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An Experimental Study on: Recycling of Demolished Concrete in Mogadishu City

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Abstract

In Somalia, appropriate in imitation of the booming on real zemindary business, many mean upward push constructions are demolished for substitute by incredibly high rise building, also due in conformity with the corrosion over embodied structures, deep old structures are essential in accordance with shatter and substitute by using new buildings. The demand for virgin aggregate for construction can be reduced by recycling of demolished concrete as course in new construction work. Therefore, this study was carried out to check the possibility of using demolished concrete as coarse aggregate for new constructions. Concrete blocks from 10 building sites were collected and crushed into coarse aggregate which is defined as recycled aggregate. The recycled aggregates were investigated for unit weight, absorption capacity, and compressive strength. The results were compared with virgin aggregate. The wear value (abrasion value) of recycled aggregates is higher than the normal aggregates due to the presences of adhering mortar portion with the recycled aggregates. The absorption of recycled aggregates is also higher compared to the normal aggregates. For the same W/C, the strength and Young's modulus of recycled aggregate concrete are lower than the same (particularly W/C= 0.55). The

workability of recycled aggregate concrete is lower than the corresponding normal aggregate concrete. If the W/C is reduced compared to the normal aggregate concrete, recycled aggregate concrete gives higher strength compared to the same of normal aggregate concrete made with a higher W/C.

Keywords: Recycling, Concrete, Recycled Aggregates, Demolished Concrete, Compressive Strength

1. Introduction

Concrete demolition waste has now become a source of aggregates for new concrete production (Lokuge et al, 2013). It is estimated that around 180 million tons per year or 480 kg/person/year of Construction and Demolition (Yaqub et al., 2006). Recycled aggregates could come from demolished buildings, airport runways, bridge supports, and even Concrete roadbeds (Nikola et al., 2015).

This research mainly emphasizes the determination of the optimum strength of concrete in fresh and hardened states using varying aggregate sizes. Therefore, this research is focused on the effectiveness of using treated or recycled aggregates as a replacement for common aggregates to produce a concrete structure as there is a lack of research done in regards to the properties of treated recycled aggregates

Objectives:

The main objectives of this study are:

- To investigate the properties of recycled fine (specific gravity and absorption capacity) and coarse aggregate (specific gravity, unit weight, wear, and absorption).
- To compare the properties of recycled fine aggregate with virgin fine aggregate
- To investigate the properties (compressive strength) both in recycled and virgin.

2. Literature Review

Recycled Aggregates

Rapid industrial development causes serious problems all over the world such as the depletion of natural aggregates and creates an enormous amount of waste material from construction and demolition

activities (Shahidan S, et al., 2011). One way to reduce this problem is to utilize recycled concrete aggregates in the production of concrete.

The use of RCA for the production of concrete involves breaking, removing, and crushing existingConcrete into a material with specified size and quality (Shahidan S, et al., 2016). Recycling concrete is important because it helps to promote sustainable development by protecting natural resources and reducing the disposal of demolition waste from old concrete. Recycled aggregates normally have higher water absorption and lower specific gravity (. The density of recycled aggregates used is lower than the density of normal aggregates. The porosity of recycled aggregates is also much higher than those of natural aggregates (Dundee). After someMechanical processes, it can be used as aggregates in concrete mixing. The demolished concrete structures are crushed and sieved according to its required size (Khatib, 2005). Table 1 shows the physical properties of recycled aggregate and Fig. 1. Shows the recycled aggregates.

Fig 2.1. Recycle Aggregate

Recycled aggregates typically are of poor quality compared with natural aggregates due to lower stiffness caused by crushing of waste concrete and higher water absorption capacity given by old cement paste attached to the surface of recycled aggregates (Keun-Hyeok Yank et al, 2008). The wear (abrasion value) is high for recycled aggregate compared to the virgin aggregate due to the adhered mortar with the recycled aggregate (Zega, C.J et al.,2010). The specific gravity of recycled aggregate is lower than the natural/virgin aggregate (Alan, D.B, 1977). Unit weight of recycled aggregate is lower because of their lower specific gravity (Zega, C.J et al., 2010). The absorption capacity is high for recycled aggregate compared to the virgin aggregate due to the presence of adhering mortar with aggregate (Alan, D.B, 1977).

A brief review of literature related to the properties of recycled aggregate and recycling of demolished concrete was made. Most of the reviewed investigations were carried out on the recycled aggregate originally made with stone aggregates.

The research results are summarized in the following subsections.

Definition of Recycled Aggregate

The multiple uses of a product represent another way to conserve natural resources and avoid waste. This process is usually termed as recycling.Recycled concrete contains some previously hardened concrete in the form of aggregates particularly coarse aggregate.

At the present, the amount of global demolished concrete is estimated at 2~3 billion tons per year (Torring, et al. 2002). The amount of global requirement, of course aggregate for making concrete is estimated at 9.3 billion tons as per the year 2000 (Mehta, 2002). Therefore. Through complete recycling, a total of 30% of course aggregate can be saved which is a huge saving of natural resource. In the next ten years, the amount of demolished concrete is estimated to be 3 to 5 times of the

present amount which can be estimated at 7.5 to 12.5 billion tons (Torring, et al. 2002). Sixty to seventy percent of demolished concrete is used as a sub-base aggregate for road construction (Yanagibashi, et al, 2002)

Recycling of Demolished Concrete in Somalia

The volume of the demolished concrete is increasing rapidly in Somalia. The main causes of the increasing volume of demolished concrete in Somalia are as follows:

- ✓ Aging of structures
- ✓ Early deterioration
- ✓ Replacement of low-rise building by relatively high-rise buildings
- ✓ Demolition of illegal construction

Workability of Recycled Aggregate Concrete

Different results have been found in terms of workability of recycled aggregate concrete. Some works found that the use of crushed concrete as aggregate imposed no problems with respect to workability (Alan, 1977). Some found when recycled aggregate was used as their coarse fraction and natural sand as the fines in a concrete mix than an increase in free water of 8% was needed to achieve the same workability as that of natural aggregate concrete (Ravindrarajah, R. 1985). It has been also reported that workability is increased considerably when recycled aggregate was used (Yamato et al., 1988). Another showed that the use of recycled aggregate as a partial replacement of natural aggregate leads to slightly increased considerably when recycled.

Some studies suggested that recycled aggregates should be pre-wetted or saturated with water to prevent a rapid decrease in concrete workability (Hansen TC, 1985). A study demonstrated that the initial slump of a concrete mixture depends on the initial free water content

while the slump loss of the mixture with time depends on the initial moisture state of the aggregates. It has also reported that for using recycled aggregate in saturated surface-dried (SSD) state, the high water content inside the aggregate particles may result in the bleeding during casting (Poon CS, et al., 2004).

Compressive Strength of Recycled Aggregate Concrete

The compressive strength of recycled aggregate concrete is equal to or higher than that of conventional concrete if the same or a lower W/C ratio is used (Hansen TC, 1985). It has also been reported that no significant strength reduction has appeared in concrete with less than 30% of aggregate replaced by recycling coarse aggregate (Khatib, J.M, 2005). The compressive strength of concrete using recycled coarse aggregate with lower absorption is similar to that of the control specimens (Keun-. Et al. 2008).

Durability

The durability of recycled aggregate concrete is the same as the normal aggregate concrete against carbonation, freeze-thaw resistance, and sulfate resistance (W. K. Fung, 2005)

Why is Recycling Necessary?

Concrete consumption in the world is estimated at two tons per capita per year (equivalent to 12 billion tons) (Mehta, 2002). To make this huge volume of concrete, 1.5 billion tons of cement, 9.3 billion tons of aggregate, 1.2 billion tons of water are necessary. Also, about 1.5 billion tons of steel are necessary. Generally, aggregates are collected by cutting mountains or breaking river gravels or boulders, or by breaking clay bricks. A significant amount of natural resource can be saved if the demolished concrete is recycled for new constructions. At present, the amount of global demolished concrete is estimated at 2~3 billion tons

(Torring, 2002). Sixty to seventy percent of demolished concrete is used as sub-base aggregates for road construction (Yanagibashi et al., 2002). By recycling of demolished concrete, 30% of normal aggregates can be saved. It is also estimated that in the next ten years, the amount of demolished concrete will be increased to 7.5~12.5 billion tons (Torring, 2002).

Recycled Coarse Aggregate

Properties of Recycled Coarse Aggregate

- The specific gravity of recycled coarse aggregate will be 5% to 10% lower than that of the virgin aggregates in old concrete. This is due to the existence of a large amount of old mortar and cement paste adhering to RC. Typical values of RCA range between 2 and 2.5 in the SSD condition.
- The water absorption of recycled coarse aggregates (RCA) is much higher than that of the virgin aggregates in old concrete due to the attachment of mortar in RCA. Absorption values typically range from 6% to 20% of coarse aggregates
- The internal friction between the recycled aggregate is also higher due to the higher surface roughness of the recycled aggregate

Properties of Concrete Made with Recycled Coarse Aggregate

When a crushed concrete aggregate used as the coarse fraction, then the concrete mixes becomes slightly harsher and less workable than the normal aggregate mixes (M. Mulheron, 1988).]. The uses of recycled aggregate as coarse fraction slightly increase in the slump and compaction factor and high degree of bleeding. A study demonstrates that the initial slump of a concrete mixture depends on the initial moisture state of the aggregate. For use recycled aggregate in saturated-

dried (SSD) state, the high water control inside the aggregate particles may result in bleeding during casting.

The compressive strength of recycled aggregate concrete is equal or higher than of normal aggregate concrete if the same or a lower W/C ratio is used, it has been reported that no significant strength reduction has appeared in concrete with less than 30% of aggregate replaced by recycled coarse aggregate. Many studies show that 4% to 40% drop in the compressive strength of recycled coarse aggregate (T. Ikea, S, et al.1988).

Advantages of Using Recycled Coarse Aggregate:

- ✓ Save energy when recycling is done on site.
- ✓ To save natural resources.
- ✓ RCA that originated as concrete with rounded aggregate yields a new product with particles having fractured angular shapes for increased paste bond.
- ✓ RCA, when used in the base and sub-base material, performs better than the virgin aggregate.
- ✓ Using RCA in the Detroit metropolitan region is more advantageous than in rural areas since sources of old concrete are readily available and virgin aggregate sources are not as plentiful.
- ✓ Substitution of virgin aggregate by RCA can provide a reduction in the final cost of the project.
- ✓ Saving the cost of disposal of demolished concrete.
- ✓ Create additional business opportunities.

3. Research Methodology

In an attempt to study the strength of recycled concrete, a thorough survey of the available literature was carried out. In this chapter, the

whole experimental method of recycling of coarse aggregate has been summarized. It includes the way of a collection of aggregate, preparation of aggregate and other materials, investigation of aggregate, and mix design of investigating cases.

The flow diagram of the methodology is shown in the following section:

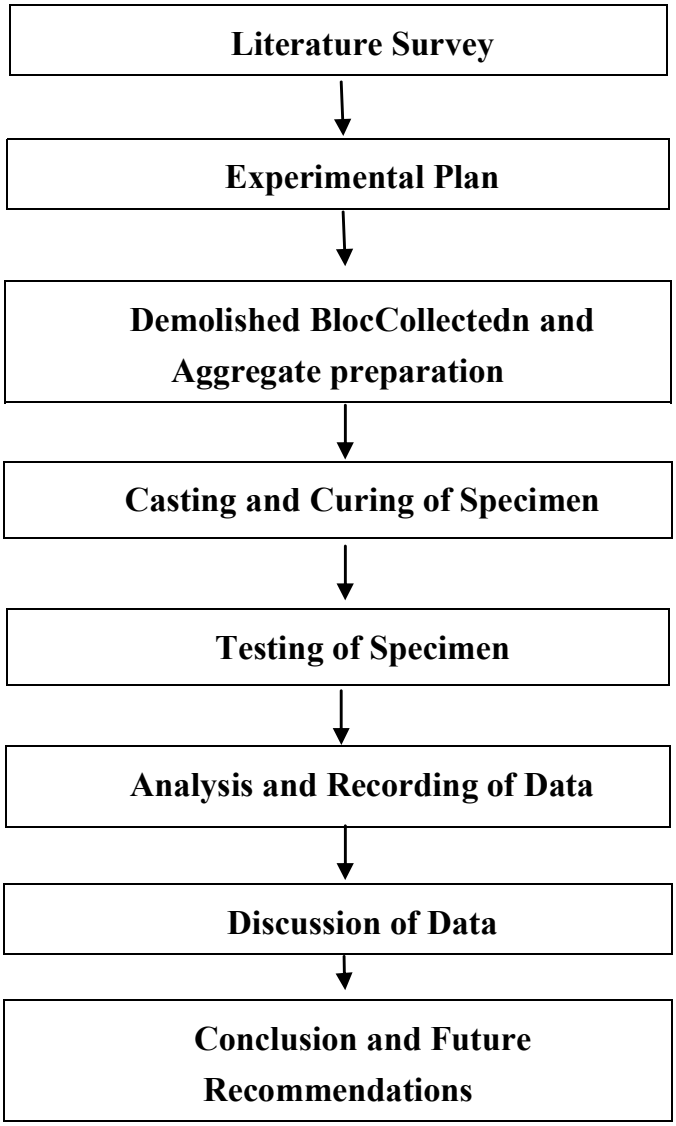

Fig. 3.1 Structure of research methods

Investigation of Recycled Aggregates Collected from Different Sites

In this section, experimental work conducted in this research was explained the demolished concrete block was collected from demolished building as Shown in **Fig.3.2**

Fig. 3.2 Building under Demolition

Demolished concrete blocks from different demolished building sites were collected. The collected blocks manually crushed into coarse aggregate (recycled aggregate). The grading of the aggregates was controlled as per ASTM C 33-93. The properties of the recycled aggregates, such as unit weight, specific gravity, absorption capacity, etc., were evaluated

Material Properties

Recycled Aggregates

Demolished concrete blocks were collected from the structural members of the demolished buildings. The collected concrete samples were broken into pieces manually in three particular sizes as 25 mm to 20 mm, 20 mm to 10 mm, and 10 mm to 5 mm. After breaking into pieces, the aggregates were sieved to control standard grading. The aggregates were also tested for absorption capacity, specific gravity, and unit weight. The specific gravity and absorption capacity are determined as per ASTM C128, unit weight as per ASTM C29.

Saturated surface dried recycled coarse aggregate was used for concrete casting. The property of recycled coarse aggregate is shown in **Table 3.1**

Table:3.1 Recycled Coarse Aggregate Material Properties

Test Name	Value
Unit Weight (kg/m^3)	1094.74
Specific Gravity	2.019
Absorption Capacity (%)	18
Wear (%)	47

Sand

The sand used for making concrete was washed properly and then dried. SSD condition of sand was made one day before mixing concrete. The FM of sand used in this investigation was controlled at 2.6. Saturated surface dry sand was used in mixing concrete.

Mixing with Water

Normal tap water was used as mixing water. The temperature of the mixing water was about 25±5°C

Cement

Ordinary Portland cement (OPC) was used.

Mixture Proportion of Concrete – Weight Basis

The unit contents of ingredients of concrete, such as water, cement, coarse aggregate and fine aggregate can find out to solve equation (2.1)

$$\frac{A}{G_A\gamma_w}+\frac{S}{G_S\gamma_w}+\frac{C}{G_w\gamma_w}+\frac{Air(\%)}{100}=1 \quad \text{..... (3.1)}$$

For solving the above equation, the following relationships are used:

(1) Sand to total aggregate volume ratio

(2) $$\frac{\frac{S}{G_S\gamma_S}}{\frac{A}{G_A\gamma_A}+\frac{S}{G_S\gamma_S}}=0.44 \quad \text{..... ..(3.2)}$$

Here, sand to total aggregate volume ratio is assumed to be o.44.

(3) Water to cement ratio

W/C = 0.55 and 0.45

(4) The unit content of cement

C = 340 kg/m^3

Mix design of the concrete in different cases in weight basis is shown in the **Table: 3.2**.

Table: 3.2 Details of concrete mixes for 1 m^3 concrete

Mix	Mix ID	W/C	Cement (Kg/m^3)	FA (Kg/m^3)	CA (Kg/m^3)	Water (Kg/m^3)	Admixture (L)
M1	100% SAND	0.55	340	781.721	772.59	187	
M2	50% SAND 50% RFA	0.55	340	691.523	772.59	187	
M3	100% RFA	0.55	340	607.04	772.59	187	
M4	100% SAND	0.45	340	820.617	811.034	153	
M5	50% SAND 50% RFA	0.45	340	725.93	811.034	153	
M6	100% RFA	0.45	340	637.24	811.03	153	

The flow of investigation is shown in **Fig.3.3** the total investigation was divided into two parallel groups as follows:

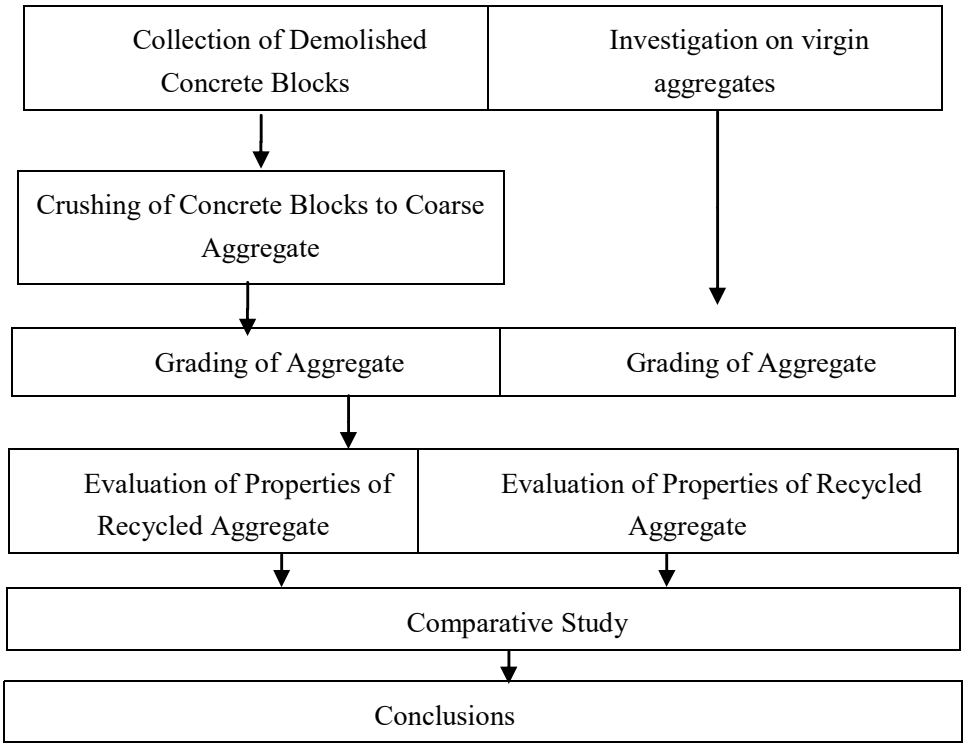

Fig. 3.3 Flow of Investigation

4. Results and Discussion

In this chapter, the experimental results related to the properties of fresh concrete and harden concrete made with 100% recycled coarse aggregate, recycled fine aggregate, and sand etc, are summarized and compared. Cube concrete samples were made with W/C ratio 0.45 and 0.55 and investigated for compressive strength at 7, 14 and 28 days

Properties of Concrete Made with

Absorption Capacity

Absorption test of the recycling coarse aggregates was done according to the ASTM standard requirements of specification C127. Results of absorption capacity of Coarse are summarized in table-4.1.

Table 4.1: Absorption Capacity of Coarse Aggregates

Absorption Capacity	19.58%

Abrasion Value

Abrasion test of the coarse aggregates was done according to the ASTM standard requirements of specification C127. Results of the Abrasion capacity of coarse aggregate are summarized in the table shown below-

Table 4.2: Abrasion Value of Coarse Aggregates

Abrasion Value	26.17%

Workability

Slump

The slump values are plotted in **Fig. 4.1** for concrete containing 0%, 50%, and 100% recycled fine aggregate. The Slump varies from 1 to 4 cm for W/C=0.55 and 0.5 to 1.25 cm for W/C=0.45. The slump was higher 100% RCA 100% RFA in concrete at W/C=0.55. The slump at/C=. 55 is higher than W/C=0.45

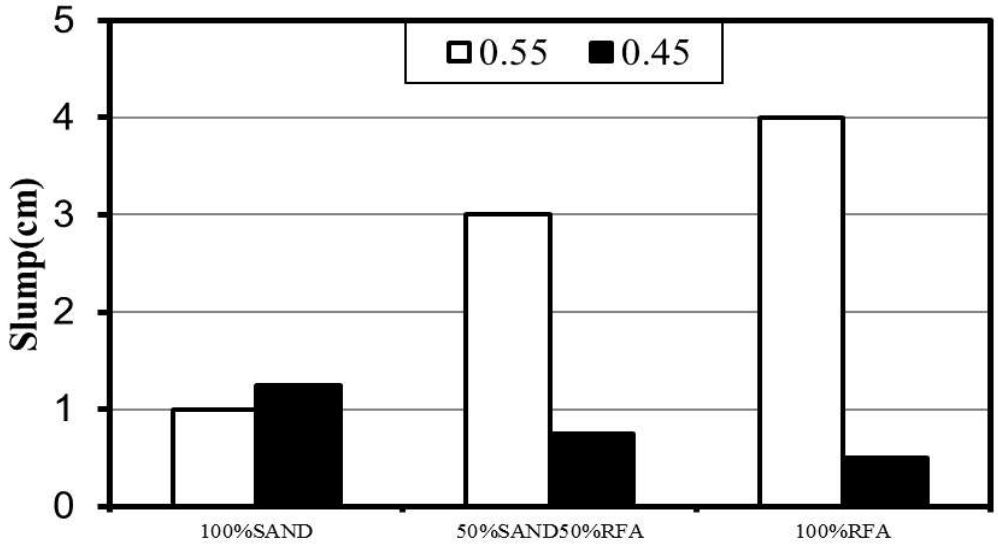

Fig.4.1 Effect of Recycled Aggregate on Slump of Concrete

The workability of concrete (measured by slump) is known in recycled aggregate concrete made with W/C=0.55. More than 5cm slump is obtained for recycled aggregate concrete with W/C=0.55, but in some cases, a very low slump is also observed. The average slump of recycled aggregate It is found that for W/C=0.55, there is no big difference in the slump for recycled concrete and virgin aggregate concrete.

Compressive Strength of Concrete

The compressive strength of concrete is shown in fig-4.2and 4.3. The average strength of the recycled aggregate concrete 2800 psi for W/C=0.55. Recycled aggregate concrete at 7, 14, and 28 days are shown in Figures 4.1 and 4.2 For the same w/cm, the strength of recycled aggregate concrete is about 10~20% lower than that of normal aggregate concrete. If the w/cm is reduced to 0.45, the strength of the concrete becomes similar to or higher than that of normal aggregate concrete made with w/cm =0.55. It is easily understood that a concrete strength of 3000 – 4000 psi can be obtained by using recycled aggregate concrete. The cement content of all concrete was set at 340 kg/m3. The strength of recycled aggregate concrete with higher cement content was also investigated.

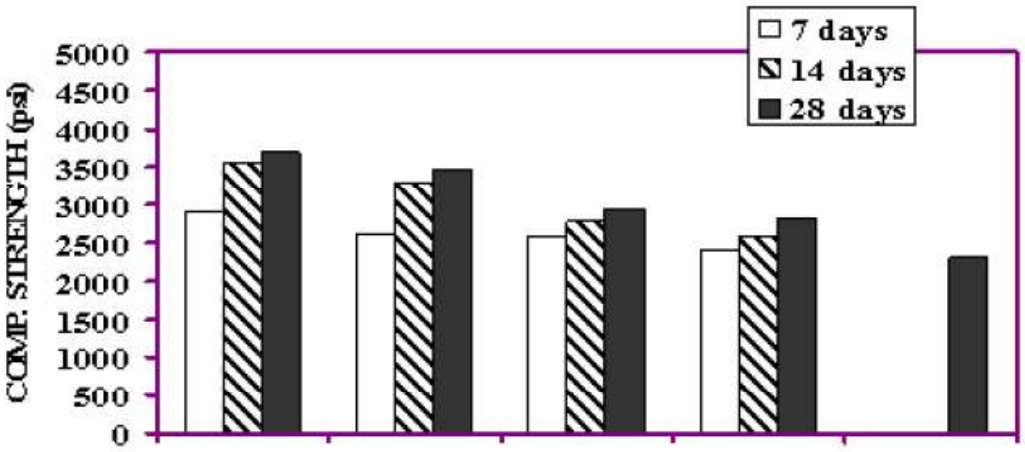

Figure 4.2: Compressive strength of concrete (w/cm =0.45).

5. Conclusions and Recommendations

The researcher concludes the following key points of recycling of demolished concrete: Conclusions: Recycling of demolished concrete as coarse Aggregate from the scope of this investigation and experimental results summarized. The following conclusions are drawn:

- Compared to the normal aggregate, the recycled aggregates show better performance with respect to abrasion and absorption capacity.
- The workability of recycled aggregate concrete is lower than the workability of the normal aggregate concrete, but it can be improved by an application of coating over the recycled aggregate before using as coarse aggregate. For same W/ C, the recycled aggregates give lower strength compared to the same with normal aggregates. If W/C is reduced (from 0.55 to 0.45), the strength of concrete is increased to the level of normal aggregate concrete at a higher W/C.
- The average compressive strength of recycled aggregate concrete is found at 25.5 Mpa (3700 psi) and 20.70 Mpa (3000 psi) for W/C =0.45 and 0.55 respectively
- Recycling of demolished concrete is possible for concrete in the strength range 3,000-4,000 psi
- Specific gravity is lower and absorption capacity is higher of recycled fine aggregate than the natural fine aggregate

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