USING OF WASTE GLASS AS FINE AGGREGATE IN CONCRETE

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Abstract

The present investigation was carried out to study the possibility of using waste glass of size up to 5mm as a fine aggregate in concrete and mortar. The waste glass was used as a partial weight replacement of sand with percentages of 10, 20, 30 and 40 %. The results have indicated that increasing the fractions of sand replacement by waste glass leads to reduce the compressive and tensile strength for both mortar and concrete. Up to 20 % replacement, the 28 days compressive strength of concrete and mortar is about 92 and 95 percent from the reference strengths, respectively. Also, it was found that the expansion of mortar specimens increase with increasing the waste glass content in the mix. At 20 % of sand replacement by waste glass, the expansion is slightly higher than that for the control specimens.

Keywords: concrete, waste glass, compressive strength, tensile strength, expansion.

استخدام مخلفات الزجاج كركام ناعم في الخرسانة

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الخلاصة

يهدف هذا البحث إلى دراسة إمكانية استخدام مخلفات الزجاج وبمقاس أقصى مقداره (٥ ملم) كركام ناعم في الخرسانة والمونة السمنتية. تم استخدام مخلفات الزجاج كبديل جزئي عن الرمل وبنسب وزنية (١٠، ٢٠، ٣٠ و٤٠) %. اظهرت النتائج بان زيادة محتوى هذه المخلفات المستبدلة من الرمل يؤدي إلى نقصان في مقاومة الانضغاط والشد لكل من المونة والخرسانة. عندما تصل نسبة الاستبدال إلى ٢٠ % فان مقاومة الانضغاط بعمر ٢٨ يوم تصبح بحدود (٩٢ و٩٥)% من الخلطات المرجعية لكل من الخرسانة والمونة على التوالي. بالإضافة إلى ذلك فقد وجد بان هناك زيادة في مقدار التمدد لنماذج المونة عند زيادة نسبة المخلفات الزجاجية في الخلطة. عند استبدال ٢٠ % من الرمل بهذه المخلفات فان مقدار التمدد للنماذج يصبح أعلى بقليل أذا ما قورن بنماذج الخلطة المرجعية.

Introduction

In recent years, there is a growing interest for using waste glass in concrete. This interest has been aggravated by the large amount of waste glass available from empty bottles, waste windows glass and containers. If such glass could be consumed in concrete, it would significantly decrease the disposal of waste glass and solve some of environmental problems.

The use of waste glass as aggregate in concrete has been attempted recently. Using such glass as a construction material is among the most strictly choise because of the potentially reducing the cost of glass disposal and concrete production.

It is expected that obvious differences occur in the structure between glass concrete and conventionally concrete. This including reduced bond strength between the aggregate and the cement paste. The interlocking shear strength between the aggregate and the cement paste is less with glass than with natural aggregate. Additionally, the friability of glass particles may weaken the concrete.

The effect of using waste glass on the mechanical properties of concrete has been investigated by many other researches including (Multon et al 2008, Newes and Zsuzsanna 2006, Xie and Xiang 2003, Zdenek et al 2000, Crais Polley et al 1998, Johnston 1974, Schmidt and Sain 1963). Their results indicated that the waste glass aggregate generally reduced strength. They attributed this behavior to that the silica in glass can be highly reactive with the alkalis in cement paste. This reaction can lead to expansion and cracking of concrete (Alkali-Silica reaction or ASR).

Recently, an experimental work has been studied by (AL-Rubaie 2007) to evaluate the properties of concrete mixes containing waste glass as partial replacement up to 20% by volume of sand. The results indicate that the concrete mixes containing waste glass show slightly reduction in compressive and tensile strength as compared with reference mixes.

In this experimental study, the effect of using locally available waste windows glass as fine aggregate on the mechanical properties of concrete was investigated. The specimens of concrete and mortar were tested for compressive strength, splitting tensile strength, modulus of rupture and expansion for various ages and glass proportions ranging from 0 to 40 % by weight of sand.

Experimental Program

The experimental program was conducted on concrete and mortar specimens. Concrete specimens were tested under compression and splitting tension, while mortar specimens were prepared for test of compressive strength, modulus of rupture and expansion.

Materials

Ordinary Portland cement conforming to IOS4:1984 and manufactured at Al-Najaf cement plant is used. The coarse aggregate used was round gravel with a nominal maximum size of 38mm and the fine aggregate used in the present study was natural sand. They were within the limits of IOS 45:1984

The source of glass aggregate used in the present research is the waste of windows glass as shown in **Plate (1)**. It was ground in the laboratory in order to obtain a grading rather similar to that for sand.

Mixes

Five concrete mixes having the proportions of (1:1.5: 3:0.5) (cement : sand : gravel: water) were made. Also, five mortar mixes were prepared with the proportions of (1 : 3 : 0.4) (cement : sand : water). Different fractions of waste glass, namely (0, 10, 20, 30 and 40%) were added to the mixes as a partial replacement by weight of sand.

Testing Procedures

The compressive strength of (152 mm) concrete cubes and the splitting tensile strength of (152×305 mm) concrete cylinders were tested at ages of 7 and 28 days according to BS 1881: part 4 and ASTM C496, respectively.

For mortar specimens, the modulus of rupture was conducted on (25×25×250 mm) prisms using test setup meeting the requirement of ASTM C293. The compressive strength was carried out on (70.7 mm) cubes according to B.S 12 : 1989 . Both tests were performed at 7 and 28 days ages. The expansion of the mortar specimens was measured using a length comparator device as shown in **Plate (2)** according to ASTM C157. Three prisms having the dimension of (40×40×285 mm) were cast for each mix and kept in water. The expansion was measured at ages of 7, 14, 28, 60, 90 days and determined as follows:

$$S = \frac{R - R_o}{L} \times 100$$

where:

S= expansion of the specimen %.

L= initial length of the specimen, mm.

R= gage reading, mm.

R_o= initial gage reading, mm.

Results and Discussion

Tables (1), **(2)** and **(3)** show the test results obtained in the current study for concrete and mortar specimens.

Compressive and tensile strength test results

In **Figures (1)** and **(2)**, the influence of partial replacement of sand by waste glass on compressive strength of concrete and mortar specimen is illustrated respectively. It is clear from these figures that the presence of waste glass in the mixes leads to decrease compressive strength as the percentage of glass is increased. However, up to 20% of substitution, the reduction is not significant. It is about (8 %) and (5 %) at 28 days age for concrete and mortar mixes, respectively.

The reduction in compressive strength can be attributed to the following two reasons: (1) the poor paste-aggregate bond because of the smooth texture of glass aggregate piece, and (2) the friability of waste glass and its relatively low resistance to aggregate fracture (Polley et al 1998, Johnson 1974).

The results of concrete splitting tensile strength and mortar modulus of rupture are plotted in **Figure (3)** and **(4)**, respectively. As with the compressive strength, the two figures indicate that the tensile strength is affected, especially at high levels of replacement. Again, the extremely poor shape, poor surface characteristics and high friability of glass particles could be the reason of this deterioration.

Expansion Test Results

Figure (5) shows the expansion of mortar prisms versus additions of different fractions of waste glass as fine aggregate. In general, it can be seen that the mixes containing waste glass show greater expansion that reference mix. However a glass content of less than 20% provided acceptable performance in the expansion test. There are many reasons stand behind this behavior. Waste glass is highly alkali silica reactions (ASR) and when used with moderate-alkalicement, certain combinations of glass exceeded acceptable expansion as early as 28 days (Johnson 1974). On the other hand, it is well known that such glass have low modulus of elasticity which offer less restraint to volume change (Neville 2000).

Conclusions

1. The addition of waste glass as a partial replacement of fine aggregate leads to decrease the compressive strength. Up to 20% of waste glass, the reduction at 28 days age is about (5) and (8) percent for mortar and concrete specimen respectively.

2. The tensile strength measured by splitting tensile strength and modulus of rupture is found to decrease with the increase in the percentages of waste glass. However, the mixes of up to 20% of waste glass exhibit slight decrease in tensile strength compared to control mix. At this level, the magnitude of splitting tensile strength of concrete and modulus of rupture of mortar decrease by only (6) and (4) percent respectively at age of 28 days.

3. When the waste glass is used, the expansion of mortar bars is higher than those without glass. This volume change is more pronounced as the percentage of substitution is increased. The acceptable expansion has been achieved up to 20% replacement.

4. Results of the present study indicate that waste windows glass aggregate can be satisfactorily substituted for natural fine aggregate at replacement levels up to 20% with the properties comparable to the control specimens.

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Table (1): Results of compressive and splitting tensile strength (MPa) for concrete mixes

Waste Glass as Fine Agg. %	Compressive Strength (MPa)		Splitting Tensile Strength (MPa)	
	7 days	28 days	7 days	28 days
٠	٢٥.٢	٣٧.٠	٢.٨٧	٣.٧٥
١٠	٢٤.٥	٣٥.٩	٢.٨٠	٣.٦٧
٢٠	٢٣.٣	٣٤.٢	٢.٧٢	٣.٥٥
٣٠	٢٠.١	٢٨.٨	٢.٤٤	٣.٢٩
٤٠	١٨.٠	٢٢.٧	١.٧٣	1.87

Table (2): Results of compressive strength and modulus of rupture (MPa) for mortar mixes

Waste Glass %	Expansion $\times 10^{-6}$				
	٧days	14 days	28 days	60 days	90 days
٠	١٤٩	١٧٥	٢٠٢	٢٥٥	٢٩٤
١٠	١١٩	١٤٠	٢١٩	٢٦١	٢٩١
٢٠	١١٢	١٩٥	٢٤١	٢٩٥	٣١٠
٣٠	١٤٤	١٦٧	٢٤٦	٣١٥	٣٥١

Table (3): Results of length change for different mixes of moist curing (expansion) %

Waste Glass as Fine Agg. %	Compressive Strength (MPa)		Modulus of Rupture (MPa)	
	7 days	28 days	7 days	28 days
٠	٣٠.٣	٤٧.٩	٣.٢١	٤.٦٢
١٠	٢٩.٤	٤٧.٢	٣.١٨	٤.٥٠
٢٠	٢٨.٢	٤٥.٨	٣.١٢	٤.٤٦
٣٠	٢٥.١	٣٨.٤	٢.٩١	٤.٠٣
٤٠	٢٠.٩	٣١.١	١.٨٧	٢.٥٢

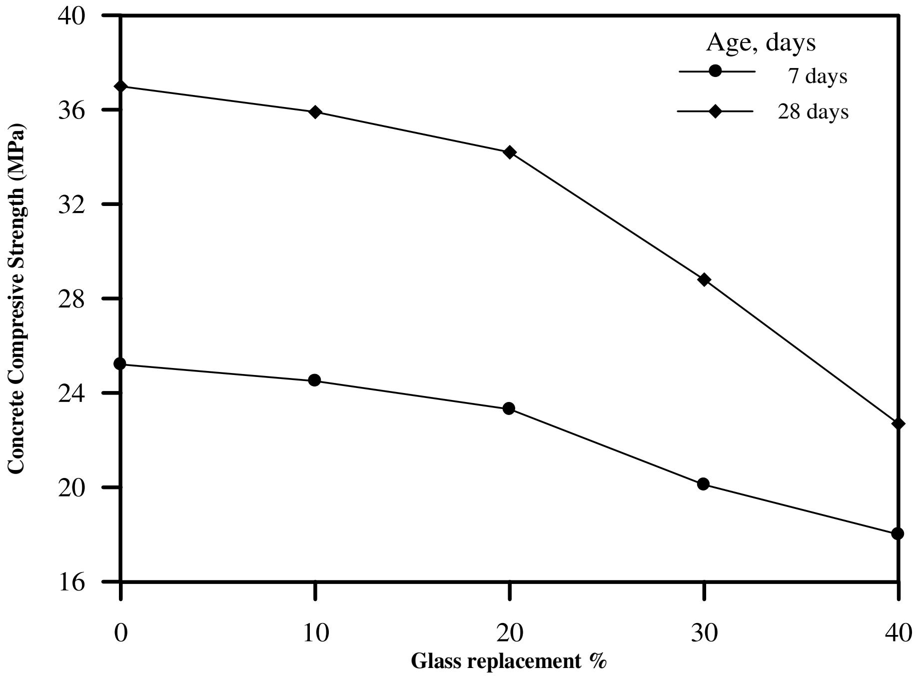

Figure (1): Relationship between compressive strength of concrete and glass content

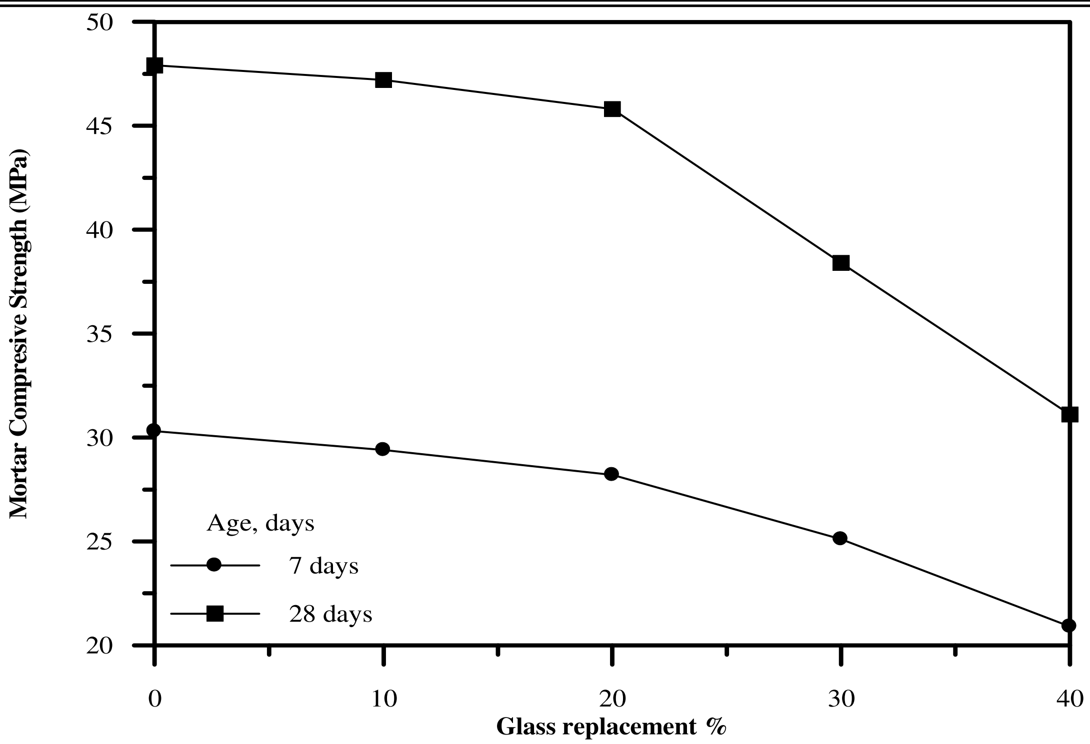

Figure (2): Relationship between compressive strength of mortar and glass content

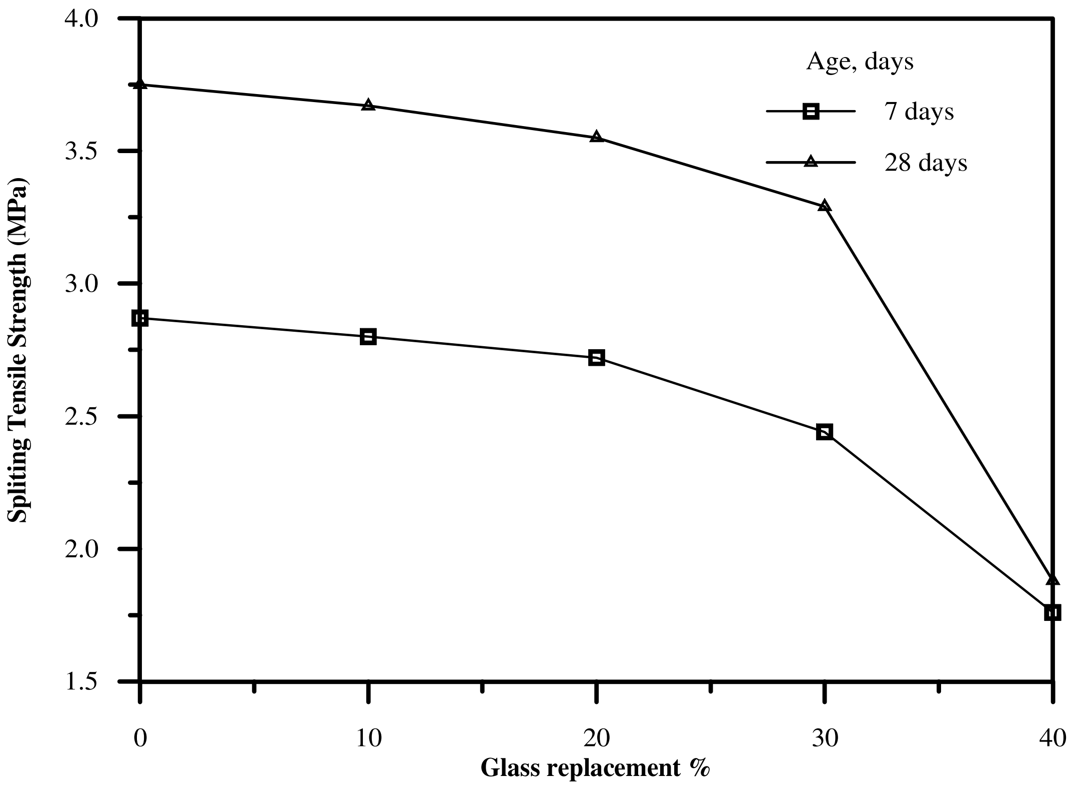

Figure (3): Relationship between splitting tensile strength of concrete and glass content

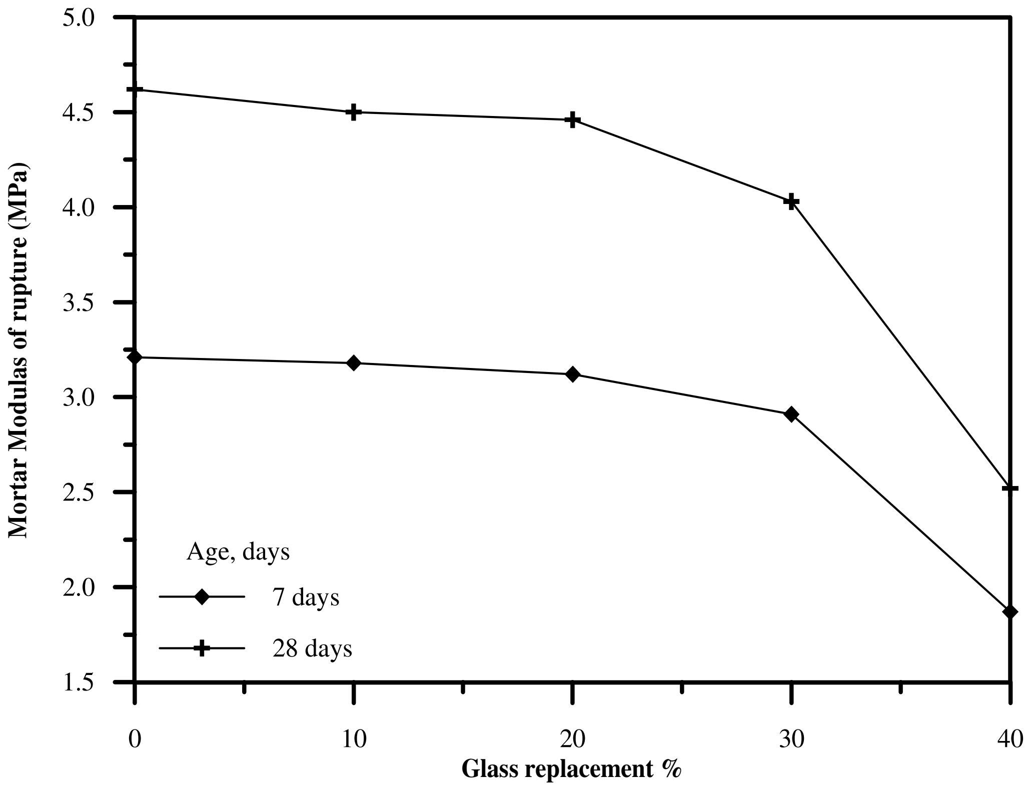

Figure (4): Relationship between modulus of rupture of mortar and glass content

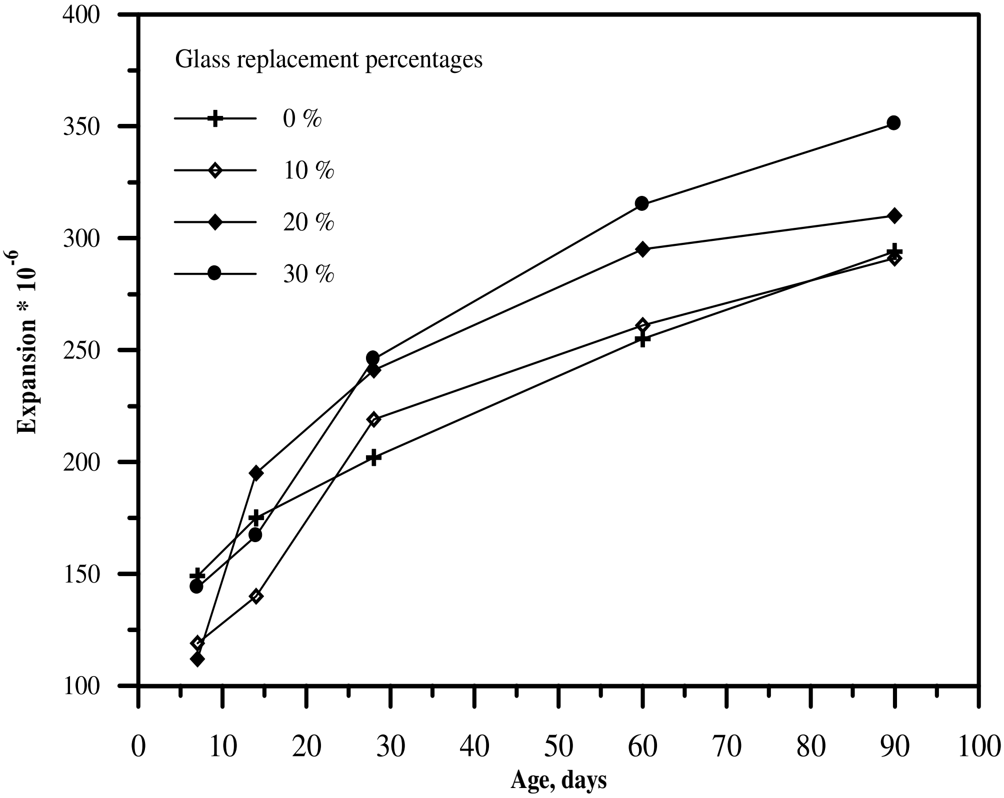

Figure (5): Percentages of length change (expansion) for different glass aggregate of mortar mixes

Plate (1): Waste of windows glass

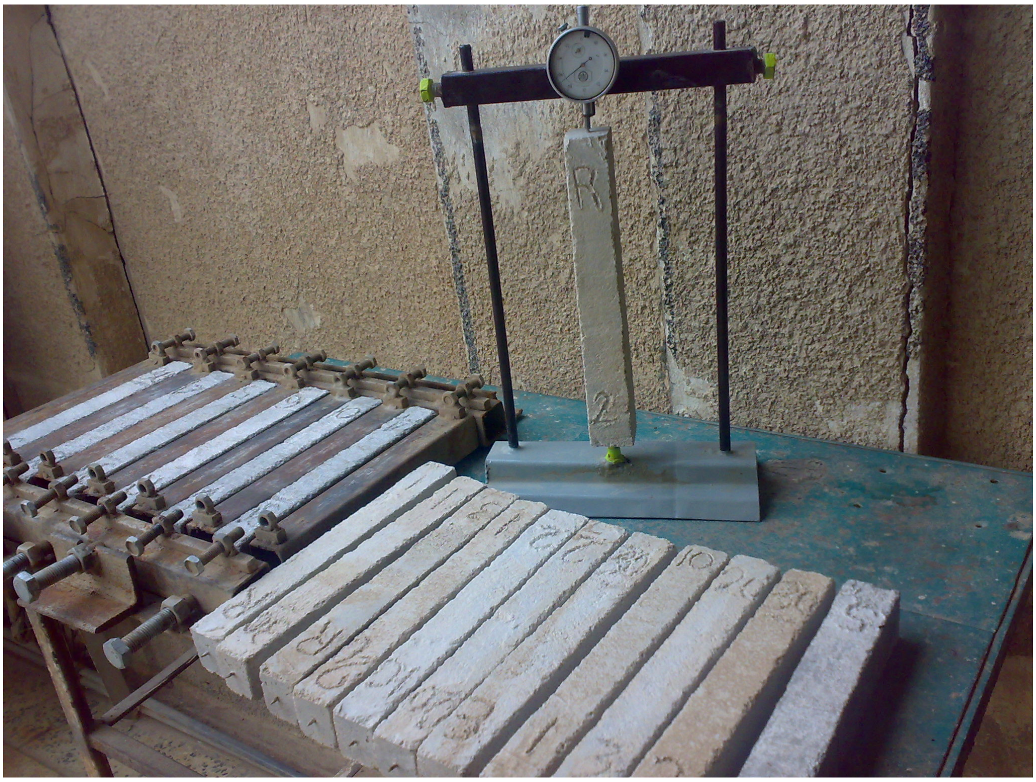

Plate (2): Expansion testing device