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STUDY THE EFFECT OF PARTIAL REPLACEMENT OF NATURAL SAND WITH ROBO SAND

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Abstract- Nowadays the construction industry in the India is facing one of the major problem that is natural fine aggregate. And court awarded total ban on excavation of fine aggregate from river because that will affect environment and change the river direction. Cement, sand and aggregate are basic needs for any construction industry. Sand is a prime material used for preparation of mortar and concrete and which plays a major role in mix design. Now a day's erosion of rivers and considering environmental issues, there is a scarcity of river sand. The non-availability or shortage of river sand will affect the construction industry; hence there is a need to find the new alternative material to replace the river sand, such that excess river erosion and harm to environment is prevented. Many researchers are finding different materials to replace sand and one of the major materials is quarry stone dust (Artificial/Robo/M -SAND). Using different proportion of this robo sand along with sand the required concrete mix can be obtained. Replacement of natural fine aggregate is done with artificial fine aggregate by 20%, 40% 60% and also the compressive Strength of that concrete cube is found. This paper presents a review of the different alternatives to natural sand in preparation of concrete and the physical and mechanical properties and strength aspect on concrete.

Keywords: Artificial/Robo/M –SAND, Natural sand, cement, concrete, course aggregate, Physical Properties, Mechanical Properties, Curing, strength.

I. Introduction

Cement, sand and aggregate are essential needs for any construction industry. Sand is a major material used for preparation of mortar and concrete and plays a most important role in mix design. In general consumption of natural sand is high, due to the large use of concrete and mortar. Hence the demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. The developing country like India facing shortage of good quality natural sand and particularly in India, natural sand deposits are being used up and causing serious threat to environment as well as the society. Rapid extraction of sand from river bed causing so many problems like losing water retaining soil strata, deepening of the river beds and causing bank slides, loss of vegetation on the bank of rivers, disturbs the aquatic life as well as disturbs agriculture due to lowering the water table in the well etc are some of the examples. The heavy-exploitation of river sand for construction purposes in Sri Lanka has led to various harmful problems.

Options for various river sand alternatives, such as offshore sand, quarry dust and filtered sand, Physical as well as chemical properties of fine aggregate affect the durability, workability and also strength of concrete, so fine aggregate is a most important constituent of concrete and cement mortar. Generally river sand or pit sand is used as fine aggregate in mortar and concrete. Together fine and coarse aggregate make about 75-80 % of total volume of concrete and hence it is very important to fine suitable type and good quality aggregate nearby site Recently natural sand is becoming a very costly material because of its demand in the construction industry due to this condition research began for cheap and easily available alternative material to natural sand. Some alternatives materials have already been used as a replacement of natural sand such as fly-ash, quarry dust or limestone and siliceous stone powder, filtered sand, copper slag are used in concrete and mortar mixtures as a partial or full replacement of natural sand Even though offshore sand is actually used in many countries such as the UK, Sri Lanka, Continental Europe, But in India and Singapore most of the records regarding use of this alternative found mainly as a lesser extent of practice in the construction field.

Due to shortage of river sand as well as its high the Madras High Court restrictions on sand mining in rivers Cauvery and Tamirabharani And Andhra Pradesh government has restricted mining of natural sand in river Godavari, The government of Telangana stopped using natural sand government constructions the statement had given by government of Telangana cabinet for using ROBO SAND /M-SAND and started a awareness program among people for use of artificial sand in place of natural sand (T. Harish Rao Minister for Irrigation, Marketing & Legislative Affairs). The facts like in India is almost same in others countries also. So therefore he need to find an alternative concrete and mortar aggregate material to river sand in construction works has assumed greater importance now a days. Researcher and Engineers have come out with their own ideas to decrease or fully replace the use of river sand and use recent innovations such as M-Sand (manufactured sand), robot silica or sand, stone crusher dust, filtered sand, treated and sieved silt removed from reservoirs as well as dams besides sand from other

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water bodies. On the other hand, lack in required quality is the major limitation in some of the above materials. Now a day's sustainable infrastructural growth requires the alternative material that should satisfy technical requisites of fine aggregate as well as it should be available locally with large amount.

Today Indian Standards are copiously used for ensuring quality of construction of buildings and other structures, which are now-a-days largely dependent on concrete constructions. Bureau of Indian Standards, the National Standards Body of the country, considering the scarcity of sand and coarse aggregates from natural sources, has evolved number of alternatives which are ultimately aimed at conservation of natural resources apart from promoting use of various waste materials without compromising in quality. These measures include permitting in the Concrete Code (IS 456) as also in the National Building Code of India, the use of slag - a waste from steel industry, fly ash - a waste from thermal power plants, crushed over-burnt bricks and tiles - waste from clay brick and tile industry, in plain cement concrete as an alternative to sand/natural aggregate, subject to fulfilling the requirements of the Code. This Code, further, encourages use of fly ash and ground granulated blast furnace slag as part replacement of ordinary Portland cement in plain as well as reinforced cement concrete. This part replacement could be of the order of 35% and 70% for fly ash and slag respectively thereby affording a large scale saving of natural limestone reserves which would have otherwise depleted in case of the use of ordinary Portland cement without such replacement. Not only this, the Code highlights how durability of concrete can be improved with the use of these supplementary cementations materials. The Indian Standard on concrete mix design (IS 10262) has been upgraded to include guidance and examples of designing concrete mixes using fly ash and slag. Provisions for compliance for requisite quality of concrete made using fly ash and slag have been duly covered for the manufacturers of ready-mixed concrete in the Indian Standard Code of practice for RMC (IS 4926).

II. Different Alternative Materials to River Sand

The world is resting over a landfill of waste hazardous materials which may substitutes for natural sand. Irrespective of position, location, scale, type of any structure, concrete is the base for the construction activity. In fact, concrete is the second largest consumable material after water, with nearly three tones used annually for each person on the earth. India consumes an estimated 450 million cubic meter of concrete annually and which approximately comes to 1 tons per Indian. We still have a long way to go by global consumption levels but do we have enough sand to make concrete and mortar? Value of construction industry grew at staggering rate of 15 % annually even in the economic slowdown and has contributed to 7-8 % of the country's GDP (at current prices) for the past eight years. Thus, it is becoming increasingly discomforting for people like common people who talk about greening the industry to have no practical answer to this very critical question. In fact we have been sitting over a landfill of possible substitutes for sand. Industrial waste and by-products from almost all industry, which have been raising hazardous problems both for the environment, agricultural and human health can have major use in construction activity which may be useful for not only from the economy point of view but also to preserve the environment as well. Some of the researchers did the work to find the alternatives for natural sand and they concluded about different industrial waste and their ability to replace the much sought after natural river bed sand.

A. Copper Slag

At present about 33 million tons of copper slag is generating annually worldwide among that India contributing 6 to 6.5 million tones. 50 % copper slag can be used as replacement of natural sand in to obtain mortar and concrete with required performance, strength and durability. (Khalifa S. Al-Jabri et al 2011). In India a study has been carried out by the Central Road Research Institute (CRRI) shown that copper slag may be used as a partial replacement for river sand as fine aggregate in concrete up to 50 % in pavement concrete without any loss of compressive and flexural strength and such concretes shown about 20 % higher strength than that of conventional cement concrete of the same grade.

B. Washed Bottom Ash (WBA)

Currently India is producing in over 100 million tons of coal ash. From which total ash produced in any thermal power plant is approx 15 –20 per cent of bottom ash and the rest is fly ash. Fly ash has found many users but bottom ash still continues to pollute the environment with unsafe disposal mechanism on offer. The mechanical properties of special concrete made with 30 per cent replacement of natural sand with washed bottom ash by weight has an optimum usage in concrete in order to get a required strength and good strength development pattern over the increment ages.

C. Quarry Dust

About 20 to 25 per cent of the total production in each crusher unit is left out as the waste material-quarry dust. The ideal percentage of the replacement of sand with the quarry dust is 55 per cent to 75 per cent in case of compressive strength. He further says that if combined with fly ash (another industrial waste), 100 per cent replacement of sand can be achieved. The use of fly ash in concrete is desirable because of benefits such as useful disposal of a byproduct, increased workability, reduction of cement consumption, increased sulfate resistance, increased resistance to alkali-silica reaction and decreased permeability. However, the use of fly ash leads to a reduction in early strength of concrete. Therefore, the concurrent use of quarry dust and fly ash in concrete will lead to the benefits of using such materials being added and some of the undesirable effects being negated.

Fig.1. Copper slag

Fig.2. Washed Bottom Ash

Fig.3. Quarry Dust

Fig.4. Construction and Demolition waste

D. Construction and Demolition waste

There is no documented quantification of amount of construction and demolition (C&D) waste being generated in India. Municipal Corporation of Delhi says it is collecting 4,000 tones of C&D waste daily from the city which amounts to almost 1.5 million tons of waste annually in the city of Delhi alone. Even if we discount all the waste which is illegally dump around the city, 1.5 million of C&D waste if recycled can significantly substitute demand for natural sand by Delhi. Recycled sand and aggregate from C&D waste is said to have 10-15 per cent lesser strength then normal concrete and can be safely used in non-structural applications like flooring and filling. Delhi already has a recycling unit in place and plans to open more to handle its disposal problem. Construction and demolition waste generated by the construction industry and which posed an environmental challenge can only be minimized by the reuse and recycling of the waste it generates

III. Materials Used

The properties of various materials used in making the concrete (M25) are discussed in the following sections.

A. Cement

Ordinary Portland cement of 43 grades satisfying all the requirements of IS 8112-1989 was used in making the concrete slab panels and cubes in the experimental work.See Table I.

B. Natural (River) Sand

The natural sand having fineness modulus of 2.78 and conforming to zone II as per IS: 383-1970 was used for the experimentation after washing it with clean water. The specific gravity of this natural sand was found to be 2.55. The water absorption and moisture content values obtained for the sand used was found to be 6% and 1.0% respectively.

C. Artificial sand (Robo sand)

The crushed sand having fineness modulus of 2.81 and conforming to zone II as per IS: 383-1970 was used for the experimentation after washing it with clean water. The specific gravity of this artificial sand was found to be 2.66. The water absorption and moisture content values obtained for the sand used was found to be 6.5% and 1.0% respectively.See Table II.

D. Coarse Aggregate

Crushed stone aggregates of 20mm size obtained from local quarry site were used for the experimentation. The fineness modulus of coarse aggregates was found to be 6.3with a specific gravity of 2.76 the water absorption and moisture content values obtained for the sand used was found to be 2.5% and 0.5% respectively.

Table I. Typical properties of Cement 43 grade IS 8112-1989

Physical properties	Values of OPC used
Standard consistency	32.5%
Sp gravity	3.15
Initial setting time	>30 min's
Final setting time	<600 min's

Table II. Properties of Fine aggregate

Properties	Natural sand	Robo sand
Specific gravity	2.55	2.66
Fineness module	2.78	2.81

E. Robo sand and properties

The artificial/robo sand produced by proper machines can be a better substitute to river sand. The sand must be of proper gradation (it should have particles from 150 microns to 4.75 mm in proper proportion). Robo sand is a purified form of quarry dust with is extracted from manufacturing of coarse aggregate which mostly in the form of chips. These baby chips are crushed to the specified size of 0-4.75mm as required. In fact both natural sand and robo sand look similar. They don't differ in many properties like water absorption. But now there they started manufacturing separate for sand.

F. General Requirements of Manufactured Sand

All the sand particles should have higher crushing strength.

The surface texture of the particles should be smooth.

The edges of the particles should be grounded.

The ratio of fines below 600 microns in sand should not be less than 30%.

There should not be any organic impurities.

Silt in sand should not be more than 2%, for crushed sand.

In manufactured sand the permissible limit of fines below 75 microns shall not exceed 15%.

G. Properties of Robo sand

Table III. Average properties from all manufacturing units (Robo silica Pvt. Ltd.)

Organic material content	NIL
Compatiblitywith cement	Use with any type of Portland cement and blended cement for various mix designs
Setting time	Normal setting time as river Sand
Yield	Rich mix
Standard mix design for M20 1:2:4 per cum	Cement-330kg Robo sand-660kg , 20mm&10mm Course aggregate -1320kg
Workability	Good
W/C Ratio	0.49 + free water 182 liters per cum. Of concrete

H. Fineness Modulus and Zone classification

The results of aggregate sieve analysis are expressed by a number called Fineness Modulu that is obtained by adding the sum of the cumulative percentages by mass of a sample aggregate retained on each of a specified series of sieves and dividing the sum by 100. The specified sieves are: 150µm (No. 100), 300µm (No. 50), 60µm (No. 30), 1.18 mm (No. 16), 2.36 mm (No. 8), 4.75 mm (No. 4), 9.5 mm , 19.0 mm , 37.5 mm , 75 mm , and 150 mm.

Fineness modulus of Natural sand = 278 ÷ 100 = 2.78

Fineness modulus of Robo = 281 ÷ 100 = 2.81

As per the above results the Natural sand(NS) and Robo Sand (RS)both are of Zone –II. And fineness module of Natural sand is 2.78 and Robo sand is 2.81.

Table IV. IS classification of zones (IS 383-1970)

IS sieve designation	Percentage passing for			
	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

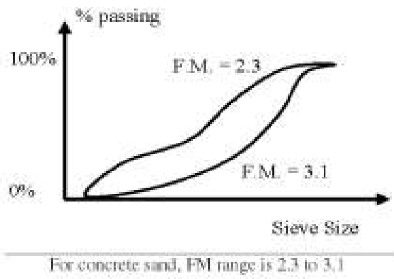

Fig.5. Graph showing fineness modules range for concrete

Fig.6. Sieve Analysis of Fine aggregate and Coarse aggregate

Table V.Fineness modulus and Zone classification

Sieve no	Percentage of individual fraction retained by mass		Percentage passing by mass		Cumulative percentage retained ,by mass	
	NS	RS	NS	RS	NS	RS
10mm	0	0	100	100	0	0
4.75mm	0	0	100	100	0	0
2.36mm	12	0	88	100	12	0
1.18mm	13	43	75	57	25	43
600micron	39	28	36	29	64	71
300micron	20	9	16	20	84	80
150micron	9	7	7	13	93	87
Pan	7	13	0	0	-	-
Total	100				278	281

IV. Types of Mixes

A. Nominal Mixes

In the past the specifications for concrete prescribed the proportions of cement, fine and Coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

B. Standard mixes

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes. IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20 M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm2. The mixes of grades M10, M15, M20 an M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

C. Design Mixes

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

D. Factors affecting the choice of mix proportions

- Compressive strength (CS)
- Workability-The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.
- Durability
- Nominal size of aggregate- Maximum nominal size of aggregates to be used in concrete may be

as large as possible within the limits prescribed by IS 456:2000.

- Quality control-The cement content is to be limited from shrinkage, cracking and creep.

V. Design Mix(Based on BIS method)

Table VI. Test data for Materials

Table Head	Table Column Head
Cement used	OPC 43 grade conforming to IS 8112
Specific gravity of cement	3.15
Specific gravity of Coarse aggregate(CA)	2.74
Specific gravity of Fine aggregate(FA)	2.77
Water absorption Coarse aggregate	0.5 percent
Water absorption Fine aggregate	1.0 percent
Sieve analysis Coarse aggregate	Conforming to Table 2 of IS: 383
Sieve analysis Fine aggregate	Conforming to Zone I of IS: 383

A. Target Mean Strength for Mix Proportioning

Ft = fck+ 1.65 s

Where

fck = Target average compressive strength at 28days,

fck= Characteristic compressive strength at 28 days,

s= Standard deviation

From Table 1 standard deviation, s= 4 N/mm^2 (IS 456 2000)

Therefore , target strength = 25 + 1.65 x 4 = 31.6 N/mm^2

B. Calculation of Cement Content

Water cement ratio = 0.44

Cement content = 182/0.44 = 413.63 kg/m^3 =414 kg/m^3

From Table 5 of IS: 456, minimum cement content for severe exposure condition = 414 kg/m^3> 300 kg/m^3, hence OK.

C. Calculation for CA and FA

Volume of concrete = 1 m^3

Volume of cement = 414 / (3.15 X 1000) = 0.1301 m^3

Volume of water = 182 / (1 X 1000) = 0.1820 m^3

Total weight of other materials except coarse aggregate = 0.1301 + 0.1820 = 0.3121 m^3

Volume of coarse and fine aggregate = 1 – 0.3121 = 0.6879 m^3

Volume of F.A. = 0.6879 X 0.33 = 0.2332 m3 (Assuming 33% by volume of total aggregate)

Volume of C.A. = 0.6879 – 0.2334 = 0.4335 m^3

Therefore weight of FA = 0.2334 x 2.55 x 1000 = 595.17 kg/ m^3

Say weight of F.A. = 595 kg/ m^3

Therefore weight of C.A. = 0.4335 X 2.76 X 1000 = 1196 kg/ m^3

Say weight of C.A. = 1196 kg/ m^3

Weight of water =178.542 kg

Water: cement: F.A.: C.A. = 0.44 : 1 : 1.43 : 2.88

D. The compressive strength for 7 days and change in strength with reference mix

After curing of cubes for 7 days, the concrete moulds of 150x150x150 mm is tested with a compressive testing machine or universal testing machine. Apply the load gradually without shock and continuously at the rate of 140kg/cm^2/minute till the specimen fails. The results are shown in Table VIII.

Table VII. Properties of concrete

Properties	Sample -1[a]	Sample -2[b]	Sample 3[c]	Sample 4[d]
NS (kg)	10	11	8.58	5.72
Specific gravity NS	2.55	2.55	2.55	2.55
RS (kg)	0	2.6	5.72	8.58
Specific gravity RS	2.75	2.75	2.75	2.75
CS inN/m m^2	23.11	30	32	33.7

Properties	Sample -1[a]	Sample -2[b]	Sample 3[c]	Sample 4[d]
after 28 days				

0% robo sand

20% replacement with robo sand

40% replacement with robo sand

60% replacement with robo sand

Table VIII. The compressive strength for 7 days.(N/mm^2)

Robo sand	Compressive strength N/mm2	Change in Strength with reference mix
0%	19.99	-
20%	23.11	+3.12
40%	20	+.01
60%	26.66	+6.67

E. Compressive strength for 28 days

After curing of cubes for 28 days, the concrete moulds of 150x150x150 mm is tested with a compressive testing machine or universal testing machine. Apply the load gradually without shock and continuously at the rate of 140kg/cm^2/minute till the specimen fails. The result are shown in table IX.

Table IX. The compressive strength for 28 days.(N/mm^2)

Robo sand	Compressive strength N/mm2	Change in Strength with reference mix
0%	30	-
20%	31.84	+1.84
40%	32	+2
60%	33.77	+3.77

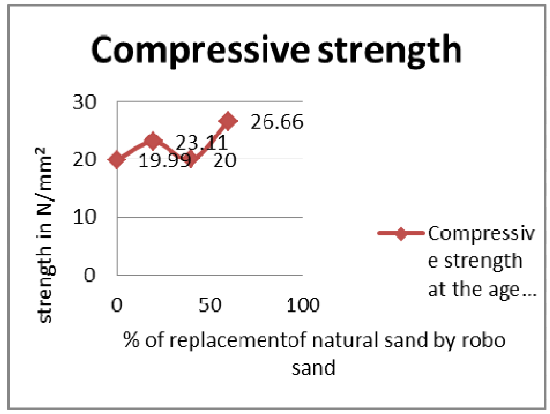

Fig. 7. Graph showing the compressive strength of concrete cured for 7 days

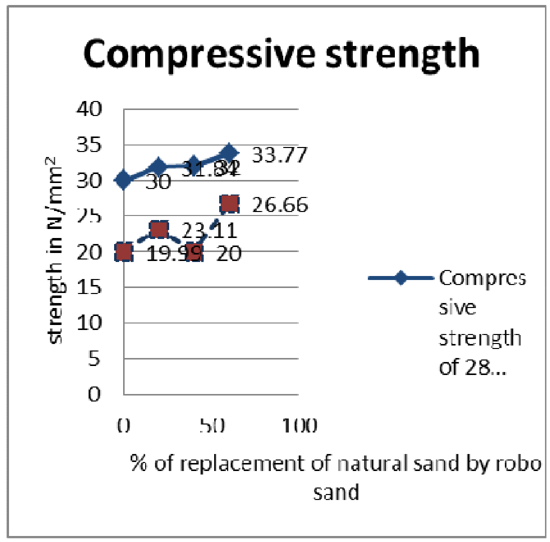

Fig. 8. Graph showing the compressive strength of concrete cured for 7 days and 28 days

VI. Conclusion

The effect of partial replacement of Natural sand by Robo sand on the compressive strength of cement concrete of grade M25 (1:1.4:2.88 –Design mix) with water cement ratio as 0.44 are studied. Results are compared with reference mix of 0% replacement of Natural sand by Robo sand. The compressive strength of cement concrete with 20%, 40%, 60%replacement of Natural sand by Robo sand reveals higher strength as compared to reference mix. The overall strength of concrete linearly increases for 0%,20%, 40%, 60% replacement of Natural sand by Robo sand as compared with reference mix.

Robo sand has a potential to provide alternative to Natural sand and helps in maintaining the environment as well as economical balance. Non-availability of natural sand at reasonable cost, forces to search for alternative material. Robo sand qualifies itself as suitable substitute for river sand at reasonable cost. The Robo sand found to have good gradation and better bonding which is comparatively less in natural sand.

According to price – service ratio the use of robo sand gives effective results, as far as we concern the cost of Robo sand is 30-50% less in market which is good for production of economical concrete. The service of robo sand is also as good enough for as Natural sand concrete.

References

[1] M.S. Shetty, Text book of concrete technology (theory and practice) S.Chand & Company Ltd

[2] IS: 10262-1982. Recommended Guidelines for Concrete Mix. Bureau of Indian Standards, New Delhi.

[3] IS: 456-2000. Recommended Guidelines for plain cement Concrete Mix & Reinforced cement concrete. Bureau of Indian Standards, New Delhi.

[4] IS 383-1979 Recommended Guidelines for fine aggregate . Bureau of Indian Standards, New Delhi.

[5] IS 8112: Specification for 43 grade ordinary Portland cement , Bureau of Indian Standards, New Delhi.

[6] M.C Nataraja, Fellow of Indian Concrete Institute, Chennai Journals of CIVIL ENGINEERING

[7] Dilip K. Kulkarni. INTERNATIONAL JOURNAL OF CIVIL AND STRUCTURAL ENGINEERING Volume 3, No 3, 2013. Indian Institute of Technology, Bombay.

[8] Ahmed. A.E. and El-Kourd, A.A. Properties of Concrete Incorporating Natural and Crushed Stone Very Fine Sand. ACI Materials Journal, Vol. 86, No. 4. pp.417- 424 (1989).

[9] Marek, C.R. Vulcan Materials Company. Importance of Fine Aggregate Shape and Grading on Properties of Concrete. Paper presented at Centre for Aggregate Research, March 2-4 (1995).

[10] Celik, T. and Marar, K. Effects of Crushed Stone Dust on Some Properties of Concrete. Cement and Concrete Research. Vol. 26, No. 7. pp. 1121-1130 (1996)

[11] Murdock, L.J. The Workability of Concrete. Magazine for Concrete Research No. 36, pp. 135-144 (1960) Hudson B.P., (1997), Manufactured sand for concrete, The Indian concrete Journal, pp 237-240.