UTILIZATION OF DOMESTIC WASTE MATERIALS AS PARTIAL REPLACEMENT OF AGGREGATES FOR IMPROVED QUALITY OF CONCRETE

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Abstract

The concrete structure is associated with occurrence of cracks, poor quality of construction and increasing cost of cement. The concrete production has basic ingredient: Coarse and Fine Aggregate [non-renewable natural resources] with depletion trend at fast rate. The partial replacement of Aggregate, with improved quality of concrete has been envisaged through utilization of domestic waste materials. The generation of domestic waste has been common at every house-hold in our prevailing society and its disposal is challenging environmental issue, without considering their further utilization on the concept- "recycle of waste into wealth".

Eight domestic waste materials namely: Human Hair Fabric, Bamboo, Used old rough paper, Discarded Plastic, Out-dated to un-repairable Electronic [e] product, Broken Glass accessories, Coconut shells and Saw dust have been identified as proven potentials for partial replacement of Coarse and Fine Aggregate, besides- improved compressive strength [quality] of Ordinary and Standard Concrete production, widely used in India, presently for Construction Industry.

Introduction

We, by majority are living in materialistic society, with utilization of materials belonging to Industrial, Agricultural and Domestic sector- as well as their disposal to our surroundings. The utilization and disposal aspects for domestic waste materials depend upon our mentality, custom, religion and inclination. The nature requires BALANCE maintenance in between utilization and disposal aspects for harmonious survival. The excessive disposal of waste material encourages environmental degradation with opening the new venture for "Recycling of waste material into wealth" towards further utilization.

This concept has been well explained for utilization of domestic waste materials like: Human Hair Fabric, Bamboo, Used old rough Paper, Discarded Plastic, Out-dated to un-repairable Electronic [e] product, Broken Glass accessories, Coconut shells and Saw dust into partial replacement of ingredients of Ordinary & Standard concrete with improved quality. This leads to the reducing cost factor of construction activity with its better economic viability, eco-friendly environment to our prevailing society.

Evolved Methodology & Objectives

The evolved methodology is based upon conventional approach as relevant literature review with scrutiny of available BIS code provision for Coarse & Fine Aggregate-as natural resources for ingredient of concrete in relation to the index and engineering properties of eight domestic waste materials. The availability of good quality of Aggregates has fast depletion trend due to its large scale exploitation. So, the partial replacement of river sand & stone chip is inevitable.

The objectives of study are as follows:

- Preliminary characterization of domestic waste materials for partial replacement of Fine Aggregate [River Sand].
- Preliminary characterization of domestic waste materials for partial replacement of Coarse Aggregate [Stone-chips].
- Comparison of Compressive Strength of Ordinary & Standard Concrete with proven partial replacement of eight domestic waste materials.

Relevant Literature Review

The domestic waste materials are of solid, non-biodegradable and renewable category, occurring in our rural and urban areas. Sometimes, it belongs to Municipal Solid Waste [MSW]. The utilization of identified domestic waste materials as replacement of Aggregates is a boon for Construction Industry, as it save our non-renewable natural resources substantially with improved quality of concrete, economically. The type of used domestic waste materials for partial replacement of ingredient of concrete has been summarized as Table1.

Concrete has four basic ingredients, belonging to artificial and natural category. Only cement belongs to artificial category, as manufactured at Cement Plant with production and emission of Carbon Dioxide in equal amount. The remaining three belongs to natural category namely-Coarse & Fine Aggregate as non –renewable and waster as renewable resources, respectively. The quality of each ingredient of natural category has been specified by particular BIS code provision and as follows:

- IS 15426-[2000] for water.
- IS 383[1970] for Coarse & Fine Aggregate from natural resources for concrete.
- IS 516[1959] for Standard methods of test for strength of concrete.
- IS 10262 [2009] for Concrete Mix proportion-revised guidelines.

S N	Concrete Grade	Partial Replacement of ingredients	Name of Domestic Waste Materials	Name of Investigator [Reference]	Place of Investigation
1	M-15	Fine Aggregate	Human Hair Fabric [HHF]	Rayed Alyonsef [10]	PSB Abdul Aziz Univ. [Saudi Arabia]
2	M-25	Cement	Used old rough Paper	Mohd. Iqbal Mirza [6]	IUST, Awantipore
3	M-40	Coarse Aggregate	Discarded Plastic	Prasson & Ravi Kumar [9]	PSN College of Engineering Thirunelveli
4	M-20 M-25	Coarse Aggregate	Out-dated to un-repairable Electronic [e] product,	Karuna Devi [3] Manikandan P [4]	Jerusalam Engineering College Chennai SMR Univ. Chennai
5	M-20 M-20 ---------- M-25	Coarse Aggregate Fine Aggregate Fine Aggregate	Broken Glass accessories Crushed - meshed Glass waste Fine powdered, grinded glass waste	Rajitha D [11] Peerzada [8] Mohd. Iqbal Mirza [6]	CMR Engineering College, Medhahal Punjab Univ. Chandigarh IUST, Awantipore
6	M-20	Coarse Aggregate	Coconut shell	Sarika V [12]	Tirupati Univ. Chittor
7	M-40 M-15	Coarse Aggregate Fine Aggregate	Ordinary Bamboo pieces Bamboo Stem Ash	Manimaran [5] Chijoke [1]	SMR Univ. Chennai Nigeria Univ.
8	M-20 ---------- C-30 [BS]	Coarse Aggregate	Saw dust	Chittra R [2] Nurul Huda [7]	Bharath Univ. Alam Shah Univ. Malaysia

Table 1: Status of domestic waste material, used as proven partial replacement for ingredients of concrete.

The strength of concrete depends upon the properties of ingredients, bonding characteristics, w/c ratio,, curing temperature, age and size of specimen. The strength of concrete is expressed as M x and in range of M-5 to M-80. M = Mix design with defined proportion. [x] = compressive strength value in N/mm2 /1 M Pa/145.037 psi. C-30 = Concrete strength as per British Standard.

The ordinary concrete has M15 & M-20 and also known as Plain Cement Concrete [PCC]. The standard concrete has grade M-25, M-30 & M-40 and also known as Reinforced Cement Concrete [RCC]. The mix proportions for ordinary and standard concrete as per BIS code is summarized as Table 2.

S N	Concrete Grade	Mix. Proportion Cement : Coarse Agg. : Fine Agg.	Category of concrete	Application
1	M-15	1 : 2 :4 1 :2.1 :3.85	Ordinary HHF	Foundation
2	M-20	1 :1.5 :3 1 :1.6 : 2.78	PCC	Flooring
3	M-25	1 :1.1 :2	Standard	C-C Road
4	M-30	1 :1 :2	RCC	House work
5	M-40	1 :1.67 :2.39	RCC	Super Structure

Table 2: Classification of major types of concrete as per BIS Code provision

The general characteristics of eight domestic waste materials, as per Table: 1 has been systematically documentated as follows for their suitability to ingredients of concrete:

[1] Human Hair Fabric [HHF]:- The waste of HHF has unique properties as stiffness, durability, elasticity, which enhances the soil bearing capacity for foundation purpose, besides more binding characteristics [10]. The physical appearance of HHF after cutting has been illustrated as Fig.1.

[2] Used old rough Paper: - It has application in sludge form for replacement of cement for preparation of ordinary concrete. The waste paper sludge contains higher silica dioxide, which provides extra strength to concrete. It has favorable specific gravity =2.6. It is sieved through standard sieve analysis to get sludge paste as illustrated as Fig.2.

Fig. 1 Physical appearance of HHF after cutting

Fig. 2 Physical appearance of paper sludge

[3] Discarded Plastic: - The index properties of Plastic waste as specific gravity, modulus of fineness, water absorption ratio are suitable for preparation of Standard Concrete. It constitutes 8% by weight of Municipal Solid Waste. It is cut into average size of 12.5 mm in different geometrical shape, avoiding circular. It is processed to sorting, shredding, washing & extruding, before concrete preparation. It is blended with Na2 SiO2, as appeared in Fig.

Fig. 3 Physical appearance of plastic waste blended with Na2 SiO2

[4] Out-dated to un-repairable Electronic [e] product: - It includes domestic computer accessories, electronic gazette, cellular phone, refrigerator, air-conditioner, washing machine etc. In, India 15 % [e] - waste is generated by individual household. It has specific gravity =2.46 to-2.86, water absorption ratio [%] =1.5-2.5. The physical appearance of [e] waste is illustrated as Fig.4

Fig.4 Physical appearance of electronic [e] waste

[5] Glass waste accessories: - In India, 0.7% glass waste accessories are generated in urban area. It contains metallic silicates in amorphous-to-transparent stage, which assists in hydration process favorably. Three kinds of glass waste occur namely: Broken colored soda water/wine bottle waste, Meshed/crushed glass waste from glass widow, door and Fine powdered-grinded glass waste.

Broken colored bottle waste has unique w/c ratio =0.4, bulk density =2462-2821 Kg/cubic meter and suitable for coarse aggregate of ordinary concrete. Crushed to meshed glass waste is collected from broken glass window, door and home appliances, following index properties of Fine Aggregate of ordinary concrete. Fine powdered-well grinded glass waste has specific gravity =2.42 and favorable durability, water absorption [%] of Fine Aggregate. The physical appearance of Fine powdered-grinded glass waste is illustrated as Fig.5

Fig.5 Physical appearance of Powdered-grinded glass waste

[6] Coconut shell :- The coconut shell are broken into two half manually and sun dried for three days for its waste. It has specific gravity =1.33, water absorption [%] =20, Bulk density =800 Kg/cubic meter, shell thickness =2.7 mm. It is suitable for partial replacement of Coarse Aggregate and is illustrated as Fig.6

Fig. 6 Physical appearance of Coconut shell waste

[7] Bamboo waste :- The Bamboo has been widely used in Hindu religion ,right from marriage [mandap] to death[dead body carrying structure to cremation], besides in construction of low cost house

in rural area. The bamboo after utilization usually disposes to waste, which has been utilized as partial replacement of Aggregate.-successfully in preparation of ordinary concrete.

The ordinary bamboo pieces have been used as partial replacement of coarse Aggregate on account of its similar index properties, specific gravity =0.5 to 7.5,w/c =0.4, moisture content =50-60 %, diameter =100 to 150 mm, wall thickness =10-15 mm, elasticity = 1.5to 2.0x10[5] Kg/cm2, height =5 to 7.5 m, age =3 to 5 year. The bamboo of above specification is used to cut into small pieces, equivalent of coarse Aggregate size- in different geometrical shape, except circular. The bamboo piece are treated with application of thin layer of epoxy solution on surface and stride by covering fine sand and is ready for partial replacement of coarse Aggregate.

Bamboo Stem Ash [BSA] is used as partial replacement of fine Aggregate. The bamboo stems are collected from jungle and sun dried for 24 hours to avoid ingress of moisture. The stems are cut in-to smaller size and placed in furnace for controlled burning at 800 degree centigrade for two hours and allowed to cool down for five hours. The burnt material is sieved firstly through 2.36 mm sieve and later on by 0.75 micron. The material is ready for partial replacement of fine Aggregate and illustrated as Fig7

Fig. 7 Physical appearance of BSA

[8] Saw dust :- It is generated in semi-urban area, surrounding forest, where timber is used to be cut for its variety of uses. It has been successfully proved as partial replacement of fine Aggregate for ordinary concrete preparation. Saw dust has equivalent index properties of fine Aggregate as specific gravity =2.15, bulk density =600-1650 kg/cubic meter and non hazardous to human health. The physical appearance of saw dust is illustrated as Fig.8.

Fig. 8 Physical appearance of Saw dust

Result & Discussion

The supply-demand chain of good quality of Aggregate has been under stressed condition, due to decreasing availability, increasing cost and strict regulations of environmental issues. This advocates the need for partial replacement of Aggregate with improved quality for adequate maintenance of concrete structure. An attempt has been made for considering such aspects through systematic approach to the desired objectives,and as follows:-

- ✓ Preliminary characterization of domestic waste materials for partial replacement of Fine Aggregate [River Sand]- Four domestic waste materials namely: HHB, Glass accessories waste as meshed/crushed waste and fine powdered-grinded product, BHA and Saw dust have proven partial replacement of fine Aggregate [river sand] for preparation of ordinary concrete. The brief for each waste is summarized as follows:

Human Hair Fabric [HHF]:-1.5% [by weight] of HHF as partial replacement to fine Aggregate for M-15 grade concrete provides satisfactory performance due to w/c ratio =0.47, length of used hair =70 mm, diameter of used hair = 95 to 130 micrometer [10].

Glass accessories waste as meshed/crushed waste and fine powdered-grinded product:-20% [by weight] of meshed to crushed glass waste as partial replacement to fine Aggregate for M-20 grade concrete provides satisfactory performance.

20% [by weight] of fine powdered to grinded glass waste as partial replacement to fine Aggregate for M-25 grade concrete provides satisfactory performance.

Bamboo Stem Ash [BSA]:-15% [by weight] of Bamboo Stem Ash [BSA] waste as partial replacement to fine Aggregate for M-15 grade concrete provides satisfactory performance as well as workability due to slump test =25 mm.

Saw dust:-5% [by weight] of Saw dust waste as partial replacement to fine Aggregate for M-20 grade concrete provides satisfactory performance and w/c ratio =0.45 at Bharath University.

5% [by weight] of Saw dust waste as partial replacement to fine Aggregate for C-30 grade concrete [British Standard] provides satisfactory performance at Alam Shah University. C-30 =5.955kg/m3 [cement] : 16.31 Kg/m3 [coarse aggregate]:6.67 Kg/m3 [river sand].

- ✓ Preliminary characterization of domestic waste materials for partial replacement of Coarse Aggregate [Stone-chips] - Five domestic waste materials namely: Discarded Plastic, Out dated to un-repairable electronic [e] product, Broken colored glass bottle, Coconut shell, Ordinary Bamboo pieces and Saw dust have proven partial replacement of coarse Aggregate [Stone Chips] for preparation of ordinary & standard concrete. The brief for each waste is summarized as follows:

Discarded Plastic:-15% [by weight] of Discarded plastic waste as partial replacement to coarse Aggregate for M-40 grade concrete provides satisfactory performance as well as good split tensile strength due to elasticity.

Out dated to un-repairable electronic [e] product:-15% [by weight] of out-dated to un-repairable electronic [e] product waste as partial replacement to coarse Aggregate for M-20 & M-25 grade concrete provides satisfactory performance for construction of Cement-Concrete road.

Broken colored glass bottle:- 5% [by weight] of Broken colored wine/soda water glass bottle waste as partial replacement to coarse Aggregate for M-20 grade concrete provides satisfactory performance.

Coconut shell:- 10% [by weight] of Broken coconut shell waste as partial replacement to coarse Aggregate for M-20 grade concrete provides satisfactory performance for flooring work.

Ordinary Bamboo Pieces:- 5% [by weight] of Ordinary Bamboo Pieces waste as partial replacement to coarse Aggregate for M-40 grade concrete provides satisfactory performance.

- ✓ Comparison of Compressive Strength of Ordinary & Standard Concrete with proven partial replacement of eight domestic waste materials – The quality of all concretes depend upon compressive strength mainly and is observed under improved category with partial replacement of eight domestic waste materials. The compressive strength has been studied through standard sixe specimen as per BIS code, after curing of 28 days at established labs of civil Engineering department in India and abroad. The determined value of compressive strength for eight domestic waste materials is summarized as Table 3.

S N	Name of domestic Waste material	Grade of concrete	Compressive strength [[N/mm2]	Remarks
1	HHF	M-15	44.3	Split Tensile Strength =5, Flexural Strength =5.2 [both in N/mm2]
2	Used old paper	M-25	36.14	+ 40% Fine Aggregate as glass waste
3	Plastic waste	M-40	43	Improving Self Compacting Capacity
4	Electronic [e] Waste	M-20 M-25	21 40.6	Split tensile Strength = 3.36 N/mm2
5	Glass Waste	M-20 M-20 M-25	45.8 38.0 27.0	Colored bottle Meshed /crushed Fine powdered-grinded
6	Coconut shell	M-20	45.8	Renewable
7	Bamboo	M-15 M-40	20 45	Bamboo Stem Ash [fine aggregate] Ordinary Pieces [Coarse Aggregate]
8	Saw dust	M-20 C-30	24.20 50.06	Bharath Univ [India] British Standard, Alam Shah Univ.

Table 3 : Comparison of compressive strength of partial replacement of different domestic waste material.

Conclusion

Eight domestic waste materials namely: Human Hair Fabric, Bamboo, Used old rough paper, Discarded Plastic, Out-dated to un-repairable Electronic [e] product, Broken Glass accessories, Coconut shells and Saw dust have been identified as their proven partial replacement to ingredients of concrete. These domestic waste materials have been studied for their equivalence index and engineering properties to fine and coarse Aggregate, scientifically.

Two commercial concrete grades namely-ordinary concrete and standard concrete have been extensively practiced in India. The improvement in quality of both concrete grades as per their compressive strength through partial replacement of domestic waste materials provides the scope for sustainable, eco-friendly and economic viable concrete built structures, with following remarks:-

- M-15 grade ordinary concrete, with partial replacement of Human Hair Fabric & Bamboo Stem Ash as fine Aggregate and improved compressive strength =20 to 44.3 N/mm2 have been successfully proved at Abdul Aziz University [Saudi Arabia] and University of Nigeria respectively.
- M-20 grade ordinary concrete, with partial replacement of Crushed/Meshed glass waste and saw dust waste as fine Aggregate and improvement compressive strength =24.20 N/mm2 in India.

M-20 grade ordinary concrete, with partial replacement of Colored bottle glass waste, electronic [e] waste and Coconut shell waste as coarse Aggregate and improvement compressive strength =21 to 45.8 N/mm2 in India.

- M-25 grade standard concrete, with partial replacement of fine powdered-grinded glass waste as fine Aggregate and improvement compressive strength =27 N/mm2 in India.

M-25 grade standard concrete, with partial replacement of Electronic [e] waste as coarse Aggregate and improvement compressive strength =40.6 N/mm2 in India.

- M-40 grade standard concrete, with partial replacement of plastic and ordinary bamboo pieces waste as coarse Aggregate and improvement compressive strength =43 to 45 N/mm2 in India.
- The coconut shell waste as renewable partial replacement for coarse Aggregate has recorded reduction in cost factor by 16.6% in flooring work at Govt. Low cost Housing scheme at Tirupati, in India.

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