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CLAY BRICK WASTE AS INTERNAL CURING AGENT IN NORMAL WEIGHT CONCRETE

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ABSTRACT

Internal curing is a technique that can be used to provide additional moisture inside the concrete for a more effective cement hydration. Prediction of the influence of internal curing on the concrete and on its final mechanical properties is an important issue in concrete research. Tests by the widely accepted methods of studying properties of concrete, such as compressive strength, splitting tensile strength, density and ultrasonic pulse velocity test made to internally cured concrete with waste of clay brick. The pore structure of waste of clay brick particles seem to have a marked influence on the availability of internal curing water and thus improve hydration of cement and improve properties of concrete.

KEYWORDS: Clay Brick, Curing, Recycling, Sustainability, Waste

INTRODUCTION

Proper curing of concrete structures is important to ensure that they meet their design life requirements and yield low maintenance costs [1]. Internal curing of concrete has been emerged as a new technology to provide the necessary additional water that accomplishing what the mixing water alone can't to do, keep relative humidity high, maximizing reactions of cement and make concrete better by improving its properties with increasing of its durability, and it is became the subject of extensive research for the last decade;it refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water [2]. The concept of provide additional internal water for curing purpose of a concrete mixture has been extended to many materials such as saturated porous lightweight aggregate (LWA) [3], super absorbent polymer (SAP), wood fiber and others porous materials [4][5], these materials can be mixed into concrete in order to supply an internal source of water, to compensate the consumed mix water by hydration of cement [6]. Previously, X-ray absorption studies of cement based materials have indicated that during drying, water will move from coarser pores to finer ones [7]. Trtik et al, have been observed that the internal curing water released from the LWA traveled at least 3 mm from the LWA into the cement paste in the first day by using neutron and X-ray tomography [8]. Another study based on a 3D microstructural model of cement paste, estimated the distance of the internal curing water migration to be approximately 100–200 mm only [9].

Internal curing has been recently used in large different site projections and successfully reduces shrinkage and cracks through incorporation of LWA in ordinary concrete [10] [11] [5].

Internal curing with LWA has been successfully used recently in researches to study properties of ordinary concrete. In the present work, a clay brick waste (CBW) was used as an internal curing material because it possess a high ability of water absorption (that calculated according to ASTM C128-07) which provides additional water for internal curing. In this study, the coarser pores are present due to the using of CBW as internal reservoirs in concrete.

HYDRATION OF CEMENT

Required Mixing Water for Hydration

In 1947, Powers has been demonstrated that, concrete mixtures with a w/cless than approximately 0.5 and sealed against loss of moisture cannot develop their full potential hydration due to lack of water [12].

ACI-308 committee have been reported, "Because hydration can proceed only in saturated space, the total water requirement for cement hydration is “about 0.44 g of water per gram of cement, plus the curing water that must be added to keep (the capillary pores of) the paste saturated”".In low w/c concrete, full hydration can't be achievable, therefore absorptive LWA, replacing some of the sand, provides water that is desorbed into the mortar fraction (paste) to be used as additional curing water. The cement, not hydrated by the low amount of mixing water, has more water available to it [10]. In normal weight concrete above a w/c ratio of approximately 0.45, drying shrinkage takes place andautogenous shrinkage is hidden, at 0.43autogenous shrinkage is quite measurable, and with decreases in w/c to 0.40and the 0.30’s autogenous shrinkage and cracking is more and more evident [17]. In this study normal weight concrete with w/c of 0.4 internally cured with clay brick waste.

External Curing

ACI-308 Committee have been defined curing is the process by which hydraulic-cement concrete matures and develops hardened properties over time as a result of the continued hydration of the cement in the presence of sufficient water and heat. At near the surface, curing has a significant influence on the properties of hardened concrete, such as strength, stress resistance, permeability, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing, and deicing chemicals. Inadequate curing can result in very weak, porous and permeable material near the surface (about 30 – 50 mm) of the concrete that is vulnerable to ingress of various harmful substances from the environment and decrease its serviceability and durability [11] [13][14].

Internal Curing

Preview on Internal Curing

As discussed in pervious section, conventional external curing techniques may be relatively non effective in foster cement hydration and preventing self desiccation in the centre of a thick concrete layer. In this case, internal curing needs to be performed, which is a very promising technique that provides additional moisture in the concrete for more effective hydration of the cement and enhancing properties of concrete, whereas, The key to the development of both strength and durability in concrete, the degree to which the cement has hydrated and the degree to which the pores between the cement particles have been filled with hydration products [15].

As internal curing improve durability of concrete, it realize a high protection of the reinforcing steel against chloride attack, for this reason internal curing has many applications in pavements, bridges and in parking structures, not only in new construction, but also in rebuilding, repair and maintenance [17].

Crushed Recycled Clay Brick for Internal Curing

For more sufficiently internal curing process, internal curing agent should be characterized with high absorption capacity and must have the ability to easily release the absorbed water under pressure [16]. The more effective materials that nucleate to be used for internal curing purpose which have 24-hourse absorption of (20-25%) or more [6], while, clay brick waste has absorption value of 34%.

A recent study has been considered the osmosis pressure between fine crushed brick waste (passing sieve 4.75mm) and mortar as a sustainable approach to sustain cement hydration and produce concrete with high quality Interfacial Transition Zone (ITZ) leading to improve mechanical properties of concrete.

Thus, crushed brick waste gradually release its water during hydration and bring additional water into the concrete mixture, which is included in the internal reservoirs which provide the cement with sufficient water to sustain the filling of those pores with hydration products because the maximum degree of hydration is a function of the availability of water. Saturated surface dry (SSD) brick waste was used as a volumetric replacement for 5% and 10% of the normal weight sand that used in concrete; it is an economical and sustainable approach by replacing sand with a waste material for concrete production, additionally this waste can be batched easily. It can make up for some of the deficiencies brought on by human beings' not following the best practices with external curing. It can even make up for some of the problems brought on by hot or windy weather [10], especially in Iraq.

LABORATORY STUDIES

The laboratory studies carried out was aimed at determining the influence of using clay brick waste as internal curing agent on different properties of concrete at early and later ages.

Experimental Program

Three concrete mixes were designed through this work according to ACI211.1. The first mix is considered as a control one (Mix-R) without any replacement, the second one is referring to a mix of (5%) partial replacement of sand with CBW, while the last mix is a (10%) as partial replacement of sand with a CBW. The two mixes of (5%) and (10%) replacements were symbol as (Mix-5)and (Mix-10) respectively.

The CBW work as an initial curing agent without any effecting on the volumetric mass of concrete. Table 1 summarizes the experimental program used through this work.

Ordinary Portland cement (ASTM type I cement)was used through this work with a relatively high amount of 563 kg/m^3 for all tested mixes, in the other hand the w/c ratio used was (0.4) which it consider a low value with respect to the amount of cement content used to show the effect of internal curing action on the concrete tested results. The bulk density of clay brick waste that used for internal curing was 1091 kg/m^3 and has been graded like a sand grading.

Table 1: Mixture Proportion of Mixes

Mixture Composition	Materials (Kg/m^3)		
	Mix-R	Mix-5	Mix-10
Portland Cement	563	563	563
Water	225	225	225
Crushed Aggregate (4.75mm – 19mm)	787	787	787
Sand	680	646.6	612.1
Clay Brick Waste*	-----	22.2	44.4
W\C	0.4	0.4	0.4
*Replacement Percentage of Sand with CBW (by Volume)			

Figure 1: Sample of Clay Brick Waste

RESULTS AND DISCUSSIONS

Compressive Strength

Strength of concrete is commonly considered to be its most valuable property, although in many practical cases other characteristics, such as durability, impermeability and volume stability, may in fact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because it is directly related to the structure of cement paste [1]. For this reason, compressive strength has been studied in this research. The results show increasing of compressive strength of internally cured concrete with 10% of clay brick waste with an increment percent's of (10.8%, 12.7%, 11.1% and 12.5%) at ages of (7, 28, 56 and 90) day respectively, while decreasing has been happened with compressive strength of internally curing concrete with 5% of (CBW) with percentages of (10.7, 10.6, 16.6 and 16.1) at ages of (7, 28, 56 and 90) day respectively, as shown in Figure 1. The significant increasing in compressive strength with 10% of CBW compared to the control mix is partly attributed to the replacement of normal weight sand with porous waste of clay brick which supplied more internal curing water, which promotes increased cement hydration process and increase its products leading to increase compressive strength. While the decreasing of compressive strength of Mix-5 relative to control mix is attributed to used of CBW which consider as weak material comparative with sand that leading to weaken concrete and the internal curing water supplied from it does not enough to sustain hydration of cement and compensates this weaken, whereas, water supplied by using 10% of CBW compensates this weaken and restore with improving compressive strength of concrete. Figure 2 show the effect of internal curing on compressive strength behavior of all mixes.

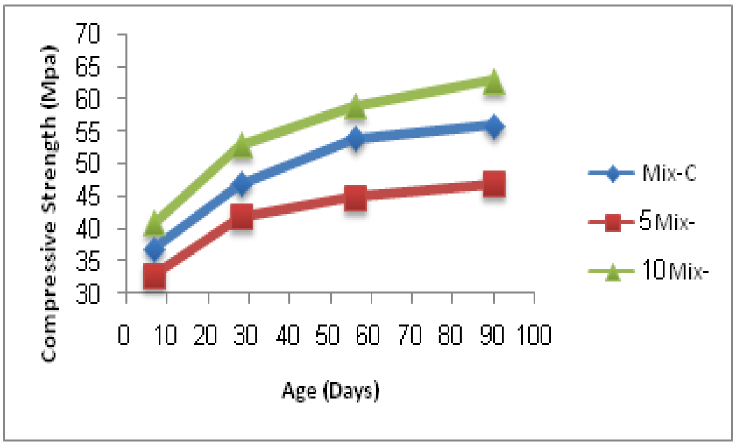

Figure 2: Effect of CBW on Compressive Strength of Concrete

Splitting Tensile Strength

The Splitting tensile strength of concrete cylinder has been determined based on ASTM C-496, and has been carried out on diameter of 100 mm and length of 200 mm size cylinder, The splitting tensile strength development for all mixes are presented in **Figure 3.** Internally cured concrete with 10% of CBW exhibited an increase in splitting tensile strength when compared to the control mix with percentages of (5.4%, 9.1%, 22.9% and 20%) at ages of (7, 28, 56 and 90) days respectively, whereas Concrete internally cured with 5% of has been shown decreasing comparatively with control mix with percentages of (2.7%, 6.8%, 16.9 and 3.7%) at ages of (7, 28, 56 and 90) days respectively, for the same reason of weakened phenomena of CBW with a low hydration increment due to it asmentioned in previous section.

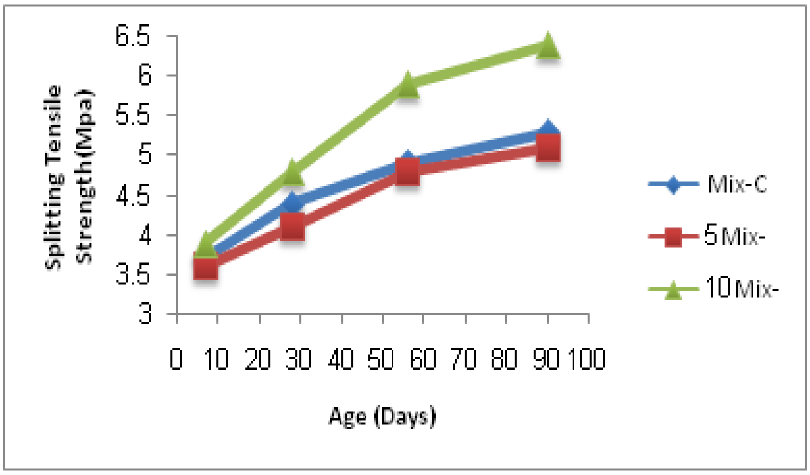

Figure 3: Effect of CBW on Splitting Tensile Strength of Concrete

Density

The density of concrete is a measure of its unit weight and expressed in kg/m^3**.** Density test has been carried out according to ASTM C-642. Mix-10 has been shown increasing with its density compared with control mix, while, Mix-5 show decreasing with its density compared with control mix, as show in **Figure 4**. This due to Mix-10 has better hydration of cement fraction provided by moisture available from the slowly released reservoir of water absorbed within the pores of CBW, this better hydration caused increase the volume of production and fill the pores with concrete and increase its density, while water supplied from 5% replacement of CBW do not sufficient to sustain hydration of cement in correct way and make voids within concrete and decrease its density.

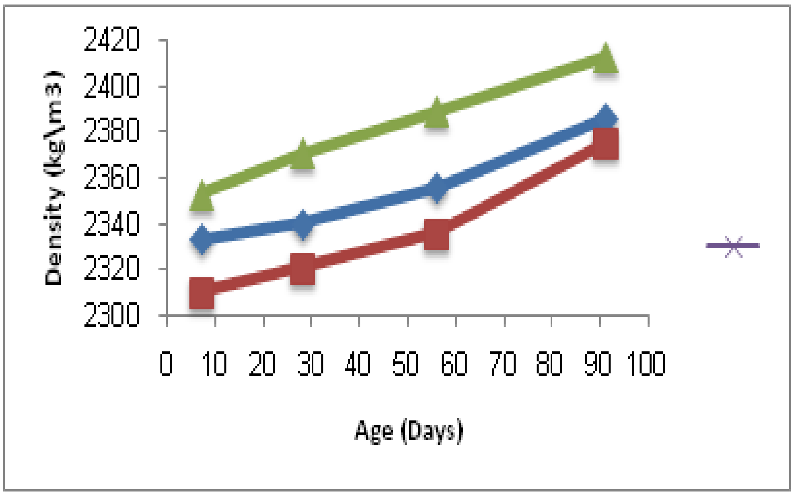

Figure 4: Effect of CBW on Density of Concrete

Ultrasonic Pulse Velocity

Measurements of pulse velocity provide means of studying the homogeneity [18], and, for this reason pulse velocity, according to ASTM C-597, has been determined in this research for all mixes, in order to observe the effect of supplied internal curing water from CBW on the homogeneity of concrete which can be consider as indication to hydration process. Pulse velocity of Mix-10 has been increased compared with control mix, and pulse velocity of Mix-5 has been decreased compared with control mix, as shown in **Figure 5**, This give an indication that internal curing water supplied from 10% of CBW sustain cement hydration and increase the hydration products that fill pores with concrete and increase its homogeneity, while replacement sand with 5% of CBW lead to create voids within concrete.

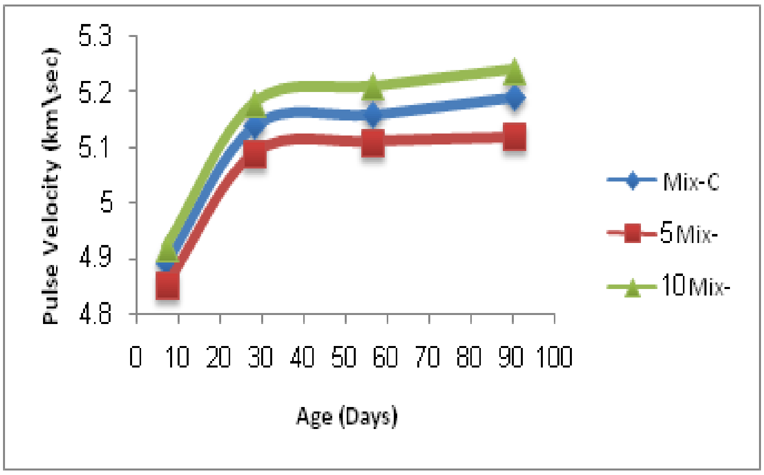

Figure 5: Pulse Velocity of Different Mixes

CONCLUSIONS

- The dramatic enhancement of all studied properties has been appeared by internal curing with 10% volumetric replacement of sand with clay brick waste with same grading.
- High Compressive and splitting tensile strength have been observed with an increment of (10.8%, 12.7%, 11.1% and 12.5%) at ages of (7, 28, 56 and 90) days, and (5.4%, 9.1%, 22.9% and 20%) at ages of (7, 28, 56 and 90) days respectively, for 10% replacement of sand with CBW.
- Reduction of compressive strength and splitting tensile strength has been recorded with a decrement of (10.7%, 10.6%, 16.6% and 16.1%) at ages of (7, 28, 56 and 90) days, and (2.7%, 6.8%, 16.9 and 3.7%) at ages of (7, 28, 56 and 90) days respectively, for 5% replacement of sand with CBW.
- It seems that, the using clay brick waste which has very high absorption of water is very effective techniquefor sustain cement hydration and increases the volume of hydration products that fill pores within concrete and increase its durability.
- By using clay brick waste for internal curing, increase pulse velocity through concrete as a result of increase the homogeneity of concrete.
- This study indicates that the density of concrete increase by mean of better hydration of cement and increase the hydration products.
- Using proper percent of clay brick waste as replacement with sand, can be found a helpful method to improve mechanical properties of normal weight concrete, although with a using of high cement content and low W\C .

- The using of clay brick waste as partial sand replacement is economic and sustainable technique to produce concrete with a better properties.

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