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Two Stage Concrete using Recycled Coarse Aggregate and Bagasse Ash

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Abstract

In this experimental research, the effect of different ratios of bagasse ash and recycled coarse aggregates in Two-stage concrete (TSC) was evaluated. TSC is not quite the same as normal concrete. In TSC, coarse aggregates are set in formwork and after that grout or mortar is infused through a pipe with high pressure. Four mixes of TSC concrete were prepared. Control Mix-I was made with 100% natural coarse aggregates. Control Mix-II was prepared with 100% recycled coarse aggregates (RCA). The third mix was made with 10% bagasse ash (BA) as a fractional substitution of cement and 100% RCA. Fourth mix was prepared with 20% bagasse ash as a fractional substitution of cement and 100% RCA. 1% super plasticizer by the weight of cement was added in concrete mixes with 10% and 20% bagasse ash. Water to cement ratio (w/c) was 0.5 and used for all mixes. Different tests like compressive strength test and split tensile strength test were performed on samples made from all four mixes. Compressive strength and tensile strength of Control Mix-I was highest among all mixes. Results indicate that tensile strength and compressive strength was increased with the addition of bagasse ash in mixes having RCA. The maximum increase in compressive strength and tensile strength was in 20% BA mix.

Keywords: Two- stage concrete (TSC), Recycled coarse aggregates (RCA), Natural coarse aggregates, Bagasse ash (BA)

1. INTRODUCTION:

The most extensively used building material around the globe is concrete (Meyer, 2004). In TSC, coarse aggregates are set in formwork and after that grout or mortar is infused through a pipe with high pressure. TSC has a number of applications, it is mainly used in concrete and masonry repair in under water construction, places where placing conventional concrete is difficult, in mass concreting where a low heat of hydration is required (Stubbs, 1959). TSC need more coarse aggregates than required in normal concrete (Abdelgader and Elgalhud, 2008). Shrinkage in TSC is lower due to point to point contact of coarse aggregates (Abdelgader and Górski, 2003). TSC costs 25% to 40% less than traditional concrete (Abdelgader, 1995).

Around 10 billion tons of concrete is produced annually, making it the largest consumer of Earth's natural resources, that are water, natural aggregates (gravel and crushed rock) and sand. Around 12.6 billion tons of natural aggregate is used annually. Cement industry releases around 7% of the total Carbon dioxide (CO_2) (Mehta, 2002). To protect our environment from depleting virgin aggregate resources, recycled aggregates has been used to produce concrete. Recycled aggregates consists of natural aggregates and adhered mortar. Concrete obtained from demolished buildings is crushed to obtain recycled aggregates. It has more absorption capacity. Due to increased absorption capacity, 5% more water is required for concrete made with recycled aggregates to acquire similar workability as that of normal concrete (Etxeberria et al., 2007).

Therefore, recycled aggregates can be used in TSC as an alternative of natural aggregate because there is no issue of workability in TSC, as coarse aggregates are placed in formwork. It will also help in conservation of natural resources of coarse aggregates. But concrete with recycled aggregates need more cement than typical concrete to achieve higher strength (Hansen, 1986).

Wastes obtained from agricultural and some other industries can be used as replacement materials in concrete (Hansen, 1986). Sugarcane contains about 25% bagasse. Bagasse is also used in paper industry. When bagasse is burnt for energy purpose, it produces 3% of ash, which is dumped in landfills (Amin, 2010). Pozzolan's silica reacts with $Ca(OH)_2$ and forms calcium silicate hydrate, which enhance the strength of concrete (Martirena-Hernández et al., 2001).

TSC is used in the foundation of an 18 storey building in Gdansk, Poland, refacing of Baker dam, Colorado, USA, piers of Mackinac Bridge, USA and repair of water dam in Czchow on the Dunajec river, Poland (Nowek et al., 2007). This significance of this research work is to tackle the issue of pollution caused by bagasse ash and concrete waste. It will help in creating sustainable development and preserve the sources of natural aggregates. Moreover, TSC will play a vital role in underwater construction, repair and mass concrete. TSC with bagasse ash and recycled aggregate will be economical and will have strength almost equal to conventional concrete.

2. EXPERIMENTAL DETAILS AND METHODOLOGY:

2.1 Materials:

2.1.1 Cementitious materials:

Ordinary Portland cement (ASTM Type-I) was used for the preparation of TSC. Fineness of cement was 93.15%. The surface area of cement was 2137 cm^2/gm. Bagasse ash was brought from Premier sugar mill, Mardan. It was grinded/crushed in PCSIR, Peshawar. It was passed through sieve#200. Specific gravity of bagasse ash was 1.35. The surface area of bagasse ash was 2840.7 cm^2/gm.

2.1.2 Aggregates:

Coarse aggregates were brought from a quarry near COMSATS University Islamabad, Abbottabad Campus. Recycled coarse aggregates were brought from an empty plot near Daewoo terminal, Abbottabad. The demolished concrete waste of a building was crushed with the help of a crusher to obtain recycled coarse aggregates. Cost of crushing concrete waste with the help of a crusher was less than purchasing natural aggregate. Twenty-five millimeter was the maximum size of both natural and recycled aggregates. Table 1 shows the physical properties of both natural and recycled aggregates.

Table 1. Physical properties of natural and recycled aggregates

Physical Properties	Natural aggregates	Recycled aggregates
Water absorption	1.85%	7.59%
Specific gravity	2.75	2.62
Impact value	14.72%	22.23%
Fineness Modulus	2.04	2.19
Density	1532.3 kg/m^3	1399.2 kg/m^3

Fine aggregates were brought from a quarry near COMSATS University Islamabad, Abbottabad Campus. Fineness modulus of fine aggregate was 2.96. Fine aggregates had water absorption of 1.1% and specific gravity 2.35.

2.1.3 Admixture:

Ultra Super Plast 470 was used throughout the casting of TSC. It was procured from Ultra Chemicals, Peshawar.

2.2 Mixture Proportions:

Four different mixes of TSC were made with ratio 1:1:2.7 (Cement: Fine aggregate: Coarse aggregate). Control mix- I was made with 100% natural coarse aggregates. Control mix- II had 100% RCA. Third mix was prepared with 10% BA as a fractional substitution of cement and 100% RCA. Fourth mix had 20% BA as a fractional substitution of cement and 100% RCA. 1% super plasticizer by the weight of cement was used in mixes with 10% and 20% bagasse ash. Water to cement ratio (W/C) used in this experimental research was 0.5. It was used for all four mixes.

Table. 2 Mix types with identification based on replacement ratio

Mix Types	Concrete Mix Proportion
CM-I	Control Mix (100% natural coarse aggregates and 100% cement)
CM-II	Control Mix (100% recycled coarse aggregates and 100% cement)
10% BA	100% recycled coarse aggregates and 10% cement replaced by Bagasse ash
20% BA	100% recycled coarse aggregates and 20% cement replaced by Bagasse ash

2.3 Specimens casting and curing:

Cylindrical moulds of 6 inches diameter and 12 inches height were used for casting of TSC. The inner surface of the mould was oiled, so that concrete should not adhere to its inner surface. A pipe of 1-inch diameter and 2-meter height was placed in the middle of a mould. In the second step, a mould was filled with coarse aggregates. In the third step, grout was injected from the top via pipe. The grout was poured under gravity pressure, which was created with the help of 2- meter pipe. This pressure was sufficient for filling the voids between coarse aggregates with grout. After the appearance of grout at the top of a mould, the pipe was removed from the mould. This procedure was used for all specimens. After 24 hours, specimens were taken out from the moulds and kept in a water tank. 72 specimens were prepared in total, each mix had eighteen specimens.

2.4 Test methods:

In this research, following tests were carried out on hardened concrete:

a) Compressive strength test was carried out according to ASTM C39/C39M-03. Tests on cylindrical specimens were done at 7,28 and 56 days.

b) Split tensile strength test was carried out according to ASTM C496-96. Tests on cylindrical specimens were done at 7,28 and 56 days.

3. RESULTS:

3.1 Hardened properties:

The results of compressive strength test of concrete cylinders at a given curing age are shown in Fig. 1. Each compressive strength is an average of three measurements. This figure shows that compressive strength at 56 days was higher than 28 and 7 days for all concrete mixes. This is because of an increase amount of hydration due to longer curing age. Nine concrete cylinders were casted for each concrete mix proportion. The compressive strength of CM-I was found to be highest for 7,28 and 56 days of curing. CM-II compressive strength is decreased by 22% when compared with CM-I at 7 days. This reduction of strength is due to recycled aggregates. Recycled coarse aggregates have inferior quality due to a porous surface caused by adhered mortar and high water absorption. The compressive strength of 10% BA and 20% BA at 7 days increases by 14% and 19% with respect to CM-II. This is due to the effect of pozzolanic reaction between $Ca(OH)_2$ and BA, which forms calcium silicate hydrate (C-S-H), enhancing the compressive strength as reported by (Martirena-Hernández et al., 2001). There was no issue of workability due to recycled aggregate because recycled aggregates were preplaced in formwork. The same pattern is followed at 28 days and 56 days. The increase in compressive strength was not expressive from 28 to 56 days. The normal compressive strength at 7 days is about 60-80% of 28 days in case of normal curing (Neville, 1996).

The results of split tensile strength of concrete cylinders at a given curing age are given in Fig. 2.The tensile strength of CM-I was highest at 7,28 and 56 days. The maximum increase in tensile strength at 56 days was 44.82% in comparison with 7 days of the same mix. This increase was in 20% BA. This was mainly due to the effect of pozzolanic reactions. The results follow the same pattern as that of compressive strength. This is because of similar reasons discussed in the case of compressive strength.

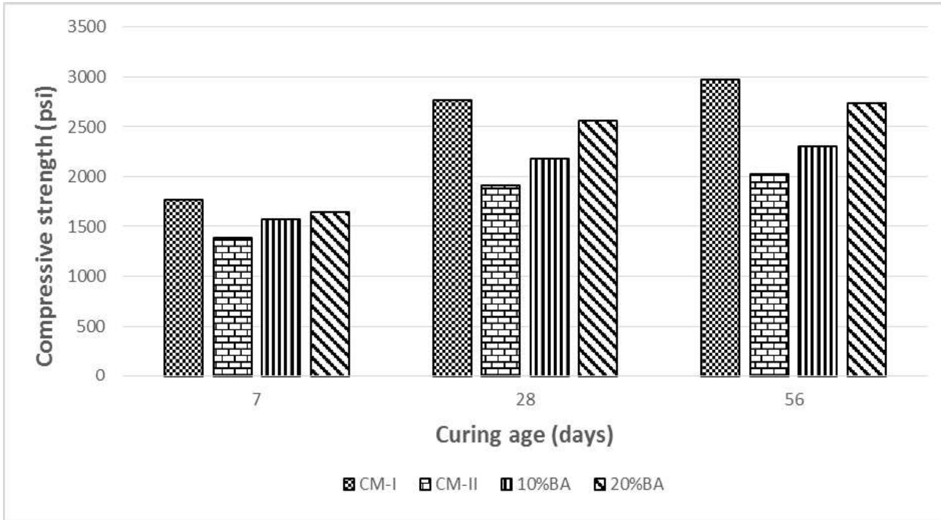

Figure 1. Curing age vs Compressive strength

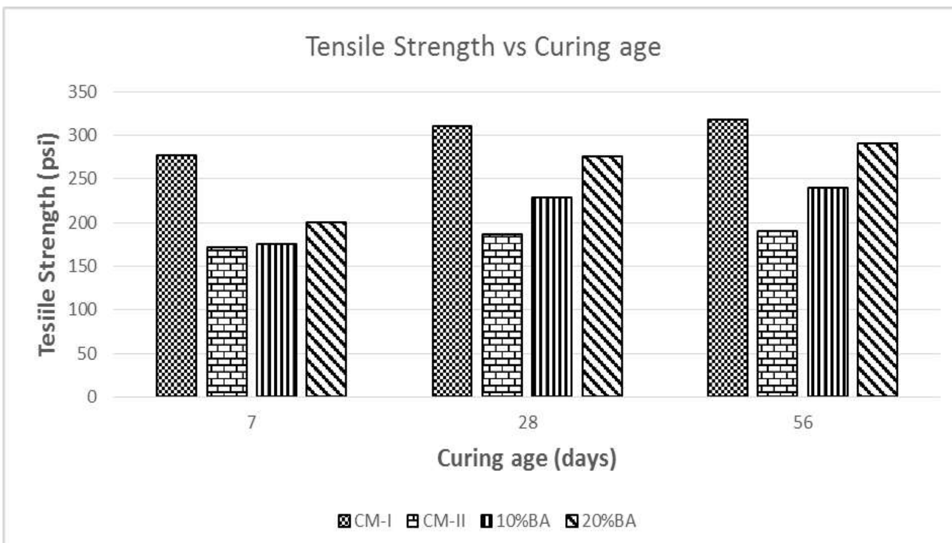

Figure 2. Curing age vs Tensile strength

4. CONCLUSIONS:

The following conclusions are drawn from results:

- Compressive strength of CM-II decreased by 22% when compared to CM-I at 7 days.
- Tensile strength of CM-II decreased by 38% when compared to CM-I at 7 days.
- Compressive strength of 20%BA increased by 35.35% when compared to CM-II at 56 days.
- Tensile strength of 20%BA increased by 52.77% when compared to CM-II at 56 days.
- Compressive strength and tensile strength of TSC decreased with recycled aggregates.
- Compressive strength and tensile strength increased with bagasse ash as fractional substitution of cement.

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