Review Paper on Partial Replacement of Cement and Aggregates with Various industrial Waste Material and Its Effect on Concrete Properties

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Abstract This study is conducted to evaluate the performance of various type of industrial waste by-products that can be used as an admixture in concrete as a replacement of cement or aggregate as the demand of cement is increasing in the market. Increased demand leads to increased production of cement at large scale which leads to environmental issues and reduction in the number of natural resources on one hand and increase in the cost on the other hand. To deal with these, alternate materials were tested experimentally for use in preparing concrete. Properties of a number of materials such as steel fibre, asphalt, slag, asbestos, lead, dry sludge, wet sludge, fly ash, bagasse ash, red mud, plastic, glass, etc., were studied to find an alternative for replacement of cement. A detailed study of compressive strength, flexural strength and slump value were made by various researchers for 7 days and 28 days respectively. This work compiles the study of a number of waste materials which makes it easy to compare the properties of these waste materials and find out which waste material is more suitable as an alternative for better performance and for environmental suitability as well.

Keywords Partial replacement · Cement · Aggregates · Industrial waste · Compressive strength · Flexure strength · Slump

1 Introduction

Concrete is a mixture of cement, coarse aggregates, fine aggregates and water. In the green stage, it can be moulded into any desired shape. The relative quantity of ingredients used in the mix, controls the property of concrete at various stages, i.e., in wet as well as at hardened stage. Two or three decades ago, due to easy availability of ingredients of concrete, construction of buildings was used to be carried out with

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OPC without considering the quality and the future of concrete structures. But, in the modern era, since last two decades, investigation has been made by engineers and scientists considering the structural stability of concrete structures which requires quality concrete with improved concrete strength, durability and other characteristics. Due to the requirement of these properties, the search for supplementary cementitious material which can be used as a replacement of cement in the concrete mix was carried out. This could be any material which has the lowest possible environmental impact and is universally sustainable.

A number of waste materials can be used as a replacement (generally partial) of cement or aggregate from the concrete mix. The present study is focused on some of the waste materials which includes plastic, dry and wet sludge, red mud, blast furnace slag, sawdust and its ash, silica fume and glass. The work done by various research scholars on replacement of cement or aggregate by waste material has been shown in Table 1.

1.1 Components of Concrete that can be Replaced by Waste Material

Concrete mix comprises of cement, water, coarse and fine aggregates, and various studies have been conducted on replacement of these constituents. The present study mainly focuses on replacement of cement and fine aggregates by waste materials and the effects of these replacements on the properties of the concrete mix. The replacement of cement and fine aggregates by waste materials has been shown in Table 2.

In present study, mainly replacement of cement and fine aggregates has been carried out by the researchers and not much study has been done regarding replacement of water and coarse aggregate in the concrete mix.

1.2 Effect of Replacement of Cement by Waste Material on Various Properties of Concrete

Table 3 shows the effect on various properties of concrete when cement is partially replaced by various industrial waste material and based on the observations it can be found out that which of the following materials is best suitable as a replacement of cement. It has been observed from Table 3 that dry and wet sludge and red mud can be used as a replacement of cement because with the addition of these materials the strength of the cement concrete increases from 20 to 30% replacement by 15.61% in case of red mud and then decreases.

Table 1 Different types of waste materials used

S. no.	References	Plastic	Dry &wet sludge	Fly ash	Red mud	Blast furnace slag	Saw dust & its ash	Silica fume
1.	Ghannam (2016)	–	✓	–	–	–	–	–
2.	Soni (2015)	–	–	✓	–	–	–	–
3.	Kale et al.	–	–	✓	–	–	–	–
4.	Ghutke et al.	–	–	–	–	–	–	✓
5.	Ashok et al. (2010)	–	–	–	✓	–	–	–
6.	Rathod et al.	–	–	–	✓	–	–	–
7.	Dubey et al. (2012)	–	–	–	–	✓	–	–
8.	Kumar et al. (2015)	–	–	–	–	✓	–	–
9.	Pandey et al. (2016)	–	–	–	–	✓	–	–
10.	Gopinath et al. 2015)	–	–	–	–	–	✓	–
11.	Ganirom (2014)	–	–	–	–	–	✓	–
12.	Raheem (2014)	–	–	–	–	–	✓	–
13.	Cheng et al. (2013)	–	–	–	–	–	✓	–
14.	Roy et al. (2012)	–	–	–	–	–	–	✓
15.	Vivek et al. (2015)	–	–	–	–	–	–	✓
16.	Jibrael et al. (2016)	✓	–	–	–	–	–	–
17.	Patil et al. (2014)	✓	–	–	–	–	–	–
18.	Subramani et al. (2015)	✓	–	–	–	–	–	–
19.	Rabie (2016)	–	✓	–	–	–	–	–
20.	Bhargava et al. (2016)	–	✓	–	–	–	–	–

Table 2 Various components of concrete mix replaced

S. no.	References	Cement	Water	Coarse aggregate	Fine aggregate $_x$
1.	Ghannam (2016)	✓	–	–	–
2.	Soni (2015)	✓	–	–	–
3.	Kale et al.	✓	–	–	–
4.	Ghutke et al.	✓	–	–	–
5.	Ashok et al. (2010)	✓	–	–	–
6.	Rathod et al.	✓	–	–	–
7.	Dubey et al. (2012)	✓	–	–	–
8.	Kumar et al. (2015)	–	–	–	✓
9.	Pandey et al. (2016)	✓	–	–	–
10.	Gopinath et al. (2015)	✓	–	–	✓
11.	Ganirom (2014)	–	–	–	✓
12.	Raheem (2014)	✓	–	–	–
13.	Cheng et al. (2013)	–	–	–	✓
14.	Roy et al. (2012)	✓	–	–	–
15.	Vivek et al. (2015)	✓	–	–	–
16.	Jibrael et al. (2016)	–	–	–	✓
17.	Patil et al. (2014)	–	–	✓	–
18.	Subramani et al. (2015)	–	–	✓	–
19.	Rabie (2016)	✓	–	–	–
20.	Bhargava et al. (2016)	–	✓	✓	–

In case of dry and wet sludge, the compressive strength increases by 5.81% for 10% replacement. Use of these waste material limits the use of cement in the construction operation.

1.3 Effect of Replacement of Fine Aggregates by Waste Material on Various Properties of Concrete

Table 4 shows the effect on various properties of concrete when the aggregate is partially replaced by various industrial waste material and based on the observations it has been found that which of the following materials is best suitable as a replacement of aggregate. The case of fine aggregate is quite different to that of cement, not a large number of waste materials have been studied for replacement of fine aggregate as compared to that of cement.

Table 3 Effect of replacement of cement by waste material

S. no.	References	Waste materials	Compressive strength	Flexural strength	Workability (slump value)	Durability
1.	Ghannam (2016), Rabie (2016)	Dry & Wet Sludge	↑ for 0–10%	–	↓	↑
2.	Soni (2015), Kale et al.	Fly ash	↓	–	↑	–
3.	Ashok et al. (2010), Rathod et al.	Red mud	↑for 0–15%, then↓	↑for 15–30%, then ↓	↑	–
4.	Dubey et al. (2012), Pandey et al. (2016)	Blast furnace slag	↓	↓	↑	↑
5.	Gopinath et al. (2015), Raheem (2014)	Saw dust	↓	–	↑	–
6.	Ghutke et al., Roy et al. (2012), Vivek et al. (2015)	Silica fume	↑ up to 10% then ↓	–	May ↑ or ↓	–

Table 4 Effect of replacement of fine aggregates by waste materials

S. no.	References	Waste materials	Compressive strength	Workability (Slump value)
1.	Jibrael et al. (2016), Patil et al. (2014), Subramani et al. (2015)	Plastic	↓	↓
2.	Bhargava et al. (2016)	Dry & wet sludge	↓	↓, up to 30%
3.	Kumar et al. (2015)	Blast furnace slag	↑up to 75%	Constant
4.	Ganirom (2014), Cheng et al. (2013)	Saw dust	↓	–

It has been observed from Table 4 that the compressive strength of the concrete increased by 16.02% for 75% replacement of FA by blast furnace slag. Blast furnace slag is the most suitable replacement because with an increase in the compressive strength it does not affect the workability of the concrete mix.

2 Conclusions

- Red mud is the best waste material that can replace cement from cement concrete as it not only leads to an increase of 15.61% in the compressive strength but also increases the durability of the mixture.
- The second material that can be used as a replacement for cement is dry and wet sludge because replacement of 10% leads to an increase of 5.81% in the strength. But further replacements show a decrease in the compressive strength.
- For replacement of fine aggregates only Blast furnace slag is suitable, because 75% replacement of fine aggregate shows an increase in the strength of cement concrete by 16.02%.

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