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Research article

Improving the strength of concrete using demolition waste

Abhishek Kumar Yadav*, Maaz Allah Khan, Akash Kumar Kannaujiya, Umme Afsheen, Vaishali Singh, Samar Bahadur Singh, Ayush Pandey

Department of Civil Engineering, UIET, Babasaheb Bhimrao Ambedkar University, Lucknow-226025, India

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ABSTRACT

Debris left over after a structure has been demolished is referred to as demolition rubbish. In India, the construction industry generates 10 to 12 million tons of demolition waste annually. Bricks, wood, metal, and other recyclable materials are recycled in India, however, more than 50% of all garbage that is made up of concrete and masonry waste is not. A standardised manual for effective management of construction and demolished waste is lacking across the regulatory bodies. Authorities periodically make rules, but they typically never enforce them. This work is intended to act as a pilot study toward the development of such a manual. This study aims to compile essential information that will illuminate global approaches to managing demolition waste and the role of regulatory organizations in this field. Due to renovation in the world, a huge accumulation of construction and demolished waste is formed. This waste can be seen as a resource that can be recycled into new building materials. This study investigated the potential applicability of using demolition waste in cement-free binders. Completely cement-free binders were formulated using demolition waste as a substitute for fine aggregate. The properties of these binders were compared to those of traditional cement binders. It was found that the use of demolition waste in completely cement-free binders can result in materials with similar or even better properties than traditional binders. These findings suggest that the use of demolition waste in completely cement-free binders could be a viable solution for reducing the environmental impact of Construction and demolished waste.

1. Introduction

Demolished waste is the waste generated from the buildings (As shown in Fig. 1), roads, bridges and other structures which are destroyed and of no longer use. Waste from such structures may vary but most part of it is concrete, wood, asphalt, brick, tiles and reinforcement rods etc. Construction industry accounts for almost 20-30% of the entire waste generated in the Australian landfills (Craven et al., 1994). Many elements of demolished building waste has potential to be recycled.

The building construction uses natural resources and generates debris. Construction and demolition waste (CDW) is the term used to describe solid waste produced by the construction and building sectors (Shen et. al., 2014). China produces the greatest CDW in the world, with almost 2300 million tons in 2019 (Zheng et al., 2017).

It is expected that rate of construction will be increased from 6 to 8% in next decades due to rapid urbanization in India, and also it is likely to be the third largest in the world in the half way in a decade. It is presumed that about 70% of the construction of buildings are yet to be done by 2030. CDW makes up more than 30% of the total solid waste produced worldwide (Ginga et al., 2020).

***Corresponding Author:**
E-mail address: abhiishekyadav21@gmail.com (A. K. Yadav)

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Fig. 1. Demolition waste (source: www.epa.gov; US EPA)

Construction of new building will require large amount of raw materials leading to stress on existing resources such a coarse and fine aggregate whose mining is already banned in some area. Therefore demolished waste has potential to compensate the stress on the building materials like sand and stone etc. India's construction boom is producing huge amounts of CDW, and this trend is expected to continue for the probable future.

Particularly in older cities, substantial destruction frequently comes before development as older structures are torn down to make room for larger ones, usually high-rise apartments. Despite the lack of accurate data, it is claimed that the India produces 12 to 15 million tons of construction and demolished waste annually (TIFAC study, 2001).

Cities around the world produces approximately 1.3 billion tons of demolished waste every year and this production is likely to be increased to 2.2 billion tons by 2025. In year 2013 the total demolished waste generated in India was found to be 530 MT, almost 44 times more than the one estimated officially (CSE India, 2014). Indian CDW production is anticipated to be 150 million tons per year, according to the Building Material Technology Promotion Council (BMTPC) in 2017. However, the declared capability for recycling is a measly 6,500 Tons per day, or only under 1%. Furthermore, unconfirmed estimates of the overall amount of waste produced in the nation place the amount at three to five times the official number (CSE India, 2020). The concrete and masonry debris, which makes up larger than 50% of trash from building and demolition operations, it is not presently recycled in India, even if recoverable materials like tiles, stone, metal, woods and bricks are present in the CDW. But concrete and masonry waste recycling is done overseas in nations including the United Kingdom, the United States, France, Denmark, Germany, and Japan (report, Central Public Health & Environmental Engineering Organization (CPHEEO) GOI, 2020).

2. Materials and Methods

Due to the various types of building materials utilized, this category of waste is complicated, but, it may include the following components:- Material like reinforcement Steel, wood, stone, Timber, railings, brick, frames, Bakelite, granite, marble, sandstone, switches, panels, GI pipes, CI pipes etc.

Concrete's strength is often determined using a compression test on a 15 cm*15 cm*15 cm cube. Since concrete increases by 99% of its strength in just 28 days, the cube is given this amount of time to cure before testing. In 1day it achieves 16%, in 3 days it achieves 40%, in 7 days it achieves 65%, in 14 days it achieves 90% and in 28 days it achieves 99% of compressive strength.

The strength of concrete increases with age (days).We have used Demolition waste in place of sand and hence compressive strength of concrete is improved. We have create 12 cubes of M25 grade for this test at ratio (1:1:2). Demolition waste replace with cement and sand by the wait. The first cube was without any demolition waste. Second cube has 10% demolition waste. Third cube has 20% demolition waste. Fourth cube has 30% demolition waste. We have used 15*15*15 size cube for this work.

2.1. Mix design

For this work, we have used Grade M25 concrete with cement, sand and aggregate in ratio 1:1:2. Table 1 shows properties of different materials have been used and Table 2 shows ration of different materials.

Table 1 Used Material properties

Grade of concrete	M25
Cement used	OPC 43 grade
Target strength	31.8 N/mm^2
Cement content	426.12 kg/m^3
Water–cement ratio	0.45 (191.6 L/m^3)
Sand content	524.68 kg/m^3
Aggregate content	1172 kg/m^3

2.2. Mix design proportion

Table 2 Material ratio

Material	Ratio
Cement	1
Sand	1
Aggregate	2
Water	0.45

2.3. Concrete mix

Hand mixing was done on a plane, smooth surface to obtain the, homogenous mixture of fine aggregate (sand) course aggregate cement and water. The mixer is blended until there is

uniform distribution of course aggregate with proper consistency.

2.4. Weight of Cubes

After curing, weight of cubes was measured (As shown in Table 3). The curing of concrete cubes at approximately 27°C was done for 7 days, 14 days and 28 days and after that water absorption test was done and weight of cubes was measured.

Table 3. Weight of cubes

Cubes	Weight(Kg)	Curing (in days)
Normal cube	7.98	28
Cube with 10%DW	7.91	28
Cube with 20%DW	7.93	28
Cube with 30%DW	8.16	28
Cube with 10%DW	7.94	14
Cube with 20%DW	7.96	14
Cube with 30%DW	8.2	14
Cube with 10% DW	7.94	7
Cube with 20%DW	7.96	7
Cube with 30% DW	8.05	7

*DW= Demolition waste

3. Results and discussion

3.1. Workability

Workability test was done to determine the easiness of placing the concrete in the mould and compacted to obtain a finished surface of samples as per IS: 6461-1973.

Fig. 2 shows that for different percentage of demolished waste in the concrete mix the slump value was found to be different. In 30% of demolished waste in concrete the slump value was obtained 160 mm and similarly 162 mm in case of 20%, 165 mm in case of 10% and 168 mm in case of normal standard concrete mix. The slump values were decreased with an increasing percentage of demolished waste.

3.2. Compressive strength

Compressive strength of cubes specimen was done to obtain the compressive strength of each cubes (As shown in Fig. 3). Cube with 20% of replacement of fine aggregate demolished waste gave strength near to that of normal concrete cubes.

The line graph showing strength of concrete with different percentage of demolished waste in concrete mix cubes, after 7 days, 14 days and 28 days of curing.

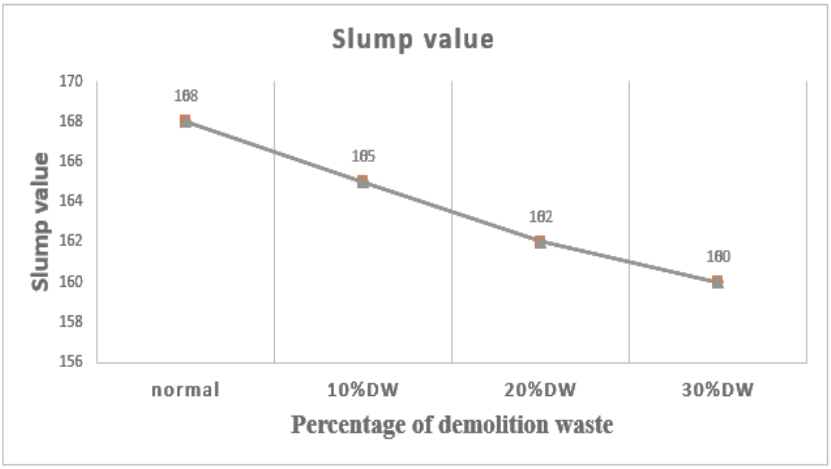


Fig. 2. Workability of various percentages of demolition waste.

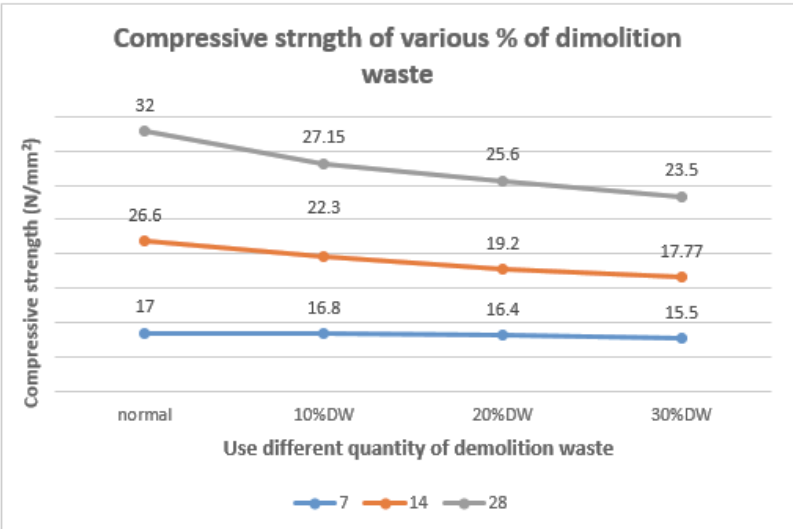
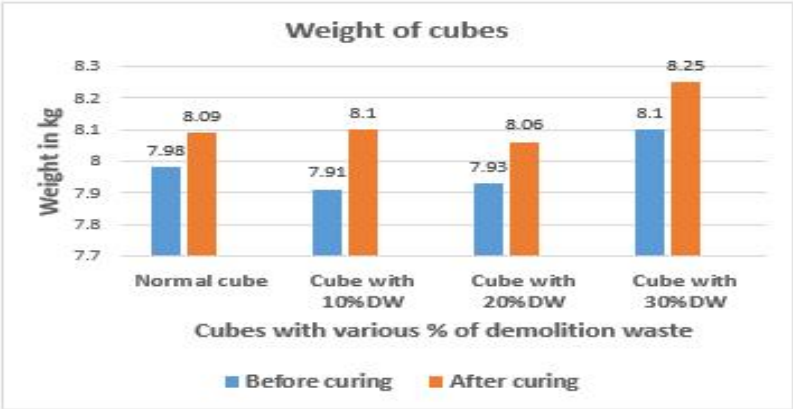


Fig. 3. Compressive strength of cubes

(a) Cube weight before curing (b) Cube weight after curing



(c) Graph showing weight of cubes before and after curing

Fig. 4. Cubes weights

3.3 Comparative statement of strength and economy (mix 1:1:2).

Table 4 demonstrate the Comparative statement with economy for 7, 14 and 28 days.

Table 4. Comparative statement with economy

Type of concrete	Average Compressive strength in N/mm^2			Cost in rupees/m^3	
	7 days	14 days	28 days		
Normal concrete	17	26.6	32	3613.32	Decrease in cost (%)
Concrete with 10% of DW	16.8	18.6	27.15	3537.52	2.84
Concrete with 20% of DW	16.4	22.3	25.6	3550	4.24
Concrete with 30% of DW	15.5	17.77	23.5	3390	6.18

3.4. Cube weight

Cube weight was done before and after curing for 28 days. The Fig. 4(a) shows cube weight before curing and Fig. 4(b) shows weight after curing and Fig. 4(c) shows the bar graph showing the weight of cubes of normal standard mix cubes, 10%, 20% and 30% of demolished waste after 28 days of curing.

4. Conclusion

On comparing in two cubes, standard concrete cube and the other one using the demolished material. It was observed that cubes with 10% replacement of demolished waste shows better compressive strength than standard concrete cube (M25 grade) on testing it after 7 days, 14 days and 28 days of curing. The flexural and compressive strength of the demolished waste concrete is 12% greater than standard concrete. Both concrete has good durability to withstand compressive and flexural failure, but demolished waste concrete is more durable and has flexural strength because demolished waste has polymeric properties. So it is suitable for rigid pavement and retaining wall as well as slope structures.

In general, managing demolition waste is crucial to protect the environment and public health. Proper disposal and recycling methods, as well as exploring the potential of using demolition waste in construction materials, can help in reducing its impact on the environment.

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Conflict of interest

There is no conflict of interest among the authors.

Contribution of authors

Abhishek Kumar Yadav has done writing original draft, conceptualization and formal analysis, Maaz Allah Khan has provided supervision and validated the manuscript. Akash

Kumar Kannaujiya has provided data, graphical images and testing of concrete, Umme Afsheen has done casting cubes, curing and testing of cubes, Vaishali Singh has done casting of cubes, curing and testing of cubes, Samar Bahadur Singh has collected debris from demolished building, mixing, casting cubes, curing and testing of concrete cubes and Ayush Pandey has conducted Sieve analysis, mixing concrete, slump testing, casting cubes, curing and testing of concrete cubes.

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