في عملية الانضاج الذاتي مما يؤدي الى مردود اقتصادي ويقلل من التلوث البيئي.
كلمات رئيسية: غبار الطابوق، مقاومة الانضغاط، امتصاص الماء، معامل التصدع، الانضاج الذاتي.

1. NTRODUCTION

Sufficient curing is very consequential for developing sufficient surface durability to resist deterioration by environmental impact, such as liableness to deicing salts that's commonly used on bridges and roads. Water curing regime is the best tests. Membrane-forming curing compounds concrete have displayed better resistibility to de-icing salts than these cured with an external equipping of water. Air entraining agent has also attested to be helper in enhancement resistance to this kind of measurability, **Tazawa,** and **Miyazawa, 1995**, **Wang,** and **Tsai, 2006**.The external curing and its procedures not being followed. Also the external curing, repair and earlier replacement costs of the concrete outstripped the relatively low initial cost of internal curing, **Zhutovsky, et al., 2002**.

The management of Waste materials is one of the imperatives of every public and it has become distinctly that best waste management can enhancement the life quality. The main objective of a management the west martials is in reducing the mass production of new, detecting ways to recycle and reuse as alternative for raw materials, **Debieb,** and **Kenai, 2008**. Hugely proportion of this demolishing waste is masonry debris consisting of clay bricks. Which are usually given away into the sites or around brick factories, whereby recycle brick dust in mortar will contribute to waste management and environmental protection. The objective of the present work is to investigate the possibility of reusing brick dusts waste in Portland cement mortar into two series mixes: as cement additive and as replacement by weight of cement. Besides, the self-curing will be assessed in this study by investigating the curing in three different conditions. Mechanical properties will be examined to verify the possibility of using brick dust as cement additive and cement replacement and to work as self- curing agent.

2. METHODS AND MATERIALS TESTS

Ordinary Portland cement (Type I) compliance with Iraqi specification, **IQS No.5/1984**, was used for casting all specimens. Natural sand with 2.3 fineness modulus was used. Specific gravity, absorption and bulk density of the used sand is 2.6, 0.78%, 1342 kg/m^3 respectively. Demolish clay bricks were obtained from a local manufacturer that salvages it off standards products , brick dust was obtained by sieving the crushed bricks and grounding the dust that pass through sieve 0.075 micro meter to a cement fineness. The chemical compositions of the materials used in this work are listed in tables 1-3.

Table 1. Chemical oxides and physical properties of the cement used.

Oxides composition	**Oxide content %**	**IQS, No.5/1984 limits**
CaO	63.74	-
SiO_2	21.68	-
Al_2O_3	5.72	-
Fe_2O_3	2.83	-
MgO	2.08	< 5.00
SO_3	1.53	< 2.8
Na_2O	0.28	-
K_2O	0.67	-
Free lime	1.12	-
Lose on Ignition	0.80	< 4.00
Insoluble Residue	1.43	< 1.50
Lime Saturation Factor	0.86	0.66-1.02
Main Compounds (Bogues Equations)		
C3S	47.95	-
C2S	29.44	-
C3A	10.37	> 5.00
C4AF	8.6	-
Physical Properties		
Fineness (Blaine)(m2/kg)	318	≥230
Initial setting, h:min	2:10	≥45 min
Final setting, h:min	4:45	< 10hr
Compressive strength (MPa) 3 days 7 days 28 days	 18.05 25.47 28.35	 ≥ 15.00 ≥ 23.00 -
Soundness Le Chatelier method, mm	1	≤ 10

Table 2. Chemical oxides and physical properties of the sand used.

Oxides composition	**Oxide content %**	**IQS, No.45/1984 limits**
CaO	3.21	-
SiO_2	80.78	-
Al_2O_3	10.52	-
Fe_2O_3	1.75	-
MgO	0.77	-
SO_3	0.08	
Na_2O	1.37	-
K_2O	1.23	-
Grading		
Sieves size (mm)	Passing%	

4.75	98	90 - 100
2.36	95	85 – 100
1.18	87	75 – 100
0.6	54	60 - 79
0.3	30	12 – 40
0.15	8	0 - 10
Physical Properties		
Specific gravity	2.6	
Absorption (%)	0.69	
Bulk density (Kg/m^3)	1350	
Fineness modulus	2.3	

Table 3. Chemical oxides and physical properties of the brick dust used.

Oxides composition	**Oxide content**	**IQS, No.45/1984 limits**
CaO	6.4	-
SiO_2	65.1	-
Al_2O_3	23.41	-
Fe_2O_3	36.5	-
MgO	0.18	-
Na_2O	9.2	-
K_2O	2.3	-
Physical Properties		
Specific gravity	1,59	-
Absorption %	23	-
Dry loose unit weight (Kg/m^3)	860	-
Dry rodded unit weight (Kg/m^3)	958	-

The aim of the present study is to assess the using brick dust as cement replacement or addition by the weight of cement on the properties of cement mortar. The possibility of using brick dust as self- curing agent was investigated also. The curing regime were experienced in this study were: water curing by immersing specimens in water for 28 days, partially water curing by immersing specimens in water for 3 days and left them in laboratory for 24 days and air curing in laboratory for 28 days without immersing samples in water to identify whether BD can be used as self- curing agent.

Sand, cement, water and (BD) were mixed to prepare fresh mix in mortar mixer in varying mixes. Mix design was (1:3) (cement: sand), two series were adopted in this study series A and series R where (BD) used as an addition to cement in series. Series A represent BD as cement addition with ratios (2,4,6,8)% by weight of cement, Mix code is given as ABD2 represent 2% BD addition to cement, ABD4 is 4% added to cement, ABD6 is 6% added to cement and ABD8 is 8% added to cement. Series R represent BD as cement replacement with ratios (1,2,3,4)% by weight of cement, mix code represent RBD1 is 1% BD replace cement, RBD2 is 2% BD replace cement, RBD3 is 3% BD replace cement and RBD4 is 4% BD replace cement.

(BD/C) represent the percentages ratio of brick dust were added/or replace by weight of cement. Materials proportion adopted in this study based on laboratory trials and it is indicated in table 4.

Table 4. Materials proportion for 1m^3 of mortar.

Series	Mix code	Brick dust/Cement ratio (%)	Cement (kg/m^3)	Sand (kg/m^3)	Brick dust (kg/m^3)	Added/or Replace (BD) by cement
A	ABD2	2	634	1904	13	Added
	ABD4	4	634	1904	25	Added
	ABD6	6	634	1904	38	Added
	ABD8	8	634	1904	51	Added
R	RBD1	1	626	1904	6	Replace
	RBD2	2	620	1904	13	Replace
	RBD3	3	614	1904	19	Replace
	RBD4	4	608	1904	25	Replace

The mortar was placed in mould to form 2 types of samples cubic (0.5×0.5) cm and prism (16×16×4) cm. Mortar was demoulded after 24 hours. Each series divided into three groups cured in three curing environments in which immersed in water for 28 days, immerse in water for 3 days and then cured in laboratory for 25 days and the third group was left air cured in laboratory without immersing in water for 28 days to assess the possibility of using BD for the self- curing in cement mortar.

2.1 Tests

2.1.1 Compressive strength

The Compressive strength is used to assess the capacity of a material to withstand axially directed forces. The compressive strength test was done at 7, 14, and 28 days ages on 5×5×5 mm cubic specimens using ELE compression testing machine with 2000 KN capacity. The compressive strength test was officiated according to **ASTM C67 – 07a**. Three cube specimens were tested per each group from the three groups which were water, partially water and air cured mortar.

2.1.2 Modulus of rupture

This test was conducted according to the **ASTM 78-02**. The test was done on simply supported prism under two points load, with dimensions of 160×160×400mm. Three samples were rested form each group which were cured in different curing regimes at 28 days age.

2.1.3 Absorption

Three samples from each curing regime was oven dried at 105 $^{\circ}$C for 24hours. The oven dried samples was immersed in water for 24hours according to **ASTM C1403-15**. The absorption of water was delineates from the difference in weight after water immersing to the dried samples. The Eq. (1) below was used to determine the water absorption:

$$A = \frac{m_w - m_d}{m_d} * 100 \quad (1)$$

Where:
A= water absorption (%).
m_w= wet mass (gm).
m_d= dry mass (gm).

3. RESULT AND DISCUSSION

3.1 Fresh and Hardened Density

Results for fresh density and hardened density for the samples cured in water curing; partially water and air curing for the two series A and R are given in table 5.

Fresh density ranged in (1757-1672) kg/m^3 and (1762- 1670) kg/m^3 for series R. Fresh density was ranged in (It is obvious to note that fresh density decreased with the increase of (BD) in the two series when used as cement additive in series A and as cement replacement in series. Hardened density for series A ranged in (2160-2125) kg/m^3 for mortar cured in air, hardened density for mortar cured partially in water varied from 2210kg/m^3 to 2109kg/m^3, for mortar cured in water varied from 2321kg/m^{3}to 2203kg/m^3.Hardened density for series R varied from 2250 kg/m^3 to 2185 kg/m^3 for mortar cured in air, for mortar cured partially in water ranged from 2287 kg/m^3 to 2204 kg/m^3, hardened density for mortar cured in water was varied from 2375kg/m^3. Hardened density was generally decreased for series A when BD was added to cement content for the three groups of curing. Hardened density for series R when BD was replaced cement was decreased as well for the three groups of curing. It may be attributed to the fact that void spaces is a measure of the porosity in a material, and the void substance of BD were higher than by few times those of crushed stone aggregate, hence the addition of (BD) to the mortar will increase the intruded pore volume, hence density was reduced as well, **Farell, et al., 2001**.

Table 5. Results for fresh density and hardened density.

Series	Mix Code	Fresh density (kg/m^3)	Hardened density (kg/m^3)		
			Air curing	Partially water curing	Water curing
A	ABD2	1757	2160	2210	2321
	ABD4	1747	2175	2148	2281
	ABD6	1727	2109	2120	2226
	ABD8	1672	2125	2109	2203
R	RBD1	1762	2250	2287	2375
	RBD2	1717	2236	2254	2300
	RBD3	1681	2221	2240	2271
	RBD4	1670	2185	2204	2225

3.2 Compressive Strength

Results for compressive strength at age 7, 14 and 28 days for the two series A and R is illustrated in table 6.

Table 6. Results for compressive strength.

Series	Mix code	Air curing (MPa)			Partially water curing (MPa)			Water curing (MPa)		
		7 days	14 days	28 days	7 days	14 days	28 days	7 days	14 days	28 days
A	ABD2	16.9	18.83	24.89	16.5	17	22.12	13.53	15.92	21.16
	ABD4	14.4	17.21	22.4	13.88	16.52	20.81	12.25	15.23	20.34
	ABD6	12.8	14.42	20.89	12	16	19.75	11.77	13.6	17.03
	ABD8	10.86	13.88	18.16	10	14	16.29	9.2	12.88	14.55
R	RBD1	14	20.35	23.96	13	19.12	19.71	12.21	17.4	18.42
	RBD2	12.12	17.83	19.85	11.43	16.53	18.46	10.1	15.89	17.12
	RBD3	11.21	14.41	18.76	10.89	13.12	17.21	10.54	12.1	16.04
	RBD4	10.16	12.85	17.24	9.67	11.54	16.33	9.1	10.67	15.12

Compressive strength for series a ranged in (24.89-18.16) MPa for mortar cured in air (AC) and (17-14) MPa for mortar cured partially in water (PWC) and from 21.16MPa to 14.55 MPa for mortar cured in water (AC). Compressive strength for all mortars decreased comparatively with reference mortar which has 26.35 MPa at 28 days. However, compressive strength for mortar cured in air was significantly higher than those cured in water and partially water as it is shown in **Fig.1**.

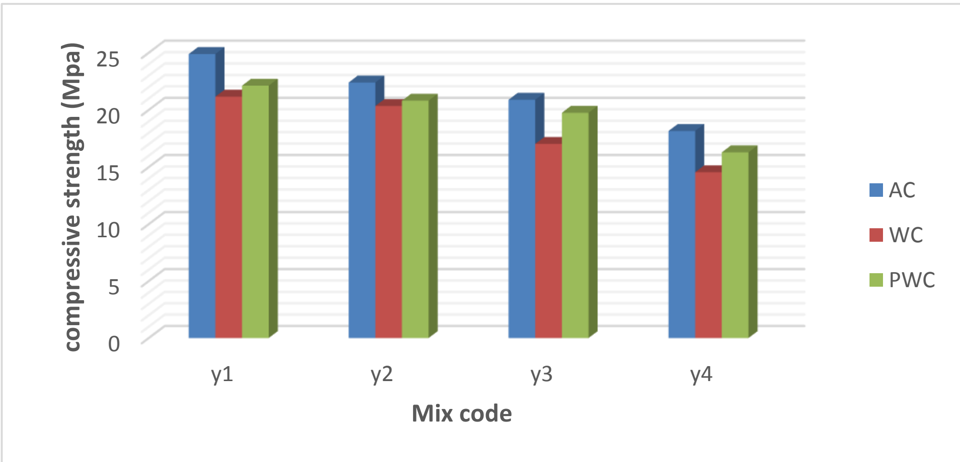

Figure 1. Compressive strength at age of curing for series A

Compressive strength for series R ranged in (23.96-17.24) MPa for mortar cured in air and (19.71-16.33) MPa for mortar cured partially in water and (18.42-15.12) MPa for mortar cured in water. Compressive strength for series R behaved similarly to series y as shown in **Fig.2**. Compressive strength reduction may be ascribable to the addition of BD to the mortar caused an increment in pore volume which decreases the compressive strength, **Farell, et al., 2010**.

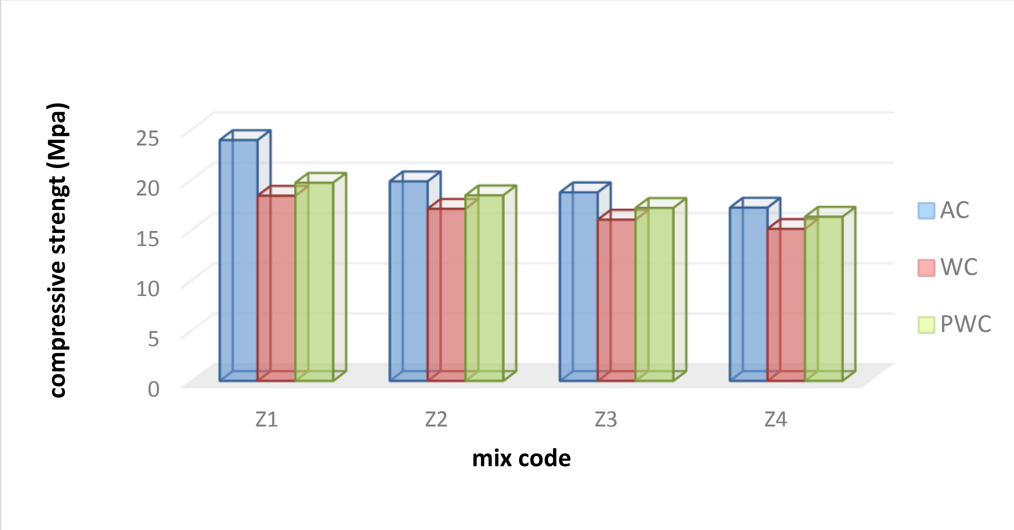

Figure 2. Compressive strength at age of curing for series R

3.3 Absorption and Modulus of Rupture

Results of water absorption and modulus of rupture are indicated in table7.

Table 7. Results for water absorption and modulus of rupture.

Series	Mix code	Water absorption (%)			Modulus of rupture (MPa)		
		Air curing	Water curing	Partially water curing	Air curing	Water curing	Partially water curing
A	ABD2	6.8	6.27	6.61	6.53	4.79	5.908
	ABD4	7.22	6.93	7.12	6.308	4.518	5.638
	ABD6	8.14	7.45	7.96	5.52	3.588	5.213
	ABD8	9	8.28	8.87	5.231	3.23	4.83
R	RBD1	5.92	4	5	5.569	4.89	5.144
	RBD2	6.7	5.5	6.1	5.135	4	4.283
	RBD3	8.23	7.11	7.91	4.87	3.52	3.98
	RBD4	9.9	8.4	8.9	4.632	3.12	3.53

Water absorption for series A ranged in (6.8-9) % for mortar cured in air, (6.27-8.28) % for mortar cured in water and (6.61-8.87) % for mortar cured partially in water. Water absorption for series R varied from 5.92% to 9.9% for mortar cured in air, (4-8.4) % for mortar cured in water and (5-8.9) % for mortar cured partially in water. It is clear to observe that water absorption is increased with the increase of BD addition to cement in series A and when BD replaced cement in series R as it is demonstrated in **Fig.3** and **Fig.4** which shows the relationship between bulk composition of BD and water absorption in series A and R consecutively. It is explained as BD is a permeable material and has high water retention, **Khaloo, 1995**.

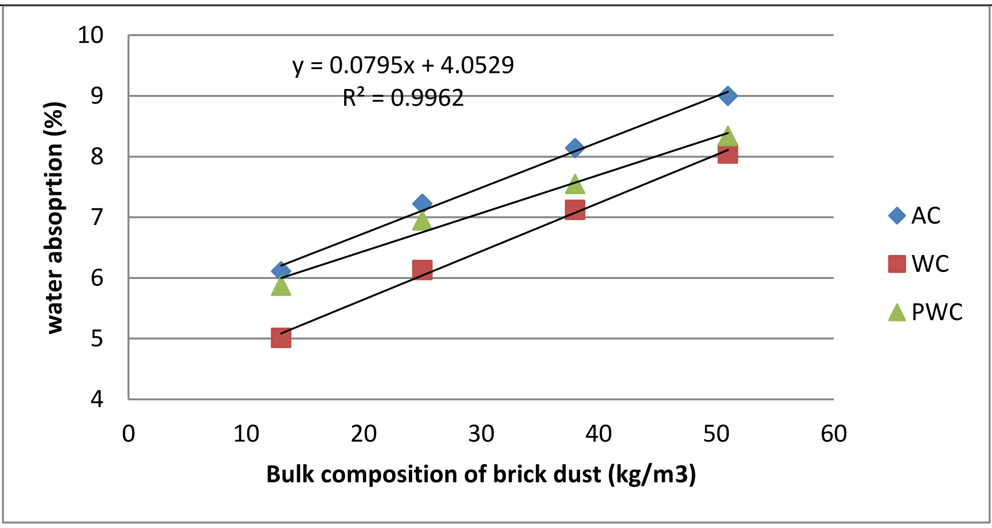

Figure 3. Relationship between bulk composition of BD and water absorption in series A

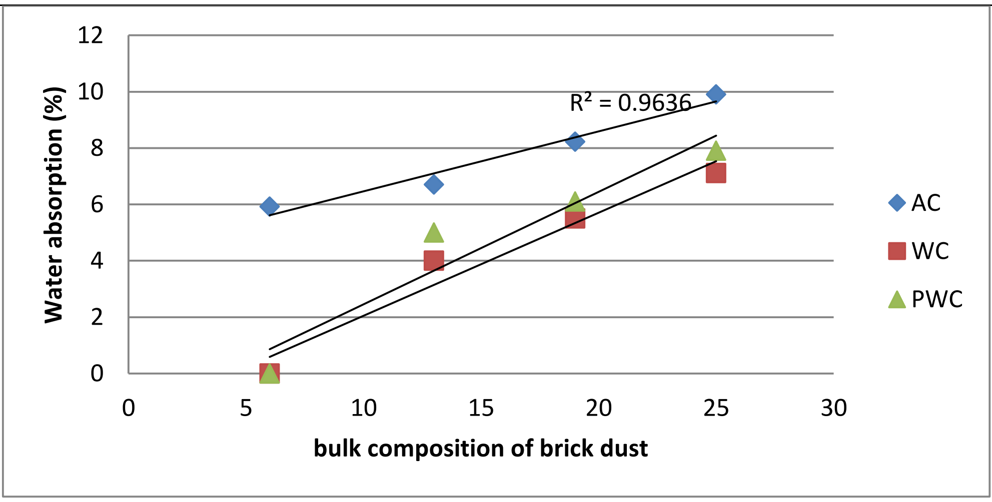

Figure 4. Relationship between bulk composition of BD and water absorption in series R

Modulus of rupture for series A ranged in (6.53-5.231)MPa for mortar cured in air, (4.79-3.23)MPa for mortar cured in water, (5.90-4.83)MPa for mortar cured in partially in water, modulus of rupture for series R ranged in (5.569-4.632)MPa for mortar cured in air, (4.89-3.13)MPa for mortar cured in water and (5.144-3.53)MPa. It is obvious to note that the modulus of rupture decreased with the increase of BD in the two series A and R. Relationship between modulus of rupture and the bulk composition of BD for series A and R is recorded in **Fig.5** and **Fig.6**. However, mortar cured in air recorded the highest modulus of rupture; hence BD could be used as self- curing agent.

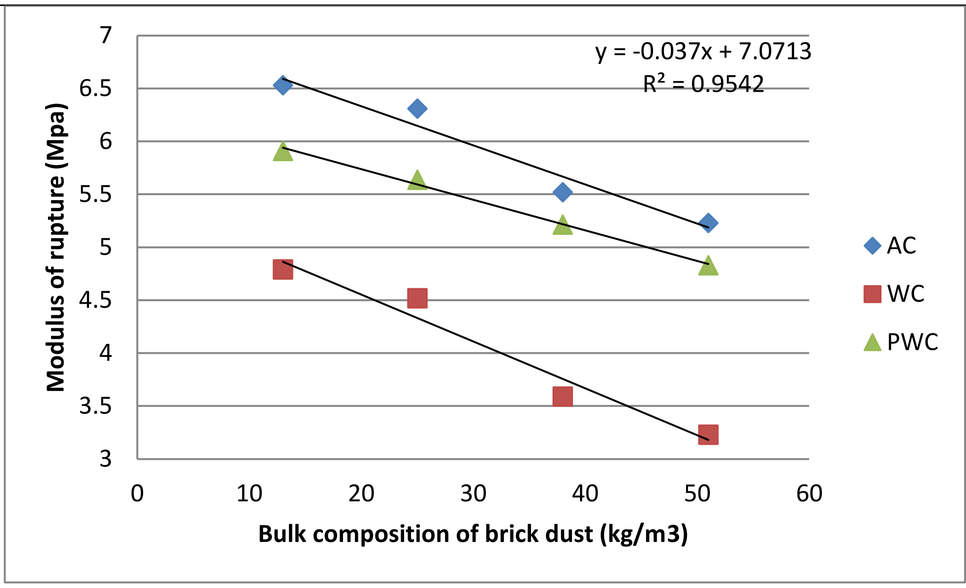

Figure 5. Relationship between bulk composition of BD and modulus of rupture in series A

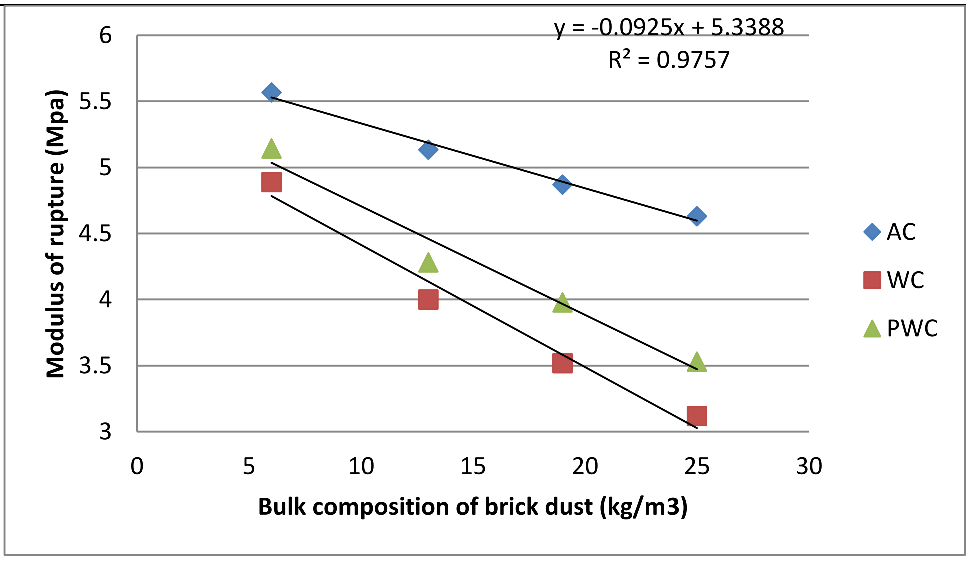

Figure 6. relationship between bulk composition of BD and modulus of rupture in series R

4. CONCLUSIONS

The conclusions below are withdrawn based on the experimental work:

- Fresh and hardened density was significantly decreased with an increase in (BD) in the two series A and R when used brick dust as cement addition and replacement by weight of cement.
- Compressive strength and modulus of rupture for the three groups cured in different conditions were decreased with increase of brick dust in mortar. However, mortar cured in air showed higher compressive strength and modulus of rupture than the mortar cured in water and the mortar cured partially in water.
- Water absorption was increased with the increase in brick dust in series A and R when used as cement addition and replacement in mortar.
- Brick dust could be used as self- curing agent in cement mortar.

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