ISSN No:-2456-2165

Influence of Stone Dust on Compressive Strength and Embodied Energy of Mortar

Fariyaz S. Bagwan*[1]
[1]M.Tech Student, (Civil Environmental Engg),
Dept. of Civil Engineering,
Walchand College of Engineering, Sangli
Maharashtra, India. 416415

Dr.K.S.Gumaste*2
[2]Associate Professor,
Dept. of Civil Engineering,
Walchand College of Engineering, Sangli
Maharashtra, India. 416415

Abstract:- In present construction industry sand is a common building material used as a fine aggregate. The availability of natural sand is being exhausted due to rapid growth in construction activities. Also good quality sand may have to be transported from long distances adds to the cost of construction and energy consumption. Hence it becomes inevitable to use alternative materials for fine aggregate. Nowadays large quantity of stone dust is produced as a by-product of crushing activities in the stone crusher units. Also, stone dust produced from such crushing zones appears as a problem for effective disposal. It has limited application in construction activities and a large amount of it is being dumped into low-lying areas. In this study, the main concern is to utilize the stone dust as a constituent for a mortar mix and to carry out embodied energy measurements. For this purpose, different mortar mixes are produced by replacing natural and manufactured sand with stone dust content. Stone dust passing by 150 microns is used for sand replacement. Mortar specimens are cast and investigated for compressive strength. To determine embodied energy of mortar energy measurement studies are carried out in a stone crusher unit located at Jaysingpur, Maharashtra. The energy required for the production and transportation of manufactured sand and stone dust is calculated. This paper reports the experimental study which investigated the influence of the replacement of sand with stone dust and thereby its effect on compressive strength and embodied energy. For this purpose cement mortar cube was studied with various proportions of stone dust as 0%, 5%, 10%, 15%, 20% and 25% by weight of sand. A comparison of energy in different types of mortar mix has been made. The experimental results showed that the replacement of stone dust for sand was found to enhance the compressive properties of mortar specimen. Use of stone dust with manufactured sand for mortar preparation can led to 8-10% energy savings. It has been Moreover the substitution of sand by stone dust will serve the solid waste minimization and waste recovery and beneficiating the environment.

Keywords:- *Stone Dust, Waste Recovery, Embodied Energy, Cement Mortar, Manufactured Sand, Natural Sand.*

I. INTRODUCTION

Mortar is a masonry product which is a matrix of concrete. It consists of a binder and fine aggregate and moreover an essential association of any structural element. Conventionally cement mortar can be made by mixing cement, fine aggregate and water and it is a composite material. The strength of mortar mix is a special concern to engineers because the mortar is responsible to give protection in the outer part of a structure as well as the brick joints in a masonry wall system.

Due to increased construction activities, the consumption of natural sand is very high. Now India is facing a shortage in good quality sand to satisfy the sudden structural growth. Therefore it is unavoidable to use easily available and less expensive alternative materials to sand. This alternative material of sand should be explored to mitigate increasing demand of sand. Due to rapid growth in construction activities use of sand for mortar preparation is also increased drastically so the sand mining. As the excessive removal of sand from river causes ecological imbalance the authorities have banned sand mining. This has led to a shortage and cost increment for natural sand. Hence use of manufactured sand becomes inevitable in any construction work. But this manufactured sand consists of considerable amount of dust content which is produced as a by-product at time of stone crushing and is not separated from sand prior to use in construction activities. Hence it becomes part of mortar mix prepared on site. The stone dust so produced is generally treated as a waste in a locality. It is not given any interest and disposed of in out engineered way. While landfills are commonly used for disposal of dust, rapid urbanization has made it increasingly difficult to find suitable landfill site. Indian construction industry is one of the largest in terms of employing manpower and volume of materials produced (cement, brick, steel and other materials).The construction sector in India is responsible for major input of energy.[3] Selection of materials and technologies for the building construction should satisfy the felt needs of the user as well as the development needs of the society, without causing any adverse impact on environment.[6] The materials used in building construction should minimize the energy uses without compromising strength of it. Embodied energy of any material consists of energy required for the production and transportation of the same. Embodied energy of different material required for series of mortar mix is discussed in this paper.

ISSN No:-2456-2165

The present study aimed to determine the acceptability of stone dust as a one of the constituent in cement mortar without compromising strength and durability aspect of mortar mix. In this research different combination of mortar mix were tested to investigate the exact percentage of stone dust which ensures the inclusion of optimum amount of stone dust in a mortar mix. This study ensures the stone powder as a building material as an alternative of sand in mortar mix. Studies on embodied energy reveals that embodied energy of mortar prepared with manufactured sand and stone dust is less as compared to that of prepared with natural sand and stone dust. Use of alternative building materials , methods and technologies can be the low cost alternative.

II. MATERIALS AND METHODS

- *Mortar Mix used on Various Sites :*

To find out the mix ratio of mortar used on site different sites were visited. The method used for making mortar mix is carefully the observed to determine their approximate proportion of mix and water cement(w/c) ratio. Flow table test on each mortar mix is performed to find out the workability of mortar mix prepared on site. The specimen were cast by using mortar prepared on site. Total six sites were visited and 15 samples were casted on each site. For this purpose moulds of size 70.7 mm x 70.7 mm x 70.7 mm were used which gives cross sectional area of 5000 mm2.Compressive strength of mortar are obtained after 7 day, 14 day, 28 day curing period. The mortar blocks were made by standard method with proper curing and tempering. The blocks are then tested by compression testing machine. The obtained results are analysed and used for further investigation which incorporated dust as a partial replacement material for both natural sand and manufactured sand.

- *Sieve Analysis for Manufactured Sand (M Sand) Samples :*

In order to establish the stone dust produced during crushing as a constituent in a mortar mix various laboratory tests are carried out. Initially manufactured sand from different locations which is being used on site in construction works is collected and analysed. From analysis their grading zone, fineness modulus and dust content is obtained. For sieve analysis of each sample 200 gm of sand passing through 4.25 mm IS sieve is used.

- *Mortar Mix Prepared in the Laboratory:*

To establish the stone dust as a constituent in mortar, the cement mortar was prepared by adding cement, water and by replacing sand by stone dust at different levels of replacements as 0%,5%,10%,20%,25%. The type of sand used for mortar mix was so selected that it satisfy the Zone I pattern as well as type required as per the BIS for masonry mortar (IS 2386 Part 1:1963).The mortar blocks were made by standard method with proper curing and tempering. 9 samples were casted for each mix. For this purpose moulds of size 70.7 mm x 70.7 mm x 70.7 mm were used which gives cross sectional area of 5000 mm^2.Water to mortar mix was added till it gives required flow percent of 115 to 120%. This water content is recorded to evaluate w/c ratio of respective mixes. Compressive strength of mortar are obtained after 7 day, 14 day, 28 day curing period by using compression testing machine.

- *Energy Consumption Measurement at Stone Crusher :*

Embodied energy can be split into: (1) energy consumed in the production of basic building materials, (2) energy needed for transportation of the building materials. Minimizing the consumption of the conventional materials by using alternative materials, methods and techniques can result in scope for considerable energy savings as well as reduction of CO2 emission. The embodied energy required in production and transportation of building materials that are used for mortar preparation is discussed here.

The energy consumption measurement was carried out in the stone crusher plant located at 15 km to South West of Sangli city of Maharashtra. The electrical energy measurements of its various sub-sections and utilities such as jaw crusher, impactor crusher,vibratory screens, pumps, conveyors, fans etc was carried out. The plant mainly relies on its 175KW MSEB power supply to meet its electricity requirements. Power Analyzer tool was used for measurement of electrical power across various motors of the stone crusher plant. Electrical power required for office room of the plant was also considered. Total electrical power was calculated by adding power across all motors and that required for office room.

From this result energy required for the production of unit m3 of sand and stone dust is determined. The proportion of material required to produce mortar mix are calculated. Transportation distance of various materials used on site is also taken into account to find out the thermal energy incorporated for transportation. A comparison of embodied energy for both types of mortar mix is also discussed.

ISSN No:-2456-2165

III. RESULTS AND DISCUSSIONS

➢ *Mortar Mix Prepared on Site :*

Table 1 Mix Details for Mortar

Site No	Mix Ratio	W/C Ratio	Davg(Cm)	Flow%
1	1:6	0.8	22.00	120
2	1:6.25	1	22.35	123.5
3	1:4.6	1.14	23.50	135
4	1:3.75	0.75	21.83	118.25
5	1:2.22	0.55	22.98	129.75
6	1:4	0.85	21.23	112.25

- Here flow% =(Davg -D0)/D0 *100
- Davg = average diameter of mortar mass after 25 strokes
- D0 = Original base diameter of mortar mass =10 cm

This flow is the resulting increase in average base diameter of the mortar mass measured on 4 diameter approximately in equal spaced intervals expressed as % off original diameter. It should be in the range of 115 to 120 %. (IS 1542:1992 Sand for plaster, clause 4.4.1 **)**From the above studies it was evident that for 50% of the time the flow was more than the limit given in IS code.

➢ *Compressive Strength*

Here compressive strength is obtained by taking average of 5 samples for each mix calculated at 7th,14th 21st and 28th day of curing.

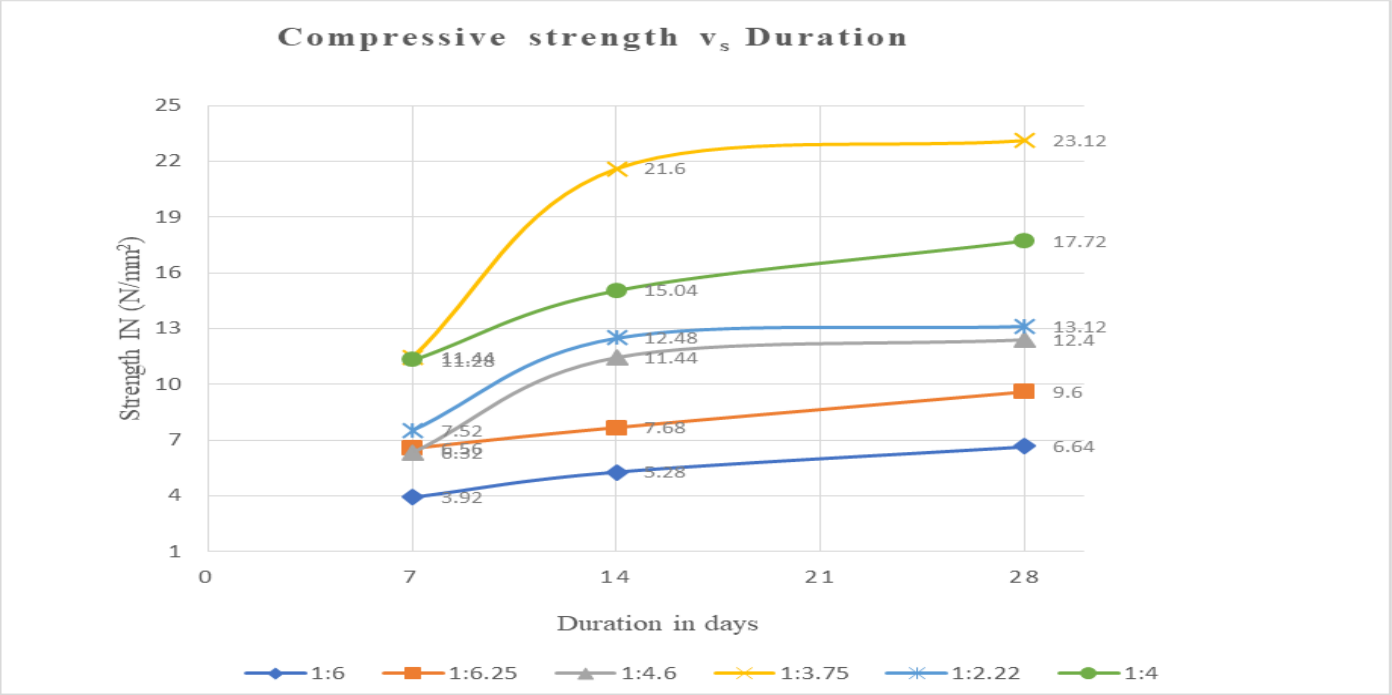

Fig 1 Compressive Strength of Mortar Specimen Cast on Site

The result showed that irrespective of type of cement, w/c ratio and type of sand the minimum compressive strength was obtained by mortar with mix ratio of 1:6. So this ratio is used as a parent ratio for mortar mix prepared by using stone dust as a one of the constituent in the mix. From fig.1 it is found that lowest compressive strength is obtained by mortar mix with proportion of 1:6.The 7 days, 14 days and 28 days compressive strength for this mix is3.92 N/mm^2 , 5.28 N/mm^2 & 6.64 N/mm^2 respectively. So this mix ratio is kept as a parent ratio for further studies.

➢ *Particle Size Distribution for Manufactured Sand Samples*

From sieve analysis of sand samples it was observed that the dust content of manufactured sand is varying from minimum of 8.5% to maximum 22 % by weight. Most of the time sand is following the zone I pattern. This information in used to cast new mortar specimens in the laboratory.

ISSN No:-2456-2165

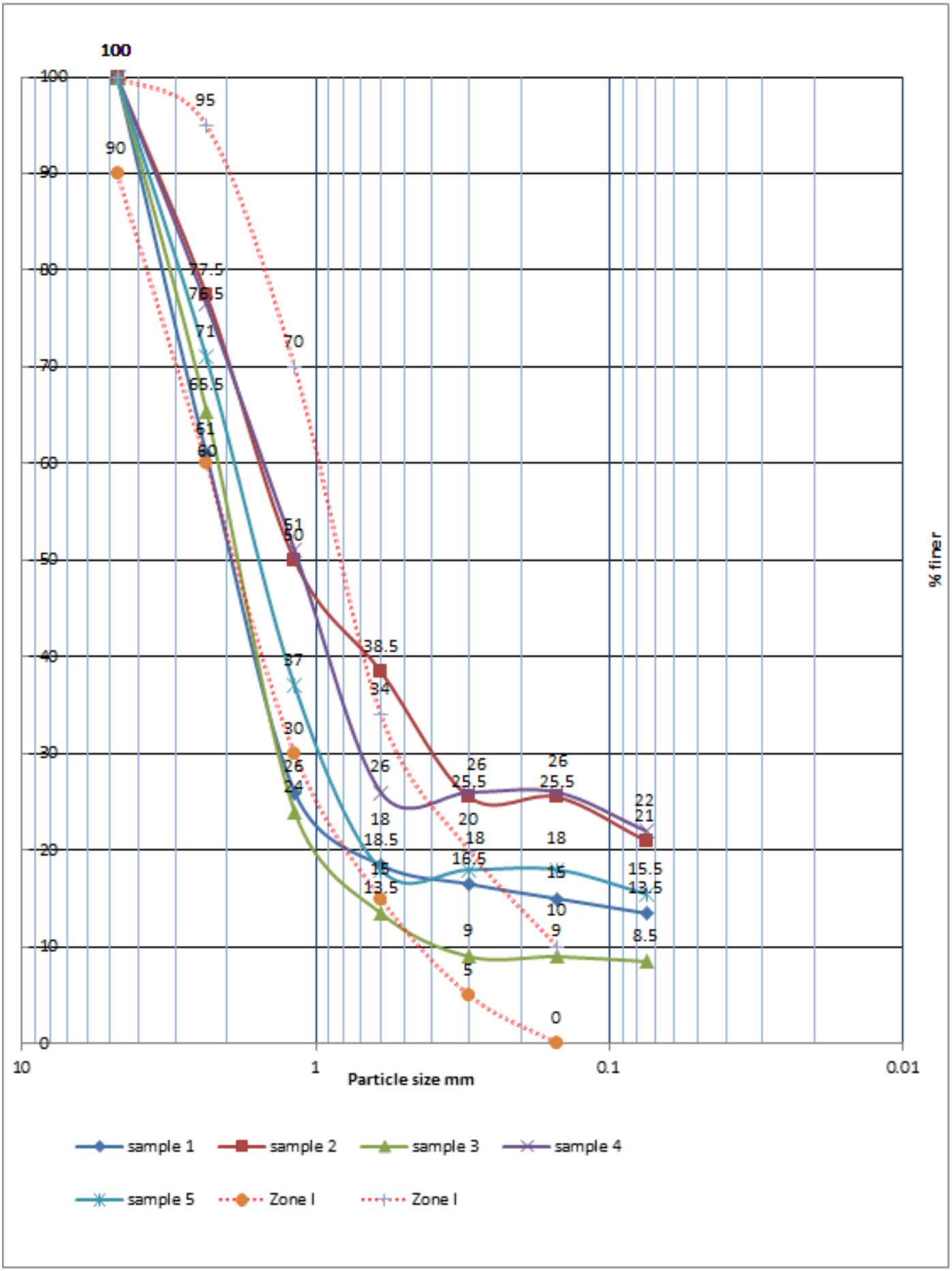

Fig 2 Particle Size Distribution for Manufactured Sand Samples

➢ *Details of Mortar Specimen Prepared in Laboratory:*

Table 2 Selected Gradation of Sand

IS Sieve Size(Mm)	Designed % Passing	% Passing for Zone I	% Passing as per BIS for Masonry Mortar(IS 2386 Part1: 1963)
2.36	**95**	60-95	90-100
1.18	**70**	30-70	70-100
0.6	**35**	15-34	40-100
0.3	**20**	5-20	5-70
0.15	**5**	0-10	0-15

Table 3 Details of Mortar Mix Prepared in the Laboratory

Mix no	% Stone dust added	W/C Ratio		Flow%	
		Natural sand	M sand	Natural sand	M sand
1	0	0.97	1.26	118	119
2	5	0.92	1.24	115	117
3	10	0.95	1.21	117	116
4	20	1	1.18	120	115
5	25	1.06	1.24	120	118

Table 4 Compressive Strength of Mortar Specimen Cast using Natural Sand

Mix No	Compressive Strength (N/mm^2)		
	7 day	14 day	28 day
1	6.8	11.2	15.2
	4.8	10.8	15.2
	6	10.8	16
(Average)	5.87	10.93	15.47
2	5.6	12.4	16.4
	6.4	14	16
	6.8	10	14.4
(Average)	6.27	12.13	15.60
3	12.8	16	22.4
	12	19.2	23.6
	12.4	16.8	24
(Average)	12.40	17.33	23.33
4	6	8	14.8
	6.4	7.6	14
	5.6	8.8	17.2
(Average)	6.00	8.13	15.33
5	10	11.6	16.8
	10	11.6	16.4
	9.6	10.4	15.6
(Average)	9.87	11.20	16.27

Table 5 Compressive Strength of Mortar Specimen Cast using M Sand

Mix No	Compressive Strength (N/mm^2)		
	7 day	14 day	28 day
1	4	8	11.6
	4	8.8	11.6
	4.8	8.8	12.4
(Average)	4.27	8.53	11.87
	5.6	9.6	13.6
	5.2	10.4	10.8
	5.2	10	10.8
(Average)	5.33	10.00	11.73
	9.6	11.2	12.4
	9.6	11.6	14.4
	8.8	11.6	14
(Average)	9.33	11.47	13.60

	10	11.6	12.4
	10	9.6	10.8
	9.6	11.6	10.8
(Average)	9.87	10.93	11.33
	9.6	11.2	13.2
	10.8	11.2	12.8
	11.6	12.4	13.6
(Average)	10.67	11.60	13.20

- **Note:** IS – 2250:1981 Code of practice for preparation and use of Masonry Mortar. For Grade 3 mortar (1 part cement : 6 part sand) 28 days compressive strength should be 3 to 5 N/mm^2.

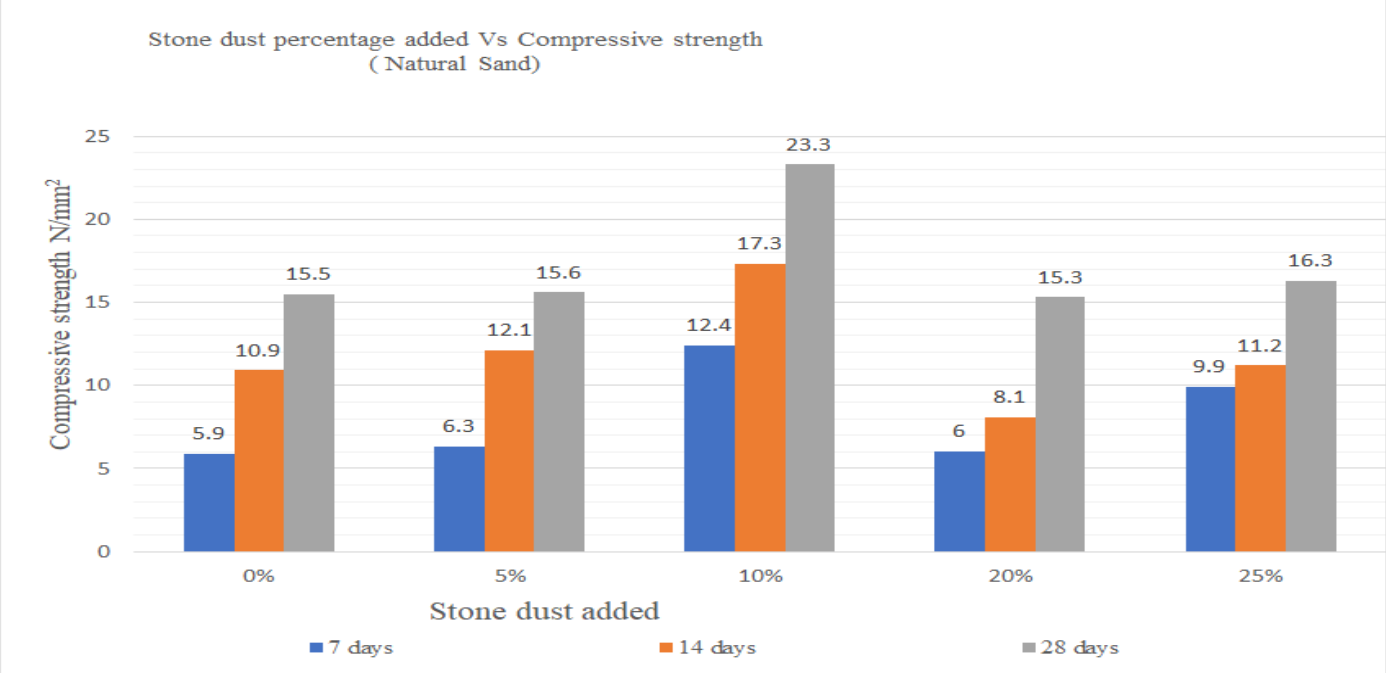

Fig 3 Stone Dust Percentage Added vs Compressive Strength for Natural Sand

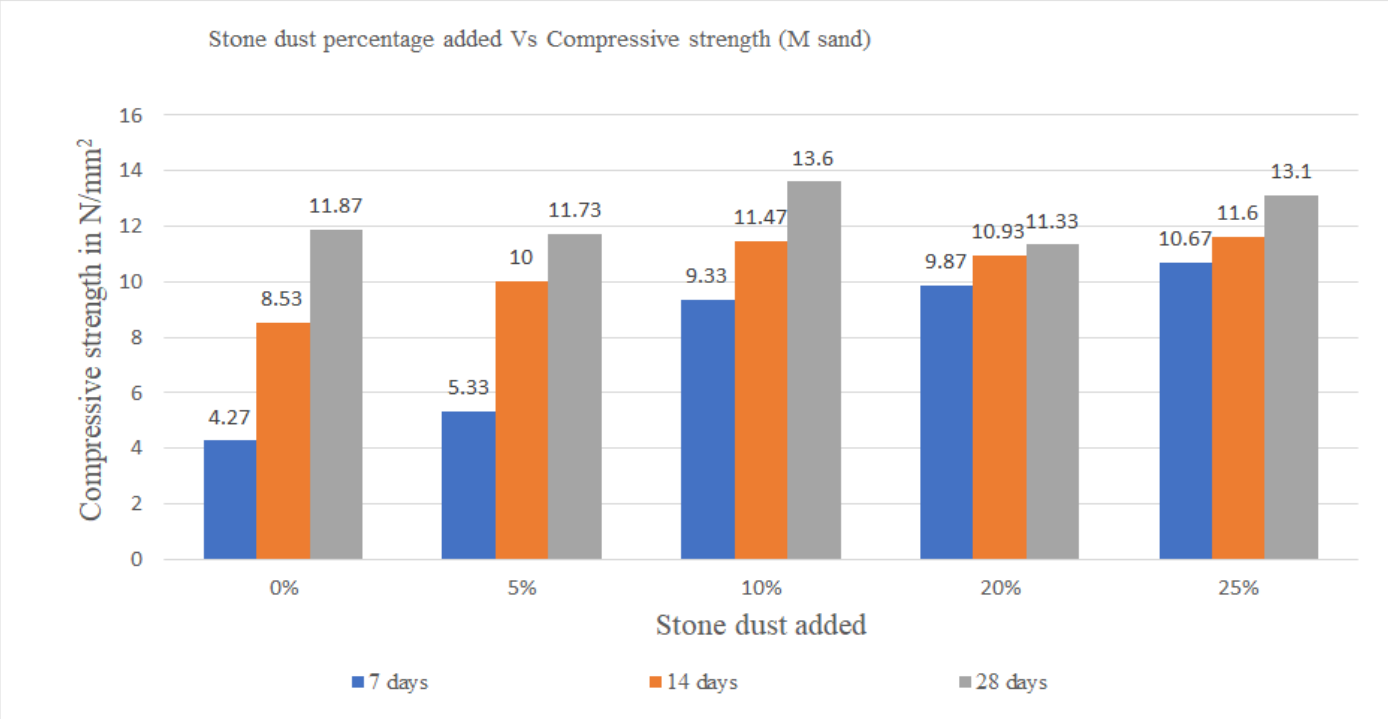

Fig 4 Stone Dust Percentage Added Vs Compressive Strength For M Sand

This study shows that the compressive strength of mortar made by natural sand and manufactured sand both gives impressive results than that of mortar specimen made without using stone dust. The fig shows that the compressive strength of mortar specimen made by using natural sand with no dust content gives 5.9 N/mm^2 for 7 days, 10.9 N/mm^2 for14 days and 15.5 N/mm^2 for 28 days.

As compared to the compressive strength of mortar specimen without dust content the compressive strength of mortar specimen using natural sand with 5% dust content is increased by 6.77% (6.3 N/mm^2 from 5.9 N/mm^2) & 11% (12.1 N/mm^2 from 10.9 N/mm^2) for 7 days and 14 days without having much change in 28 days strength i.e. 15.6 N/mm^2 .The highest compressive strength is obtained by specimens with 10% dust content. The 28 days compressive strength is increased by 50.32% with respect to strength obtained by the mortar specimen with no dust content. (23.3 N/mm^2 from 15.5 N/mm^2) .the 7 days and 14 days compressive strength for this sample is 12.4 N/mm^2 and 17.3 N/mm^2 respectively.

For mortar specimen with 20% dust content the strength is decreased than the strength obtained by adding 10% dust content. It follows the same strength pattern that of the specimen casted without dust content. The 28 days and 7 days compressive strength are 15.3 N/mm^2 and 6 N/mm^2 respectively. But in case of 14 days it is decreased from 10.9 N/mm^2 to 8.1 N/mm^2.For mortar specimens with 25% dust content the 28 days strength is increased only by 5% than that of the specimens casted without dust content (16.3 N/mm^2 from 15.5 N/mm^2). The 7 days and 14 days strength are 9.9 N/mm^2 and 11.2 N/mm^2 respectively.

From fig it is shown that the overall compressive strength obtained by mortar specimen casted using manufactured sand are lower than the strength obtained by using natural sand. The fig shows that the compressive strength of mortar specimen made by using manufactured sand with no dust content gives 4.27 N/mm^2 for 7 days, 8.53 N/mm^2 for14 days and 11.87 N/mm^2 for 28 days.

As compared to the compressive strength of mortar specimen using manufactured sand and no dust content the compressive strength of mortar specimen using manufactured sand with 5% dust content is increased by 24.82% (5.33 N/mm^2 from 4.27 N/mm^2) & 17.23% (10 N/mm^2 from 8.53 N/mm^2) for 7 days and 14 days without having much change in 28 days strength i.e. 11.87 N/mm^2

For specimen casted using manufactured sand the highest compressive strength is obtained by using 10% dust content. The 28 days compressive strength is increased by 14.57% with respect to strength obtained by the mortar specimen with no dust content. (13.6 N/mm^2 from 11.87 N/mm^2). The 7 days and 14 days compressive strength for this mix is 9.33 N/mm^2 and 11.47 N/mm^2 respectively. For mortar specimen casted using Manufactured sand and 20% dust content the compressive strength for 28 days is decreased than that of the mortar specimen casted using manufactured sand without using dust content. (11.33 N/mm^2 from 11.87 N/mm^2). But for 7 days and 14 days the compressive strength is increased (i.e. 9.87 N/mm^2 from 4.27 N/mm^2 and 10.93 N/mm^2 from 8.53 N/mm^2 respectively).

For mortar specimens casted with manufactured sand and 25% dust content the 28 days strength is increased only by 13.58% than that of the specimens casted without dust content (13.2 N/mm^2 from 11.87 N/mm^2). The 7 days and 14 days strength are 10.67N/mm^2 and 11.6 N/mm^2 respectively.

- *Energy Consumption for Production of Materials :*

Electrical energy is being utilized in all the sections of plant. The section wise power consumption per hour is presented in table given below.

Table 6 Electrical Power Utilized by Different Component of SCU

Motor	No of motors	Specific Power(Kw)
VSI Crusher	1	18.94
Jaw Crusher	1	7.687
Conveyor	2	1.532
		0.559
Vibrator	3	0.789
		0.952
		1.054
Conveyor	2	1.237
		1.275
Sand machine	5	0.538
		0.479
		0.841
		0.617
		0.325
Return conveyor	1	0.538
Feder	2	0.491
		0.586
Total Power (Kw)		36.339

ISSN No:-2456-2165

In studied SCU initial feed of boulders to primary jaw crusher yields 70% , 20% and 10% of aggregate, Manufactured sand and dust respectively within 20 minutes of crusher run. Initial feed of (2 brass) i.e. 5.66 m^3 boulder yields 3.962,1.132,0.556 m^3 aggregate, Manufactured sand and dust respectively. From energy consumption measurement it is found that the studied SCU utilizes 36.339 Kw of specific power in an hour.

Hence energy consumed in 20 min. $= \frac{36.339*20}{60}$ Kwh = 12.11 Kwh

Energy required per m^3 production of building material = $\frac{energy\ consumption}{volume\ of\ material\ produced}$

Table 7 Energy Required for Production of Building Material

Type of Material	Energy required for production	
	Kwh/ m^3	MJ/m^3
Aggregate	3.05	11
Manufactured Sand	10.69	38.84
Stone Dust	21.39	77

In India, cement is manufactured by employing both the wet (old cement plants) and dry (new plants) process. Wet process used in earlier cement plants leads to an energy consumption of 7.5 MJ/kg of cement, whereas modern plants employing pre calcination and dry process consume 4.2 MJ/kg of cement. The value of 5.85 MJ/kg of cement represents the average value of 7.5 and 4.2 MJ. The average value of 5.85 MJ/kg of cement has been used in the computation of energy in various mix of mortar. Also from literature reviewed it is found that cement transportation consumes 1MJ of energy per tonnes per km. generally cement is required to transport within 8 to 10 km of distance.

Natural sand does not require any energy for production but it consumes 87.5 MJ/m^3 energy per 50 km transportation. In Sangli city good quality sand required to transport from Ghodeshwar (Solapur district, Maharashtra) located at 150 km NE to Sangli. So it requires 262.5 MJ energy for sand transportation.

In sangli manufactured sand and stone dust is available from 25 km distance.

AS per the Fuel consumption standards of heavy duty vehicle in India : For N3 tractor trailer (GVW more than 12 tons with 60 kmph speed) for 12 axle transport vehicle with diesel powered engine mileage is 3.13 to 2.67 kmpl. So consider average mileage as 2.9 kmpl.

Fuel required for 25 km transportation of stone dust and manufactured sand will be 8.62 litres. From this energy consumption can be calculated by using density and calorific value of the fuel.

Table 8 Energy Consumption for 25 Km Transportation

Total fuel used (High Sulphur Diesel)	8.62 lit
Density of fuel	0.832 Kg/lit
Calorific value	42MJ/kg
Energy consumption	301.21 MJ

- *Proportion of Materials for Mortar Preparation*

For unit m^3 mortar with 1:6 proportion we require 0.19 m^3 cement and 1.14 m^3 sand. Considering density of cement as 1600 kg/m^3 it will require 304 kg cement. So energy required for transportation of cement will be 0.304 MJ for 10 km. Following table represents the proportion of material required for unit m^3 volume of mortar.

Table 9 Proportion of Building Materials for Mortar

Mix No	Cement (Kg)	Sand (m^3)	Stone Dust (m^3)
1	304	1.14	0
2	304	1.083	0.057
3	304	1.026	0.114
4	304	0.912	0.228
5	304	0.855	0.285

- *Energy in Mortar:*

Total embodied energy of mortar is obtained by adding energy required for production and transportation of Cement , sand and stone dust.

ISSN No:-2456-2165

Table 10Embodied energy of mortar

Mix No	Embodied Energy in MJ		Energy savings %
	Natural sand	Manufactured sand	
1	2077.954	2124.184	-2.22
2	2368.583	2126.363	10.23
3	2358.014	2128.532	9.73
4	2336.864	2132.890	8.73
5	2321.904	2135.064	8.05

Above table represents the comparison of embodied energy for mortar using natural sand and manufactured sand.

From above result it can be seen that mortar made with natural sand without using stone dust has least embodied energy. But after addition of stone dust the mortar made with natural sand requires more embodied energy than that of made with manufactured sand. Here mix no 3 has given highest compressive strength for both types of sand. For this mix 9.73% of energy savings can be obtained by using mortar made with manufactured sand and stone dust.

IV. CONCLUSION

The controlled grading of sand with the use of stone dust as a constituent in mortar mix has shown impressive results for both natural sand as well as manufactured sand.

The compressive strength with 10% replacement of sand by stone dust reveals highest strength as compared to parent mix in 1:6 ratio for both types of sand.

The compressive strength with 20% replacement of sand by stone dust has also shown 28 days compressive strength nearly same as that of without dust content for both types of sand.

However the compressive strength has again increased for 25% dust content for both types of sand than that of parent mix with no dust content.

All the mix combinations have shown more strength than that of required as per BIS for masonry mortar. So we can also say that if the cost optimisation is required we can also opt for higher dust content without causing any compromise on strength.

Instead of treating stone dust as a waste material, market value should be created to use it as a construction material and thereby helping waste recovery and waste minimization.

Studies on Embodied energy shows that Embodied energy of Mortar made with M sand and stone dust is less than the mortar made with natural sand and stone dust. The Embodied energy for mortar made with natural sand increases with increasing stone dust content whereas for mortar made with M sand the embodied energy decreases with increasing stone dust content.

8 to 10 percent embodied energy savings can be obtained by preferring mortar made with M sand and stone dust over mortar made with natural sand and dust content.

REFERENCES

[1]. Ahsan H., Md. Abdus Salam, Begum R., (2015), " Effect of stone dust on mechanical properties of adobe brick" *International Journal of Innovative Science, Engineering & Technology*",(2), 631-636.

[2]. IS 2250 (1981): Code of Practice for Preparation and Use of Masonry Mortars

[3]. Moray S., Throop N., Seryak J., Schmidt C., Fisher C., D'Antonio M.,(2005) "Energy Efficiency Opportunities in the Stone and Asphalt Industry" *ACEEE Summer Study on Energy Efficiency in Industry*, (3) ,71-83

[4]. Rajput S.P.S, Chauhan M.S.,(2014), "Suitability of crushed stone dust as fine aggregate in mortar" *International journal of emerging technologies and advanced engineering*,(4), 87-89

[5]. Ram Rathan Lal B., Marjive Vaishali., (2016) "An Experimental Study on Stone Dust and EPS Beads Based Material" *Geo-Chicago 2016 GSP 272, ASCE*,33-41

[6]. Venketarama Reddy B.V., Jagdish K.S.,(2003), "Embodied energy of common and alternative building materials and technologies."

[7]. *Energy and Buildings,WWW.elsevier.com/ locate/ enbuild*, (35), 129-137