Evaluation of the Effects of Bagasse on Tensile and Compressive Strength of Lightweight Concrete

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Abstract: Mechanical characteristics of lightweight concrete contained bagasse, including splitting tensile and compressive strength have been examined. Bagasse as an agricultural waste was obtaining in the form of small wood chips after extracting cane sugar in the Khouzestan state of Iran. In this research, at first a fixed mix design was considered according to ACI-21. Then some samples were prepared corresponding to the above mentioned design code and by inserting 20,30,40 and 50% bagasse as a replacement for aggregates in concrete mixture and consequently these samples were tested. The results showed that by increasing of the content percentage of bagasse, compressive strength decreased and this decrease for concrete containing 20% bagasse is about to 36%.The concrete containing 20% bagasse has more splitting tensile strength in compared to normal concrete approximately up to 13%. Finally, based on the obtained findings, it can be concluded that concrete with 20% bagasse could be introduced as an alternative lightweight concrete regarding to its lower unit weight and higher splitting tensile strength.
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Keywords: Bagasse; Lightweight concrete; Compressive strength; splitting tensile strength

1. Introduction

Using of lightweight concrete as an alternative to normal concrete in construction can decrease the building's dead load as well as the force exerted on the structure due to earthquake excitations and the resultant collapse weight of the building if it falls down (Liu, et al., 1995). The use of lightweight aggregate concrete (LWC) can lead to reduction in costs of the both superstructures and foundations. Furthermore, the better thermal insulation, the greater the fire resistance and the substantially equivalent sound-proofing properties make it preferable with respect to normal weight concrete (NWC) to use in building structures (Cavaleri, et al., 2003). In bridges and other precast construction, the lightweight concrete helps to reduce the costs of shipping and crane capacity, inclusive considering the higher cost of the aggregates (Tito, et al., 2010). Lightweight concrete provides high strength-to-weight ratio and is ideal for long span structures, super high-rise buildings and offshore floating structures. For example, in Norway (LWC) has been successfully used in offshore structures for oil drilling platforms, storage tanks and vessels (Koh, et al., 2008).

On the other hands, development of industries and stepping towards industrialization requires performing comprehensive research on consuming agricultural, mineral and industrial wastes in construction in order to decrease environmental pollutants. Bagasse is one of these agricultural wastes. It is a by-product of cane that is produced in the form of small wood chips after extracting cane sugar. At present, about one million tons of bagasse is produced in Iran annually which leads to environmental and retrieving management problems. So far, no significant research has been conducted on using bagasse in making concrete in Iran. Thus it is felt that such a study could be useful in this field.

Ganesan et al., (2007) studied on the effects of using bagasse ash as a replacement for cement in making concrete mixture on physical and mechanical characteristics of hardened concrete. They found that the bagasse ash was a useful mineral that its optimal replacement amount for cement in concrete mix was approximately 20%. Another research on using bagasse ash as a replacement for cement in concrete manufacturing has been conducted by Chusilp et al., (2009). He and his colleagues evaluated compressive strength, permeability and temperature characteristics of obtained lightweight concrete containing bagasse ash. They concluded that the optimal amount of bagasse ash which could be replaced with cement in preparing concrete would be about to 20% by weight of cement and increasing this ratio to 30% caused lower permeability and compressive strength. They also found that the maximum temperature rise of concrete containing 10-30% bagasse ash was less than that of control concrete so that an increase replacement ratio led to decrease in equivalent temperature rise.

Most of the researches on bagasse in concrete were associated with using it as a replacement for cement in order to improve concrete mortar. In this study, fibers of bagasse are used, in a

new vision, as a replacement for aggregates so that its effects on mechanical characteristics of concrete such as compressive and tensile strength and relation between them could be investigated.

2. Material and Methods

2.1. Materials

2.1.1. Cement

Since today the most dominant type of cement used in Iran is type II , in this study cement of type II produced in cement factory of Doroud of Lorestan province located in the west of Iran has been used with density of 3.15 and specific area of about 3350 cm^2 /gr.

2.1.2. Bagasse

Figure 1 show fibers of bagasse which used in this study. The needed bagasse has been supplied from Haft Tappeh Cane Sugar plant. The specific weight of bagasse can be found in table 1.

Figure 1. Bagasse fibers

Table 1. Unit weight of bagasse

	incompact	compact
Unit weight) kg / m^3 (	64	129

2.1.3. Water

Water which has been consumed for this study is drinking water of Ahvaz city of Iran.

2.1.4. Aggregates

Aggregates which used for this research are broken river materials from Dezful city of Iran. The coarse aggregates have two dimensions with combination of 50% 3/8in and 50% 3/4in, which makes well-graded materials. Table 2 shows physical characteristics of aggregates. In addition, according to Los Angles test on aggregates, percentage of lost materials has been determined as 16.2%.

Table 2. Physical characteristics of aggregates

	Coarse	Sand
Humidity (%)	1.16	5.80
Unit weight(kg / m^3)	1526	1724
Void (%)	43	35
Density	2.68	2.64

2.2. Methods

2.2.1. Mix design, product and curing

Control concrete (CC) mix design has been provided according to ACI-211 and after creating experimental samples and making some modifications; final design obtained and has been illustrated in Table 3.It should be mentioned that mix design has been designed for 7±1cm slump and corresponding 28day cylindrical compressive strength which gained was equal to 300 kg/cm^2.

Since the purpose of this study is to examine the replacement of fibers of bagasse with aggregates in concrete mixture, we used bagasse as a replacement for aggregates with 0, 20, 30, 40, 50% volumetrically. It should be noted that because of 50% moisture absorbing of bagasse, water of the mixture has been increased as much as the half of the weight of bagasse to prevent decrease concrete humidity.

Table 3. Mix design (kg per one cubic meter of concrete)

	Coarse	Sand	Cement	Water	Bagasse
CC	1130	840	340	160	0
CB20	904	672	340	176	32
CB30	791	588	340	184	48
CB40	678	504	340	192	63
CB50	565	420	340	200	79

After being produced of mixtures, they are molded in 3 layers and each layer was compressed with 25 impacts by standard bar. Samples are then taken out from moulds after 24hours and put into curing basin for 7, 14, 28 days and then tested.

3. Results and discussions

3.1. Compressive strength

Figure 2 shows trend of growth of compressive strength of cylindrical samples according to curing time duration for each replacement percentage of bagasse.

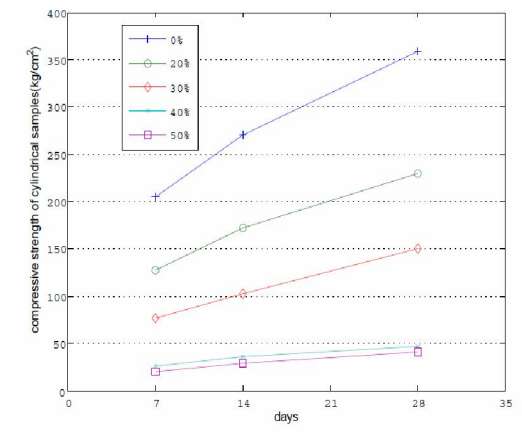

Figure 2. Relation between compressive strength and curing time duration

As it can be observed, compressive strength of concrete samples reduces with increase of bagasse amount as a replacement for aggregates contents, which it can be attributed to weakening of concrete skeleton because of reduction of the amount of aggregates. Furthermore, the slope of growth of compressive strength of samples reduces with respect to the amount of baggase used in the mixture.

Figure 3 indicates the change in compressive strength of samples in relation to the percentage of bagasse used for different curing time duration. Loss of compressive strength of concrete with increase of bagasse percentage can be observed much better from this figure.

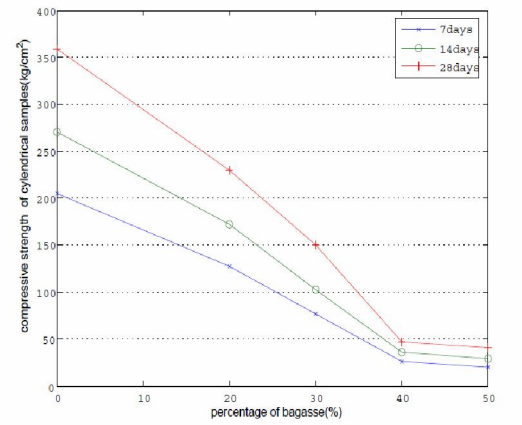

Figure 3. Relation between compressive strength and percentage of bagasse

Since the weight of the concrete samples is an important factor in surveying of mechanical properties of the samples and comparing with normal concrete, the variations of compressive strength in unit weight of the specimens i.e. C/W ratio at different curing time duration are given in Figure 4 for different percentage of bagasse, and Figure 5 indicates variations of (C/W) ratio with different percentages of bagasse for each curing time duration.

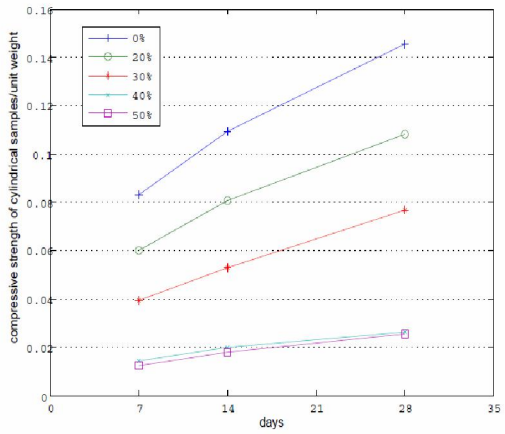

Figure 4. Relation between (C/W) ratio and curing duration

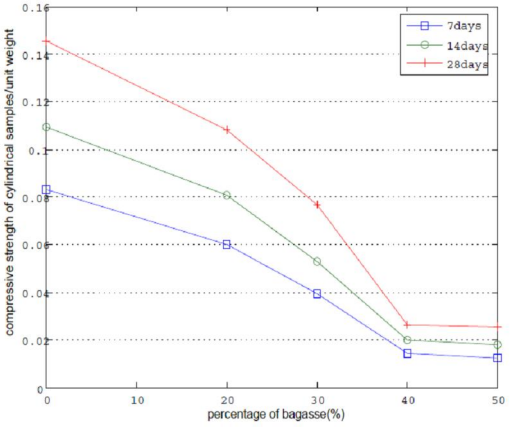

Figure 5. Relation between (C/W) ratio and percentage of bagasse

From the above figures it can be inferred that however unit weight of concrete decreases with increasing of percentage of bagasse, but loss of compressive strength is more and this ratio decreases. Therefore, it can be declared that compressive strength of concrete containing bagasse which replaced as a percentage of aggregates would decrease.

3.2. Splitting tensile strength

Figure 6 indicates the splitting tensile strength of concrete with respect to different curing time duration for each percentages of bagasse.

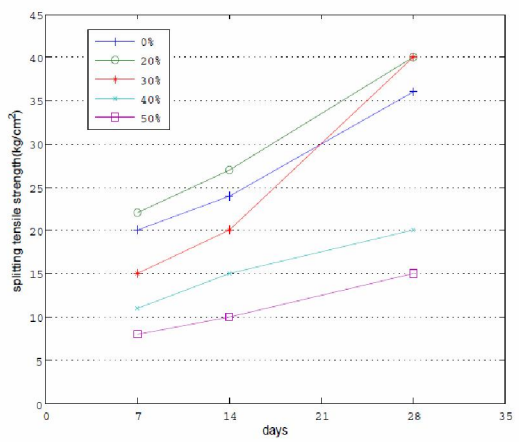

Figure 6. Relation between splitting tensile strength and curing duration

According to the above figure, behavior of tensile strength of lightweight concrete containing bagasse differs from that of compressive strength. Tensile strength of CB20 at all ages is more than that CC, which is considered as an advantage given to have an acceptable 28days compressive strength. Also 28days splitting tensile strength of CB30 is more than that of CC. For better observation of these variations, you can refer to figure 7 that show the relation between splitting tensile strength of concrete in different time curing and percentages of bagasse used in concrete.

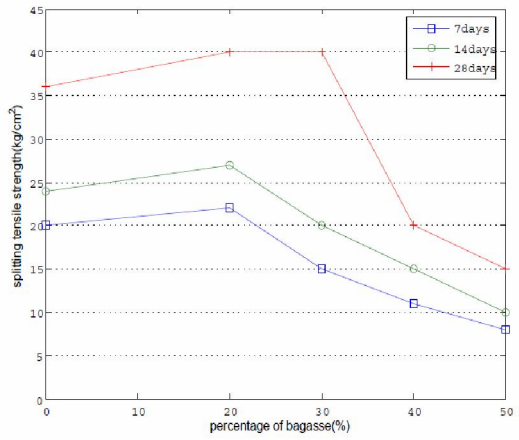

Figure 7. Relation between splitting tensile strength and percentage of bagasse

Since the weight of concrete decreases with increasing of percentage of bagasse replaced for aggregates, this increase is more obvious. Figure 8 illustrates the change trend of tensile strength of lightweight concrete divided by its weight containing bagasse at different age of concrete specimens.

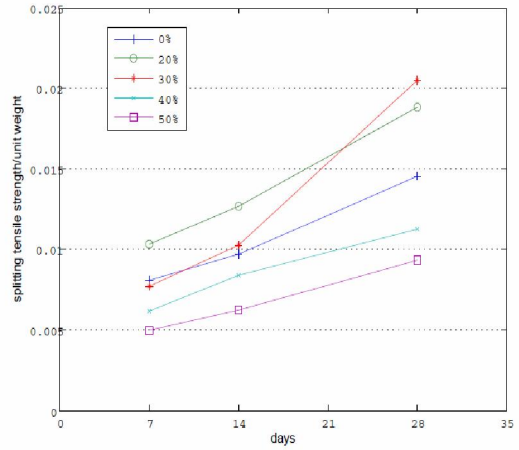

Figure 8. Relation between (T/W) ratio and curing duration

As it can be understood, tensile strength to unit weight ratio (T/W) of CB20 and CB30 is more than CC, which can be attributed to fiber quality of bagasse. Figure 9 gives (T/W) ratio in relation to percentage of bagasse. By comparing this diagram with figure 5, it can be found that in contrast to C/W, the T/W ratio has an increasing trend at the first stages and after that we have decreasing curves. It shows that up to certain amount of added bagasse we can gain higher tensile strength of lightweight concrete. This can be related to the fiber structure of bagasse which improves the maximum resistant tensile stress of concrete. But after certain percentage of added bagasse i.e. 20% in this study, by increase the content of bagasse, the water in concrete which suctioned by fibers of bagasse also will be increased and consequently the w/c ratio (water to cement ratio) would be larger so both the tensile and compressive strength of concrete would decreased.

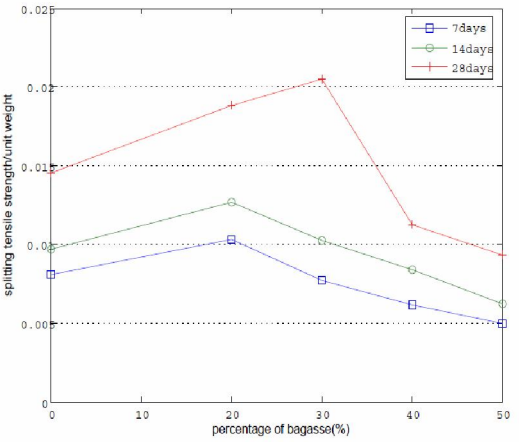

Figure 9. Relation between (T/W) ratio and Percentage of bagasse

3.3. Tensile/compressive strength ratio

Figure 10 and 11 displays the relation between tensile and compressive strength of lightweight concrete containing bagasse with respect to curing time duration and the percentage of bagasse replaced with aggregates, respectively.

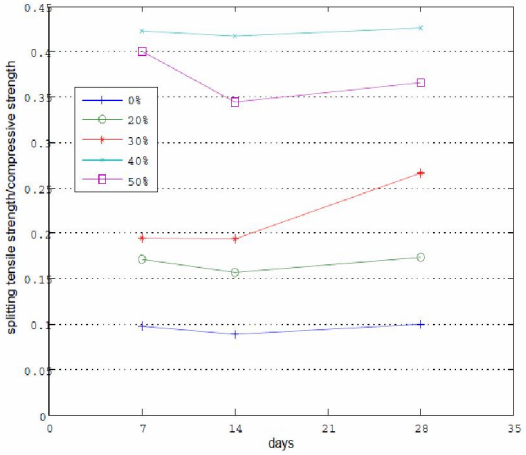

Figure 10. Relation between (T/C) ratio and Curing duration

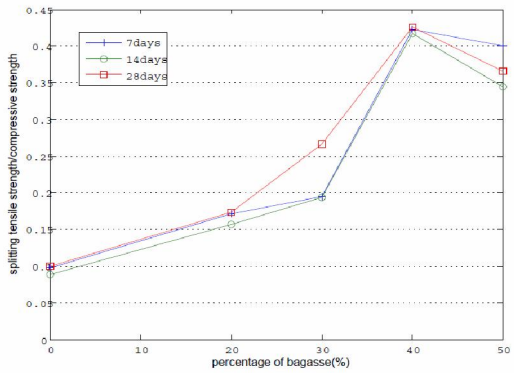

Figure 11. Relation between (T/C) ratio and Percentage of bagasse

As it can be indicated, tensile strength of CC is about 10% of its compressive strength that it has been predictable according to ACI standard. Also from the above figures it can be derived that (T/C) ratio of CB40 is maximum (0.43). This proofs that mechanical characteristic of splitting tensile strength of concrete containing bagasse is better compared with its compressive strength.

4. Conclusions

- All concretes containing 20% and more bagasse can be considered as lightweight concrete.
- By increasing of bagasse as a replacement for aggregates in concrete, compressive strength decreases that it can be attributed to weakening of concrete skeleton, i.e aggregates.
- Although unit weight of concrete decreases by increasing of the percentage of bagasse, but loss of the compressive strength is more than its weight and this ratio also decreases. Therefore, it can be declared that compressive strength of concrete containing bagasse as a replacement for aggregates would be always decreased.
- Tensile strength of concrete containing 20% bagasse at all ages is more than that of normal concrete which can be considered as an advantage gained to have an acceptable 28days compressive strength and lower unit weight concrete when compared to normal concrete.
- Tensile strength divided by weight ratio of concrete containing 20% and 30% bagasse is more than normal concrete, that it can be attributed to fiber quality of bagasse.
- By increasing of the percentage of bagasse, tensile to compressive strength ratio increases up to 40%,that maximum of this ratio is for concrete containing 40%(0.43).

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