EXPERIMENTAL STUDY ON THE EFFECT OF INCORPORATING MARBLE DUST AS A SUBSTITUTE OF SAND IN CONCRETE

Md. Izharul Haque Azad*[1] and Abu Saif Md. Nasim Uddin[2]

[1] *Lecturer, Department of Civil Engineering, BAUST, Bangladesh, e-mail: izharce@gmail.com*
[2] *Lecturer, Department of Civil Engineering, BAUST, Bangladesh, e-mail: saifmuhammad370@gmail.com*

***Corresponding Author**

ABSTRACT

Concrete is one of the basic and most important components of modern structural system. The strength, specially compressive strength, of this concrete is a matter of great concern which is obtained from its constituent elements - cement, sand and stone or brick chips. Among all these, sand is a prime material which serves as a filler, provides workability and also imparts strength to it. The basic source of sand is the extraction of it from river bed. But in recent times there has been a scarcity of river sand due to the erosion of natural river beds and rapidly changing environmental conditions. This increasing shortage of natural sand puts emphasize on the search of a suitable and compatible alternative of it to be used in concrete technology. A number of research works have been conducted on this with different substitutes. Such a possible alternate could be the powder waste of marble. Marble dust is generated in a remarkable quantity as a by-product in the marble industry. It is finer than sand particles and has some cohessive properties as well. This paper represents the results of an experimental work regarding the use of this powder waste as a partial and full replacement of natural sand in concrete. The only parameter that was studied in this research work is the compressive strength of concrete. The reference samples were pepared for a particular ratio by weight (1:1.5:3) and their compressive strengths were determined in the laboratory which were found to be 15.49 MPa and 21.22 MPa after 7 days and 28 days of curing respectively. Then the sand particles were replaced by a percentage of total weight (10%, 20%, 30%, 40%, 50% and 100%) by marble dust and the same tests were conducted for the determination of compressive strength of those samples. The findings of this experimental study indicates that among all the ratios of marble powder used, two proved to be effective for both 7 days and 28 days tests. The compressive strengths after 7 days of curing increased by 8.20 percent and 39.77 percent respectively for 10 % and 40 % of replacement of sand. The tests after 28 days show an increase of 7.02 percent and 17.39 percent for the same content of marble dust (10% and 40%) respectively. The other marble contents (30%, 50% and 100%) have showed reduction in the compressive strength. This results finally illustrates that the waste marble dust proves to be effective as a partial replacement of natural sand in conventional concrete and this use will reduce the amount of disposed marble wastes and eventually lessen the environmental hazards associated with it.

Keywords: *Concrete, marble dust, compressive strength, alternatives, percentage replacement.*

1. INTRODUCTION

Concrete, the artificial stone, is the basic element used in the development of modern infrastructures. It is and has been the major component of the structural system from the very dawn of modern construction. Concrete provides strength as well as the core skeleton to the infrastructures. And it gains its strengths from its constituent elements such as binder, fine aggregate, coarse aggregate and admixtures (if required). Among all these, stone provides strength and volume to concrete, sand performs the job of filler by filling up the voids in between coarse particles and cement binds these elements in a compact mass in the presence of water. Sand is extensively used as fine aggregate in concrete and the major source of this natural sand is the extraction of it from river bed. This source is limited and the uncontrolled extraction of sand from the rivers are changing the course of these natural water bodies thus creating environmental hazards. Eventually it will cause a scarcity of sand in near future.

Again, with the increasing urbanization and industrialization, the quantity of inorganic waste generation as a by-product in different industries is also increasing at an alarming rate, wastes that can only be used for dumping and cannot be properly disposed.

Sand in concrete can be replaced with some of these industrial wastes that serve as a suitable and compatible substitute. A remarkable number of research works have been conducted from time to time with these alternatives. The use of copper slag, siliceous stone powder, quarry dust, filtered sand, fly ash, etc. as a replacement of sand in concrete has been observed as found in various literatures (Sukesh et al., 2013).

The use of copper slag is found to be effective in increasing the compressive as well as the flexural strength of pavement concrete by 20%. It kept the strength of concrete unchanged up to 50% substitution (Arivalagan, 2013). The experiment on the granulated blast furnace slag (GBFS) as a substitute of natural sand in concrete showed that it can be used up to the 70% of total mass of sand (Nataraza, 2013). 100% replacement can cause some problems such as excessive bleeding but up to 80% can be recommended (Sundarvizhi & Ilangovan, 2013). For foundry sand which contains a high amount of silica in it, it was observed that it can be used up to 50% in place of sand in concrete. It will be economical in the production of concrete (Prajapati et al., 2013). Some other possible alternatives could be brick dust, fine particles obtained from demolition waste, stone dust, etc.

Like all the materials stated above one is waste marble powder which is generated during the manufacturing process of marble products, their cutting, polishing, etc. These are generated in huge quantity which are disposed over spared land, outside of the city, side of highways (Figure 1) or sometimes directly into the water bodies. The disposal of this inorganic waste has adverse effect on environment in the form of water logging, porosity and permeability reduction of topsoil, etc. Even the fertility of soil is also affected by the alkalinity of such wastes. When in its dry state they cause severe air pollution and eventually causes health issues too.

Figure 1: Dumping of marble waste

All these adverse effects of marble dusts can be reduced to some extent if we are able to use them in some sectors such as concrete production. An experiment for the same was carried out to replace the coarse aggregate in lean concrete by a varying percentage of 20-100%. The result showed an increase of 40% and 28% in the 7 days and 28 days strength respectively (Sudarsan et.al., 2016). Another research work illustrates that the incorporation of marble waste as coarse aggregate shows no significant change or decrease in the workability, durability, hardening, and strength of concrete compared to the conventional one (Andre et.al., 2014).

An experimental investigation was carried out using marble wastes as coarse aggregate in concrete and that for cement as well. 5% replacement was found to be the optimum dose in green concrete

(Memon et al., 2020). Some other research works related to the replacement of cement were also conducted and the effects of this substitute are found to be quite promising (khan et al., 2018). Another experiment shows that marble dust can be used with combination of alccofine as a replacement of cement for the development of sustainable concrete (Sawant et al., 2019). Its influence on the improvement of expansive clay soil (Hassan et al., 2021) and subgrade soil (Ahmed, 2020) was also studied extensively.

This research work aimed at using marble dust as a partial and full replacement (10%, 20%, 30%, 40%, 50% and 100% by dry weight) of natural sand in conventional concrete and studying its effects in terms of its compressive strength. By doing so, a recommendation can be made on the reuse of marble dust and eventually a proper way will be found out about reducing the amount of disposed wastes that harm the environment in various ways.

2. METHODOLOGY

The detailed experimental work includes the followings: collection of materials, determination of their physical and mechanical properties, preparation of reference samples, preparation of test samples with the selected proportion or percentage content of marble dust, curing of specimens, testing after 7 days and 28 days of curing and finally comparing the result to set a proper conclusion and recommendation.

2.1 Material Collection

The materials that are generally used in the production of conventional concrete are chosen for this experimental work. The list of materials includes- stone chips (CA), sylhet sand (FA), Ordinary Portland Cement (OPC), potable water and marble dust.

2.2 Material Properties

The material properties were determined according to the standard procedure as prescribed below:

2.2.1 Aggregates

Stone chips of 20 mm downgrade size were used as coarse aggregate in the concrete. Its specific gravity, water absorption and unit weight were determined according to ASTM C127, ASTM C 127 and ASTM C29 respectively and the values were 2.97, 2.04% and 1764.15 kg/m^3 respectively.

Sylhet sand was used as fine aggregate. Different properties such as specific gravity, water absorption, fineness modulus (FM) and unit weight were determined according to ASTM C128, ASTM C128, ASTM C136 and ASTM C29 testing standards respectively and the values were found to be 2.71, 6.61%, 3.01 and 1797.74 kg/m^3 respectively. The sieve analysis to know the gradation and fineness modulus of sand was also conducted and the data is given in Table 1.

Table 1: Data of sieve analysis and fineness modulus of sand (Total sample 500 gm)

Sieve No.	Sieve Opening (mm)	Materials Retained (gm)	% of Materials Retained	Cumulative % of Materials Retained	% Finer	Fineness Modulus
4	4.75	0	0	0	100.00	3.01
8	2.36	22	4.40	4.40	95.60	
16	1.19	143	28.60	33.00	67.00	
30	0.59	183	36.60	69.60	30.40	
50	0.30	126	25.20	94.80	5.20	
100	0.15	21	4.20	99.00	1.00	
Pan	-	5	1.00	-	-	
Total		**500**	**100**	**300.8**		

Different physical and mechanical properties of marble dust, similar to that of sand, such as specific gravity, water absorption, fineness modulus (FM) and unit weight were determined according to their respective standard procedures and the values were found to be 2.58, 6.83%, 1.67 and 1559.25 kg/m^3 respectively. The data of sieve analysis are given in Table 2 below:

Table 2: Data of sieve analysis and fineness modulus of marble dust (Total sample 500 gm)

Sieve No.	Sieve Opening (mm)	Materials Retained (gm)	% of Materials Retained	Cumulative % of Materials Retained	% Finer	Fineness Modulus
4	4.75	0	0	-	100.00	1.67
8	2.36	12	2.40	2.40	97.60	
16	1.19	29	5.80	8.20	91.80	
30	0.59	27	5.40	13.60	86.40	
50	0.30	174	34.80	48.40	51.60	
100	0.15	230	46.00	94.40	5.60	
Pan	-	28	5.60	-	-	
Total		**500**	**100**	**167**		

Figure 2 below shows the comparison between the gradation curve of sylhet sand and marble dust.

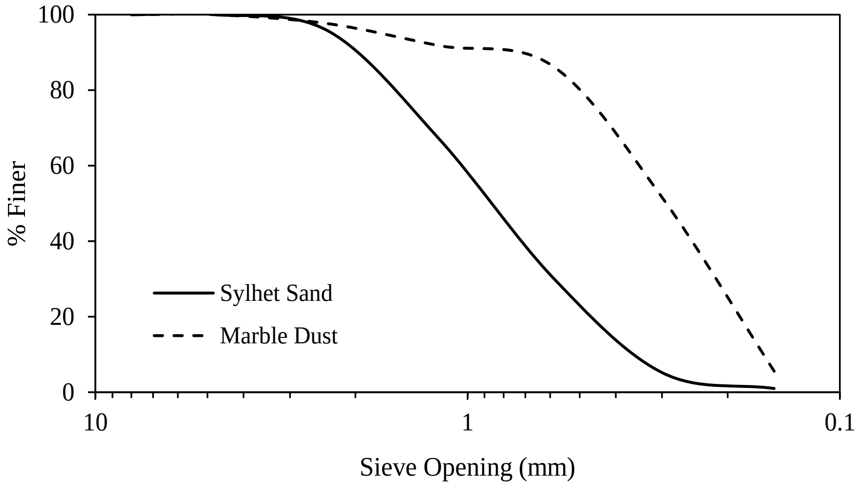

Figure 2: Gradation curve for sylhet sand and marble dust

Table 3: Combined fineness modulus of fine aggregates

Marble dust (%)	0%	10%	20%	30%	40%	50%	100%
FM$_{COM}$	3.01	2.87	2.74	2.61	2.47	2.40	1.67

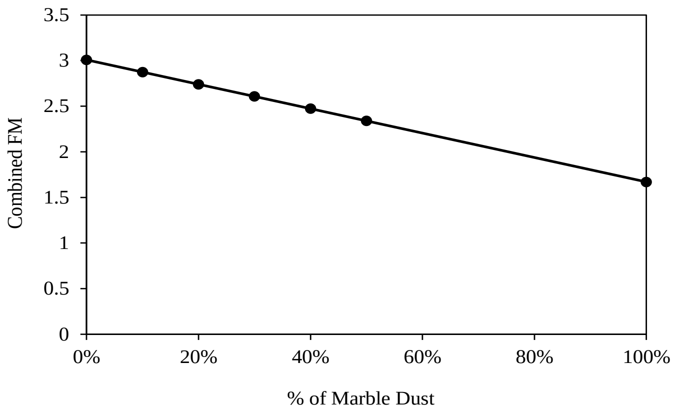

Figure 3: Combined fineness modulus of fine aggregate

2.2.2 Binder

Ordinary Portland Cement (OPC) was used as binding agent. The normal consistency and setting time of cement was determined in the laboratory and the values were found to be 28%, 35 minutes (initial setting time) and 350 minutes (final setting time) and the specific gravity was 3.12.

2.3 Sample Preparation

Total seven sets of cylindrical sample were prepared including one set of control specimen. The dimension of the specimen was 100 mm x 200 mm (diameter x height). A typical mix ratio of 1:1.5:3 with w/c ratio of 0.4 targeting a 20 MPa crushing strength after 28 days of curing was selected to replicate the conventional concrete used for mass construction in our country. Each set of samples includes 6 specimens for the test of compressive strength after 7 days (3 specimen) and 28 days (3 specimen) of curing.

Another six sets of samples were prepared by replacing the sand in them by 10%, 20%, 30%, 40%, 50% and 100% of its dry weight by marble dust. Then the specimens were cured under water in full submerged condition before testing them after stated time period.

2.4 Testing of Samples

Three cylinders from each set were tested first after 7 days of curing under the action of compressive load in UTM machine. The load was applied on the circular flat surface till failure. The obtained load was divided by the corresponding area to determine their respective compressive strengths.

Same test procedure was followed for the rest of the samples from each batch after 28 days of curing and the data were collected for further analysis. The dimension of each sample was properly measured prior to testing.

3. ILLUSTRATIONS

The experimental data from the lab tests are illustrated in the result and discussion section below:

3.1 Result and Discussion

The data collected from the compressive strength test was analysed to study the effect of marble dust incorporation in concrete. Table 4 below shows the detailed data obtained in the test.

Table 4: Compressive Strength Test Data

Details of Samples		7 Days Compressive Strength (MPa)			28 Days Compressive Strength (MPa)		
Marble Dust (%)	**Sample No.**	**Load (kN)**	**Compressive Strength**	**Average Strength**	**Load (kN)**	**Compressive Strength**	**Average Strength**
0% (Reference Sample)	1	120	15.28	15.49	160	20.37	21.22
	2	125	15.92		170	21.65	
	3	120	15.28		170	21.65	
10%	1	120	15.28	16.76	185	23.55	22.71
	2	140	17.83		180	22.92	
	3	135	17.19		170	21.65	
20%	1	105	13.37	15.28	135	17.19	19.74
	2	125	15.92		165	21.01	
	3	130	16.55		165	21.01	
30%	1	95	12.10	12.10	97	12.35	15.19
	2	95	12.10		136	17.32	
	3	95	12.10		125	15.92	
40%	1	170	21.65	21.65	190	24.19	24.91
	2	175	22.28		187	23.81	

	3	165	21.01		210	26.74	
50%	1	125	15.92	15.49	165	21.01	20.58
	2	120	15.28		165	21.01	
	3	120	15.28		155	19.74	
100%	1	75	9.55	9.00	100	12.73	13.03
	2	72	9.17		100	12.73	
	3	65	8.28		107	13.62	

The data illustrated in table above show that the control specimen has an average compressive strength of 15.49 MPa after 7 days and 21.22 MPa after 28 days of curing. Compared to this, 10% replacement of sand by marble dust increases the strength slightly for both 7 days and 28 days test. But further addition shows a fall in the strength up to 30% replacement. Then the value increases again and provides the maximum of 21.65 MPa (at 7 days) and 24.91 MPa (28 days) of compressive strength for 40% marble dust. Then again the strength start to decrease with further addition of marble powder. Eventually the lowest value was obtained for 100% substitution of natural sand.

The variation of strength is shown in the bar diagram from Figure 4 to Figure 7 below and also the percentage increase or decrease is illustrated herewith.

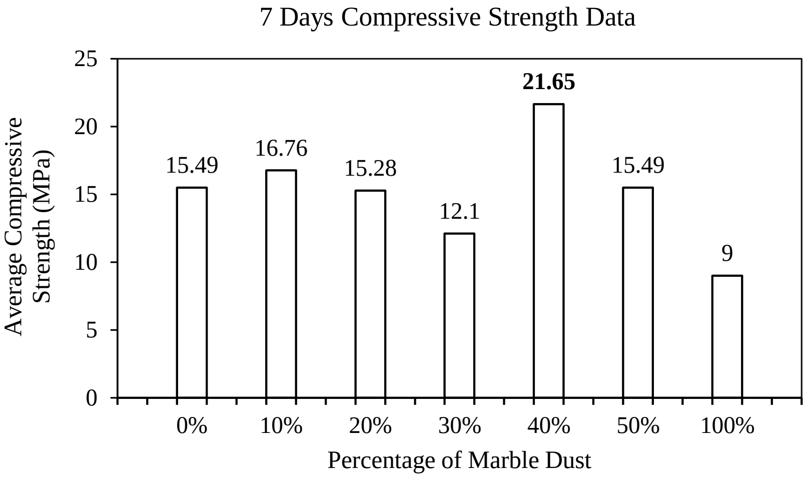

Figure 4 : Bar diagram showing the variation in strength for 7 days test

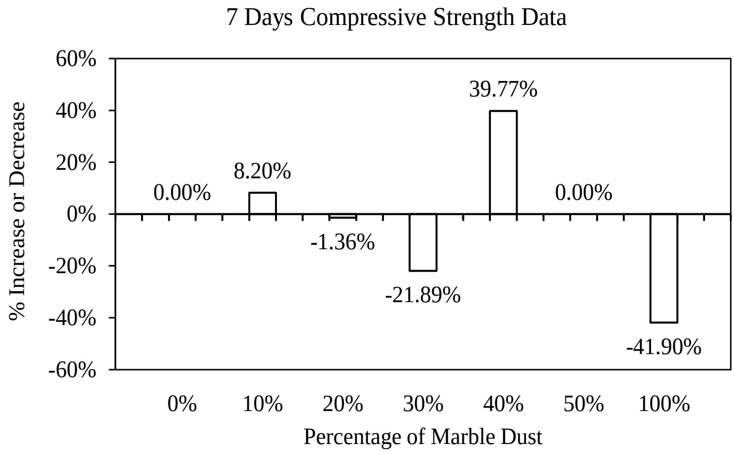

Figure 5 : Percentage increase or decrease in 7 days compressive strength

The figures above show that initially the strength of concrete after 7 days of curing increased by 8.20% for 10% of dust content. Then the value decreased for 20% and 30% progressively and eventually there is a jump to 39.77% increase in strength for 40% dust content. It was found to be interesting that the ocmpressive strength remained unchanged for 50% substitution. The maximum fall of 41.90% was found for 100% replacement.

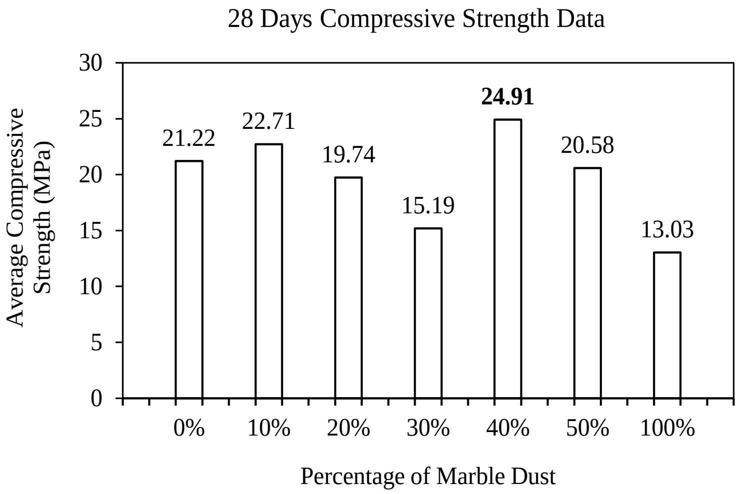

Figure 6 : Bar diagram showing the variation in strength for 28 days test

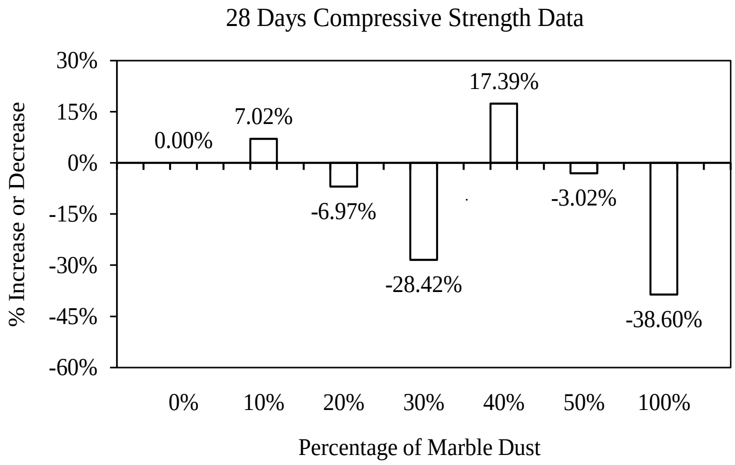

Figure 7 : Percentage Increase or Decrease in 28 days compressive strength

The experimental data and graphs given in Figure 4 to Figure 7 clearly illustrate that the marble dust incorporation along with natural sand has almost same type of influence on the 7 days and 28 days compressive strength of concrete. Marble powder with a ratio of 10:90 and 40:60 are proved to be effective in increasing the crushing strength of concrete. Though the effect of 40% marble dust (with 60% sand of total required fine aggregate) is noteworthy (17.39%). The other ratios decrease the strength remarkably. Again the effect of total removal of natural sand and the use of marble dust as the only fine aggregate proves to be catastrophic. This can also be observed from the gradation curve of the two samples. The sand sample was well graded as it should be but that for marble dust shows very irregular shape. This type of sample is not good for concrete production and our experimental data also justifies the same.

The increase in strength can also be explained considering the large amount of finer particles which eventually fill up the voids in between the sand particles and again as most of its constituent element is $CaCO_3$ it could have provided some adhesive property to the concrete as well.

4. CONCLUSIONS

This experimental investigation finally let us conclude the followings:

- The waste marble dust can be used in conventional concrete as a partial replacement of sand.
- Compared to the conventional concrete used in mass construction with a ratio of 1:1.5:3 (the compressive strength of which is found to be 21.22 MPa), the strengths with 10% and 40% of marble dust is quite impressive (22.71 MPa and 24.91 MPa respectively after 28 days).
- The incorporation of marble dust by 20%, 30%, 50% and 100% decreases the strength so they are not recommended for substitution sand in concrete.
- For 10% marble dust content, the increase in strength was 8.20% and 7.02% after 7 days and 28 days of curing respectively.
- The increase in strength is remarkable for 40% marble wastes which are 39.77% and 17.39% after 7 days and 28 days respectively.
- The use of marble dust as a partial replacement of sand in concrete is, therefore, proves to be effective and it will be able to serve as a mean of reducing the amount of disposed marble wastes and will eventually solve some of the environmental issues. So this research work recommends the use of waste marble powder in concrete.
- However, it is recommended that the other properties of concrete such as tensile strength, shear strength, flexural behaviour, workability, etc. can also be studied for a profound analysis.

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REFERENCES

Ahmed, S. E. (2020). “Improvement of subgrade soil by using marble dust-(Libya, Case Study)”, *The International Journal of Engineering and Information Technology*, Vol.6, No.2.

Andre, A., Brito, J.D., Rosa, A., & Pedro, D. (2014). “Durability performance of concrete incorporating coarse aggregates from marble industry waste”, *Journal of Cleaner Production*, 65 (2014) 389-396

Arivalagan, S. (2013). “Experimental study on the flexural behavior of reinforced concrete beams as replacement of copper slag as fine aggregate”, *Journal of Civil Engineering and Urbanism*, 2013, Vol. 3, 176-182.

Hassan, A.M.A., Hussein, M.M.A., & Ye, H. (2021). “Influence of waste marble dust on the improvement of expansive clay soils”, *Advances in Civil Engineering*, Vol. 2021, Article ID 3192122.

Khan, M.M., Khan, A., Zaki, S.A., Abbas, A., & Khan, M.A. (2018). “Study of compressive strength of concrete by partial replacement of cement with marble dust powder”, *International Journal of Recent Scientific Research*, Vol. 9, Issue, 4(J), pp. 26196-26201.

Kore, S.D., & Vyas, A.K. (2016). “Impact of marble waste as coarse aggregate on properties of lean concrete”, *Case Study of Construction Materials* 4 (2016) 85-92

Memon, M.U., Memon, B.A., Oad, M., Chandio, F.A., & Ahmed, S. (2020). “Effect of marble dust on compressive strength of recycled aggregate concrete”, *Quest Research Journal*, Vol. 18, No.1, PP.11-18.

Nataraja, M.C., Kumar, P.G.D., Manu, A.S., & Sanjay, M.C. (2013). “Use of granulated blast furnace slag as fine aggregate in cement mortar”, Int. J. Struct. & Civil Engg. Res., 2013, Vol. 2, 60-68.

Prajapati, V.D., Joshi, N., & Pitroda, J. (2013). “Techno- economical study of rigid pavement by using the used foundry sand”, *International Journal of Engineering Trends and Technology (IJETT)*, 2013, Vol. 4, 1620-28.

Sudarvizhi, M., & Ilangovan, S. (2011). "Performance of copper slag and ferrous slag as partial replacement of sand in concrete", *International Journal of Civil & Structural Engineering,* 2011, Vol. 1, 918-27.

Sukesh, C., Krishna, K.B., Teja, P.S.L.K., & Rao, S.K. (2013). "Partial replacement of sand with quarry dust in concrete", *International Journal of Innovative Technology and Exploring Engineering (IJITEE),* 2013, Vol. 2, 254-58.

Sawant, R.P., Pathak, S., & Mane, S. (2019). "Partial replacement of cement with combination of alccofine and marble dust for development of sustainable concrete", *International Journal of Recent Technology and Engineering*, ISSN: 2277-3878, Vol.8, Issue.4.