Sustainable Use of Waste Material as Coarse Aggregate for Concrete Preparation - A Review

M. Shiva Rama Krishna, Kastro Kiran. V, T. Karthik Chary, M. Jayaram

Abstract: ***Coarse Aggregate makes the predominant part in concrete which by implication implies it turns into the key segment in the solid blend, finding an option in contrast to customary coarse total in a way to such an extent that not bargaining with properties of ordinary one is an approach to the maintainable turn of events, it is likewise a need of the present to utilize the option in contrast to exhausting normal assets and make appropriate use or deterioration of existing waste. In this survey, an itemized report of examination done on the utilization of various waste material, for example, plastic waste, electronic waste, marble squander, squashed earthenware squander, Ferrochrome slag total, Induction furnace slag, Cuddapah stone waste and so forth in substitution or expansion to coarse aggregate in preparation of concrete is tended to. The diverse compound, mechanical and physical properties of waste material are looked at and talked about. It is seen that squander materials when added to the coarse total in ideal substance really increment quality properties, different properties of concrete are additionally contrasted with that of ordinary coarse total and particular change in properties is definite. The conversation is likewise finished concerning the correlation between what exploration is said and the code and arrangements of administration of India in IS 383:2016.***

Keywords: Waste management, Industrial waste, Marble waste, coarse aggregate, ceramic waste.

I. INTRODUCTION

Planet Earth has got limited resources which are to be served even for the upcoming generations which create a demand for sustainability. Concrete is one such that is comprehensively used construction material (Prabhu et al., 2014) which comprises about 70% of aggregate material that consumes annually a huge amount approximately between8-12 million tons of natural aggregate (Devi and Gnanavel2014; Jabri et al.,2009). Classification of coarse aggregate as per IS 383:2016 is that aggregate, most of which is retained on 4.75mm IS sieve and containing only so much finer material as is permitted for the various types described in the standard. Coarse aggregate is the vital part of the concrete that decides major factors such as compressive strength, workability, durability, strength, weight etc. of concrete. Coarse aggregate is usually larger component of mix than cement and fine aggregate in any mix proportion depicting the volume of the aggregate. Use of the conventional coarse aggregate is high due to increasing construction activities especially in a country like India which is expanding its urbanization rapidly. Thus the. need of coarse aggregate is growing more to meet increasing demand, this increasing demand is causing for non-availability of conventional coarse aggregate for quality construction creating a menace for both environment and economy of the nation. India has also seen a drastic increase in mining activities for various construction aggregates; soon mining activities would reach a saturation point to avoid overexploitation of resources so there is a definite need for search of alternative, inducing waste material into coarse aggregate would actually solve both problems of depleting natural resources and reusing waste material. Plastic waste and electronic waste are one that cause nuisance to the biological system as being majorly non-biodegradable, so reusing such materials would actually lessen the burden on biological system for a cleaner environment. It is stated that in India 960Mega Tones of solid waste is generated annually, out of which 290Mega Tones are unwanted inorganic waste of mining & industrial division (Pappuet al. (2007)). Regular resources are depleting rapidly and waste material is increasing predominantly, making a cost efficient coarse aggregate using waste majorly industrial waste without actually compromising with the properties of concrete will be stupendous. (Bahoria et al., 2013) saysutilization of waste items in concrete makes it inexpensive and reutilization of wastes is supposed to be the best ecological option for taking care of the issue of waste disposal. Different types of waste material such as Marble waste (Kore and Vyas 2016; Kore and Vyas 2015;Mamun et al, 2017), ceramic waste, plastic waste, e plastic waste (Aditya et al., (2016); Singh and Pandey 2017),e waste (Sunil et al 2016), river pebbles, demolished concrete waste (Prakash et al 2016; Dakwale and Ralengoankar 2013;), ferrochrome slag aggregate, stone chips (Farhana et al 2013), Cuddapah stones, recycled coarse aggregate, Induction furnace slag, agricultural waste (rice straws)(Tyagi, 2018), steel slag (Devi and Ravi 2015;Palankar et al., 2015;), iron slag (Kumar and Kumar 2013; Raza et al., 2012) etc., are partially or fully replaced with coarse aggregate in preparation of concrete and their properties with control concrete are compared. Ferrochrome slag produced as water cooled granulated slag is a major solid waste generated during manufacture of ferrochrome alloy.

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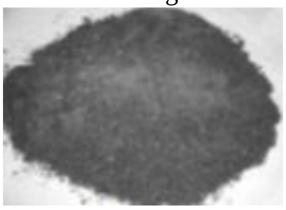
Imperial smelting furnace (ISF) slag is produced during the pyro metallurgical refining of sulphidemetal. Steel slag is the waste product of steel and iron creating process. Electric arc furnace steel slag has low or no pozzolanic activities and not suitable to be utilized in blended cement manufacture. This paper presents a comprehensive study about various waste materials or byproducts that can be used as replacement in coarse aggregate for concrete preparation which would ultimately reduce the amount of waste material to be disposed and an alternative to existing natural resources, there by leading to smaller part of sustainable development. Physical properties describe the outlook of the waste material, each waste material was shown up in tabular form along with chemical and mechanical properties of each. Different authors have used other additional mixtures such as flyash, blast furnace slag etc., along with replacementi of different wastes in coarse aggregate to not comprimise with properities of conventional concrete

Iron Slag

Polypropylene Fiber



FerrochromeSlag

Blast Furnace Slag

Steel Slag

Marble dust

II. PHYSICAL PROPERTIES OF INDUSTRIAL WASTES AS COARSE AGGREGATE

Physical properties of wastes such as grain size distribution, density, specific gravity, absorption help to acknowledge its suitability and workability to be replaced as coarse aggregate in concrete.

A. Shape and Appearance

Shape and appearance describes the physical outlook any material, like marble dust is granular and powdered form mostly in white color. Ceramic waste is crystalline and granular having various colors.Marble dust is essentially made by macerating marble in a macerator or pulverizes and is acquired from pounding the marble into powdered structure. Marble is one of the non-foliated changeable rocks which is made out of recrystallized carbonate mineral that is most ordinarily calcite or dolomite (Kishore and Chowdary 2016). The blast furnace slag is dark smooth particle and granular whereas ISF slag is dark in shading, vitreous, granular and contain toxic metals like lead and zinc. Electronic waste is random in shape and mostly of plastic composition having non-biodegradable properties whereas agricultural waste such as coconut shells is of appearance such as fibers which look brownish in color.

B. Particle gradations

Particle gradation describes the distribution or Cumulative passing of the material through IS sieve, Iron slag is one such waste material which is passing through 40 mm sieve as described by and 95% retained on 4.75mm IS sieve. Steel slag is passing by 96% by weight through 10mm IS sieve and is retained by 98% through 2.36 mm IS sieve. Ferrochrome slag has a cumulative passing of 100% through 20mm IS sieve and Recycled coarse aggregate has 100% cumulative passing through 40mm IS sieve and 5% retained on 20mm IS Sieve.

C. Bulk density

Bulk density is defined as the dry weight of soil per unit volume of soil. Bulk density considers both the solids and the pore space; whereas, particle density considers only the mineral solids.

Steel slag has loose bulk density ranging between 1050 – 1726 kg/m3 and compacted bulk density ranging between 1375 Kg/m^3 – 1935 Kg/m^3 and Unit weight of Steel Slag being in range 1600 – 1926 kg/m3 as stated by the researcher. Recycled Coarse Aggregate has loose bulk density ranging between 1350 Kg/m^3 – 1440 Kg/m^3, Ferrochrome Slag has loose bulk density of 1783 Kg/m^3 and Recycle aggregate with bulk density of 1300 Kg/m^3.

D. Water absorption

The amount of water absorbed by the waste material determines the water absorption capacity of the material, having high water absorption requires increased water cement ratio in concrete mix to keep in balance with high water absorption of the waste material used in with replacement of coarse aggregate. It is found that Electronic waste has the least water absorption percentage of 0.04% and highest being coconut shell categorized under agricultural waste having 25% Water absorption. Various other wastes as listed by the authors being Steel slag 2%-5%, Iron Slag having 1.05%, Ferrochrome Slag 2%, Marble waste ranging between 2%-5% and ceramic waste having 6% of water absorption.

E. Specific gravity

Specific gravity is defined as the ratio of density of a substance to the density (mass of the same unit volume) of a reference substance (Ahirwar et al., 2016). Here is few values of specific gravity of waste materials used as replacement to coarse aggregate, starting with electronic waste Specific gravity as per Ahirwar et al., 2016 is 1.20, as in Mathur et al., 2017 and (Prasanna and Rao, 2015) specific gravity of electronic waste is 1.10. Specific gravity of Iron slag ranges between 2.67- 2.8 with one researcher adding polypropylene fiber along with Iron slag as replacement to coarse aggregate. Specific gravity of steel slag is ranging between 3.12-3.84 used as replacement to coarse aggregate. Specific gravity of various other waste materials considered by different researchers is listed in the table accordingly. There is a definite effect of specific gravity with the way a material behaves as coarse aggregate and following results are interpreted and discussed in the upcoming discussions.

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Particle size distribution of different Industrial wastes

Sieve (mm)	Cumulative Passing (%)										
	Steel slag	Iron slag	Ferrochrome Slag	Recycled coarse Aggregate	Recycled Aggregate	Marble Waste	Ceramic Waste	Stone Waste	Plastic Waste	Electronic Waste	AgricultureWaste
40		100		100		100				100	100
20		95	100	95		95		100	100	95	95
10	96	38				54.88	100				
8											5
5											
4.75	36	5		20		6.5				0	
4											
3.35											
2.36/2.4/2.34	2										
2											
1.7											
1.8/1.2											
1											
0.85											
0.6											
0.5											
0.3											
0.212											
0.25											
0.15											
0.125											
0.1											

III. DISCUSSION ABOUT CHEMICAL PROPERTIES CONSIDERED BY VARIOUS AUTHORS

A. Steel Slag:

Calcium oxide is the major component of Steel slag forming about 40%-52% by weight of steel slag. Calcium oxide has a property in reduction of setting time of concrete but increases the binding strength. Ferric oxide and Silicon dioxide are other major components influencing the weight of the steel slag. Ferric oxide inhibits properties of color and hardness to concrete, even Ferric oxide effects setting time of concrete which makes it hard in practice to deal with ferric oxide and calcium oxide though they are good strength inhibitors, Silicon dioxide increases strength of concrete. Authors considering steel slag as aggregate replacement in coarse aggregate found increasing compressive and flexural strength of concrete when compared to control concrete but the properties of workability and setting time are mentioned to be decreasing.

B. Iron Slag:

Silicon dioxide and Lime are the two major components of Iron slag which effect majorly soundness and strength of concrete, Silicon dioxide reduces the setting time of concrete so workability reduces but it is found that Iron slag up to a percentage about 40% by weight increases compressive strength, split tensile strength and flexural strength compared to control concrete. Iron slag contains Sulphur which increases the worseness effect due to Sulphur attack on hardened concrete leading to reduction in compressive strength of concrete and durability of concrete compared to control concrete due to less Sulphur attack resistance.

C. Ferrochrome Slag:

Majorly contains Silicon dioxide, Aluminum Oxide and Magnesium Oxide. Silicon dioxide increases binding strength of concrete whereas setting time is effected, Aluminum Oxide leads to quick setting time of concrete that would make it difficult to actually execute at the site, and optimum setting time is required for ease of workability and construction. Magnesium oxide is used to impart hardness to concrete also it imparts color, excessive Magnesium oxide reduces workability of concrete and setting time of concrete.

D. Recycled coarse aggregate:

Coarse aggregate that has been recycled from previous session actually possess chemical properties similar to conventional coarse aggregate, Calcium Oxide increases strength of concrete and improves soundness. Authors found that increasing compressive strength, flexural strength and tensile strength of concrete that is prepared from recycled coarse aggregate as replacement by weight in percentage but there was a huge effect on workability of concrete where drastically workability decreased.

E. Plastic Waste:

Plastics are usually classified by: the chemical structure of the polymer's backbone and side chains; some important groups in these classifications are: the acrylics, polyesters, silicones, polyurethanes, and halogenated plastics. Plastic waste considered has varying chemical composition with different polymerizations, physical properties are listed.

F. Marble Waste:

Marble waste is generally obtained from the quarry having high calcium oxide as marble is rich in Lime and Manganese Oxide. Marble dust used as coarse aggregate replacement for concrete preparation was obtained from western Indian places having similar properties that of Marble with chemical composition being highest in Calcium oxide (Lime) and Manganese Oxide (MnO) Calcium Oxide reduces setting time of concrete imparting strength factor, random marble dust of different grades of marble were used in the experiment which does not lead to clear determination of varying properties. Manganese Oxide reduces both setting time and workability of concrete which effects slump value drastically but compressive strength is found to be increasing until a particular percentage of replacement as shown by researchers in various experiments.

Physical properties of waste materials

Component	Steel slag) in %	Iron Slag	Ferrochrome Slag	Recycled coarse aggregate	Recycled Aggregate	Marble waste	Ceramic waste	Stone waste	Plastic waste	Electronic waste	Agricultural waste
Specific gravity	3.12-3.84	2.67-2.8	2.72-2.84	2.36-2.5	2.06-2.95	2.64 - 2.88	2.45	2.43 – 2.87	3.15	1.1	2.5 - 3
Loose bulk density (kg/m^3)	1050-1726		1783	1350-1440	1300-1469		1200				460 - 600
Compacted Bulk Density (kg/m^3)	1375-1935						1325				515 - 1353
Unit weight (kg/m^3)	1600-1920										
Fineness modulus			2.87-6.22	6.06-6.89	2.77 – 7.358	6.5 – 7.25	2.67 - 6.88	2.87		6.3 - 6.937	
Water Absorption%	2-5	1.05	0.42 - 2		0.32-8.5	0.05 – 0.5	0.72 – 14.4		2	0.04 – 1.7	8 - 33
Particle grading zone	As per IS 383					As per BIS 383			1		
Abrasion values%	18%			27.08		10.46 - 34.87	28			3.57	1.63 – 4.8
Crushing value %	62.03	2.95	29.97	31.78	17.29 – 36.3	17.29 – 30.1	27			21	2.5 - 8
Impact value %	25.26	8.3	24.67	13.66	13.31 – 35.2	13.31 – 22.68	21	118.3		17	3.91 - 22

G. Ceramic waste:

Increasing ceramic waste has got unique chemical composition, In ceramic chemistry, fired glazes are viewed as composed of oxides (examples are SiO_2, Al_2O_3, B_2O_3, Na_2O, K_2O,CaO, Li_2O, MgO, ZnO, MnO, Fe_2O_3). Each oxide is known to contribute specific properties to the fired glass. Ceramic is a hard substance but not as hard as concrete, its addition to coarse aggregate increases the compressive strength but various properties are to be studied.

H. Electronic Waste:

Computer's waste and cathode ray tubes are such electronic waste which can be recycled than disposing as it would decrease the energy and increase economy in the process of recycling such material rather than transporting for disposing them. All of the electronic waste cannot be recycled but major part of them can easily be sent for recycling. The Government of India has drafted E-waste Management and handling rules 2011 which came into effect from 1st May 2011. In this following review paper authors have considered various electronic waste which are parts of computer materials, cathode ray tubes, broken electrical or electronic devices in powdered form, crushed parts of mobile phones, television etc.

IV. FRESH PROPERTIES OF CONCRETE

A. Slump Test

Different necessities such as stability, mobility, compatibility and placeability incorporate a mix property of fresh concrete known as consistency. Slump test is one such that is used all over world extensively in site work. Suggested values for low, medium and high workability of concrete, slump values are 25mm-75mm, 50mm-100mm and 100mm-150mm respectively (IS 456-2000). Slump values reported by various researchers using waste material in replacement with coarse aggregate are as follows:

B. Electronic Waste

Ahirwar et al., 2016 used crushed electronic plastic waste as replacement with coarse aggregate along with OPC 43 grade cement, natural sand from Narmada River, natural crushed aggregate and observed slump values 27mm,31mm,38mm,47mm,61mm,70mm and 73mm for replacement by weight in coarse aggregate as 0%,5%,10%,15%,20%,25% and 30% respectively.

C. Ferrochrome Slag

Sathwiket al., 2016 considered ferrochrome slag as replacement in coarse aggregate along with OPC 43 grade cement, Natural River sand as fine aggregate and Rock ballast as coarse aggregate obtained from local quarry. Slump test results are in terms of compaction factor as 0.95, 0.98, 0.99, 0.99 and 1 for percentage of replacement as 0%, 25%, 50%, 75% and 100% respectively where water cement ratio was kept at 0.33. In an research article by Panda et al., 2013, where ferrochrome slag is used as replacement with coarse aggregate along with natural stone as coarse aggregate, OPC and PPC cement and natural fine aggregate is used where slump is reported within the range of 48-60 mm respectively with compaction factors within the range of 0.88-0.92 indicating medium workability for concrete products.

D. Iron Slag

Raza et al., considered Iron slag as in replacement with coarse aggregate along with OPC 43 grade cement, Super plasticizer Conplast SP 430 to increase workability of concrete, natural coarse aggregate as per IS 383:1970, natural sand from River are considered where the slump is reported within the range of 50-75mm for a replacement of iron slag with coarse aggregate replacement by weight in percentage as 0%, 10%, 20%, 30%, 40% and 50%.

Chemical composition of different waste materials

Component	Steel slag in %	Iron Slagin %	Ferrochrome Slagin %	Recycled coarse aggregate in %	Recycled Aggregate in %	Marble waste in %	Ceramic waste in %	Stone waste in %	Plastic wastein %	Electronic waste in %	Polypropylene Fiber in %
SiO_2	10-19	32-42	27.33-28.87	19.90		3.75					45-55
Al_2O_3	1-3	7-16	19.57-22.84	4.30							14
Fe_2O_3	10-40	0.1-1.5	2.85-4.12	4.24		10.66				80	5-14
CaO	40-52		2.49-2.96	64.34		33.12					
MgO	5-10	0.2-1	30.32-32.28	2.04				4-6		15.5	
MnO	5-8					17.9					
Metallic Fe	0.5-10										
K_2O	0- 0.05			1.05							
SO_3	0-0.08			2.88						1.5	
Insoluble residue	0-9.97										
Loss of Ignition	0-0.25							32-35			
Lime		32-45						37-39			
Magnesia		5-15								3	
Sulphur		1-2									
P_2O_5		0.5-1		0.13							
Cr_2O_3			.32-10.97								
Na_2O				0.31							
TiO2				0.33							0.5-2
Others				0.23							2-6
LOI						45.02					
Silica								24-26			

E. Marble Waste

Kore and Vyas 2016, considered marble waste as replacement to coarse aggregate along with Natural coarse aggregate, natural sand conforming to grading zone II as per BIS 383 1997, and PPC cement fulfilling the requirement as per BIS 1489 Part I 1991, where the slump values reported are 78mm, 90mm, and 95 mm with percentage of replacement being 0%, 75% by weight and 75% by packing density approach respectively. In another experiment reported by Mamun et al., 2017, where marble waste was used as coarse aggregate slump values reported are 65mm, 57mm, 52mm and 46mm respectively where replacement in percentage is 0%.10%, 20% and 30% respectively by weight.

F. Ceramic Waste

Kumar and Sagar 2016, conducted laboratory experimental study on utilization of ceramic waste as partial replacement of coarse aggregate in concrete where slump values reported are 120mm, 122mm, 127mm, 134mm, and 140mm for percentage by weight replacement as 0%, 10%, 20%, 30% and 40% by weight as replacement.

G. Recycled aggregate

Gadde et al., 2017 considered demolished concrete as a partial replacement to coarse aggregate where the slump results reported are 50mm, 45mm, 42mm, 35mm and 25mm for percentage by weight replacement as 0%, 25%, 50%, 75% and 100% respectively, they considered OPC 53 grade cement along with natural coarse and fine aggregate.

H. Recycled Coarse aggregate

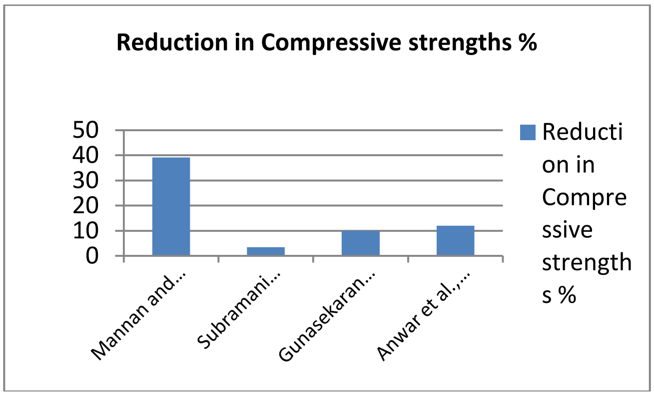
Jain et al., 2015 considered Recycled coarse aggregate as replacement with coarse aggregate and reported slump values as27mm, 22mm and 18mm with replacement by weight in percentage as 0%, 50% and 100% respectively. When used a super plasticizer 0.25% by weight to addition with concrete the slump results are 34mm, 32mm and 30mm for replacement in coarse aggregate by weight in percentage is 0%, 50% and 100% respectively.

V. DISCUSSION

A. Agricultural Waste

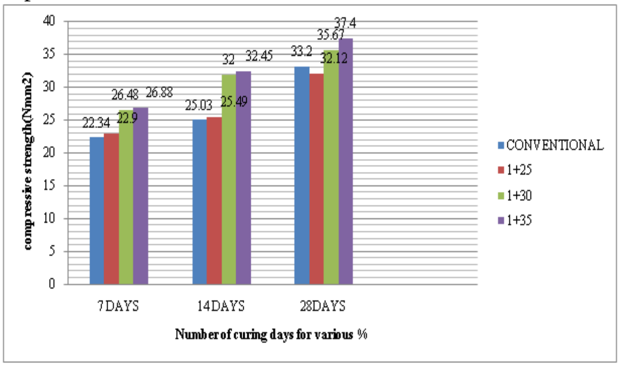
Mannan and Ganapathy 2003, experimented using Oil Palm shell in Concrete along with FDN super plasticizer for increasing workability, Slump values found increasing highly and following are the results of compressive strength found after curing about 28 days with Normal concrete as 39.75 MPa and with 100% OPS concrete as 24.22 MPa causing a decrease in Compressive strength about 39.2% after 28days curing. Water-cement ratio was kept at 0.41 for the whole experiment. Subramani and Anbuvel 2016, found experimental behavior of reinforced concrete beam with concrete shell as coarse aggregate where Size of coconut shell was Maximum kept to 20mm, fineness modulus 6.48, water absorption 23% and shell thickness for about 3-6 mm. After 28 days of curing following results were observed, Compressive strength for 0%,5%,10%,15% an d 20% replacements were 20.3 MPa,19.60MPa,18.84MPa,18.62 MPa,18.46MPa respectively. Split tensile strength results for same percentages of replacement as above were 2.39, 2.12, 1.86, 1.24 and 0.8 in MPA respectively. It was found that for optimum percentage of replacement there was reduction in compressive strength for about 3.44% and for split tensile strength there was about 11.2% reduction compared to control concrete. Gunasekaran et al 2011, experimented to find long term behavior of compressive and bond strength of coconut shell in coarse aggregate under 3 different water conditions, full water curing, partial water curing and Air dry condition, in this paper full water condition is considered for comparison with other results. After 28 days of curing Compressive strength under 3 conditions were found to be 27, 27.5 and 26 MPa respectively.

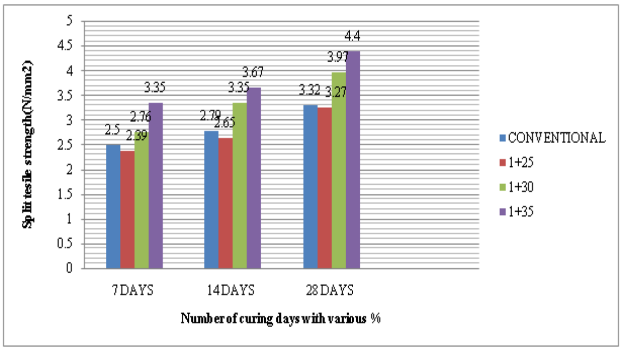
Anwar et al, 2016, experimented to know performance of concrete shells as coarse aggregate in concrete where compressive strength in MPa is found to be for replacement of percentage of 0%, 5%, 10%, 20%, 30%, 40% and 50% as 23.25,21.45,20.75,19.63,18.67,17.03 and 16.20 respectively. Optimum percentage of replacement was declared to be 10% replacement by weight with coarse aggregate. After considering following papers, the results were plotted in a graph and following was observed.

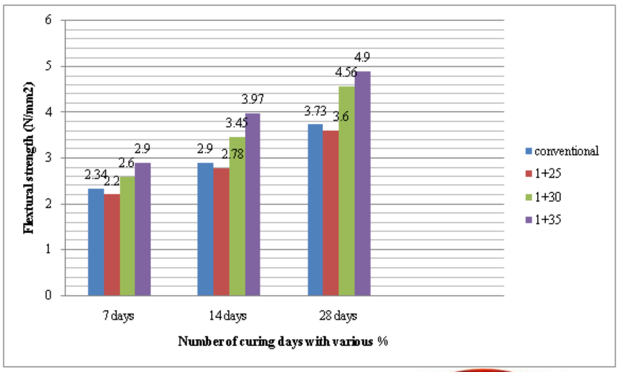


B Iron Slag:

Kumar and Kumar 2016 experimented to study with partial replacement of coarse aggregate by Iron slag. Control concrete with 25%, 30% and 35% coarse aggregate replacement was done and compressive strength in MPa was found as 33.2, 32.12, 35.67 and 37.4 respectively, similarly for percentages of replacement split tensile strength in MPa was found to be 3.32, 3.27, 3.93 and 4.4 respectively. Flexural strength results in MPa were 3.97, 3.6, 4.56 and 4.9. Graphs of the results are attached.



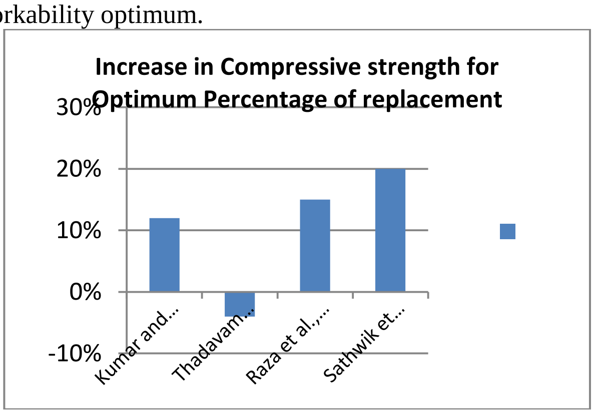




Thandavamoorthy 2016, experimented to know feasibility of making concrete with Iron slap scrap as coarse aggregate with percentage of replacement as 0%, 25%, 50%, 75% and 100%. Compressive strength in MPa for 28 days of curing was found to be 49.25, 42.50, 48.00, 45.33 and 48.33 respectively. Split tensile strength in MPa for 28 days of curing was found to be 1.98, 2.12, 2.12, 2.26 and 1.98. Water cement ratio was kept at 0.45 and was designed for M25 Design Mix. Optimum percentage of replacement was found to be 50% in this case and decrease of compressive strength was about 4%.

Raza et al, 2014 experimented to do strength analysis of concrete by using Iron slag as a partial replacement of normal aggregate in concrete where different proportions of replacements 0%, 10%, 20%, 30%, 40% and 50% designed for Design mix of M40. Compressive strength in MPa was after 28 days of curing was found to be 41, 43, 46.63, 49.76, 42.22 and 40 MPa. Flexure strength in MPa after 28 days curing was found to be 6.37, 6.94, 7.63, 5.63, 5.04, and 4.40 respectively. Optimum percentage of replacement was found to be 20% by weight of replacement in coarse aggregate by Iron slag. Percentage of Increase in Compressive strength was about 15% compared to control concrete.

Sathwik et al, 2016 experimented on Development of high strength concrete using ferrochrome slag aggregate as replacement to coarse aggregate. Super plasticizer was used to keep the workability high with water cement ratio as 0.33. Percentages of replacement were 0%, 25%, 50%, 75% and 100%. Compressive strength in MPa after 28 days of curing was found to be 50.27, 52.49, 57.47, 70.34 and 55.98 respectively. Split tensile strength in MPa after 28 days of curing was found to be 3.53, 4.03, 4.58, 5.26 and 4.64 respectively whereas flexural strength in MPa after 28 days of curing was found to be 3.65, 3.76, 4.31, 6.54 and 4.55 respectively. Optimum percentage in this case was found to be 75% of replacement by weight of coarse aggregate with ferrochrome slag; super plasticizer was used to keep the workability optimum.



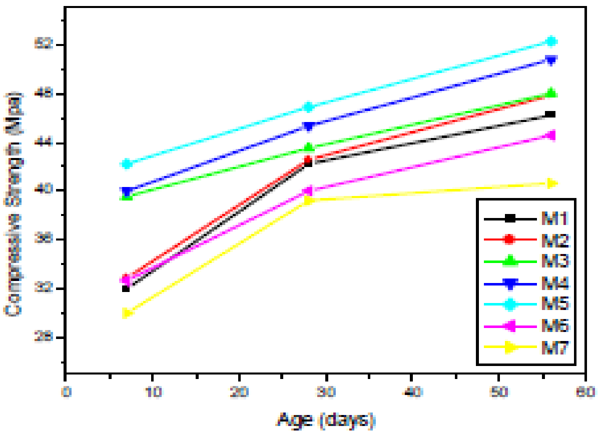
C Recycled aggregate:

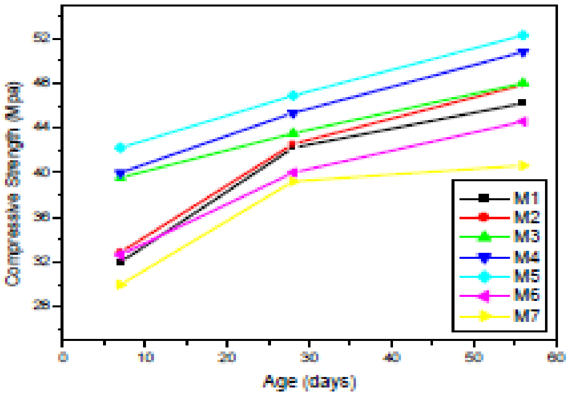
Dabhade et al., 2012 studied performance of recycled aggregate in concrete with different water cement ratios 0.5, 0.6 and 0.7 with 100% replacement of natural aggregate with recycled aggregate following results were obtained where compressive strength in MPa after 28days of curing was found to be 27.67, 26.53, 26.82, 25.92, 25.57 and 23.73 respectively. Split tensile strength in MPa after 28days of curing was found as 3.24, 3.073, 2.82, 2.73, 2.23 and 2.09. Optimum Percentage of replacement was found to be 20% by weight of coarse aggregate, where the reduction in compressive strength is 2%.

Kamala and Rao 2012, experimented using building demolition waste as replacement to natural coarse aggregate. Coarse aggregate was replaced by different percentages of 0%, 10%,20%, 30%, 40%, 50% and 60% with water cement ratio as 0.5. Compressive strength in MPa after 28 days of curing was found to be 42.22, 42.56, 43.51, 45.34, 46.88, 40.00 and 39.22 respectively where design mix was M40. Split tensile strength in MPa after 28 days of curing was found to be 3.15, 3.49, 3.55, 3.64, 3.72, 2.84 and 2.45 respectively.

Fresh concrete properties with respect to replacement of coarse aggregate to fresh concrete

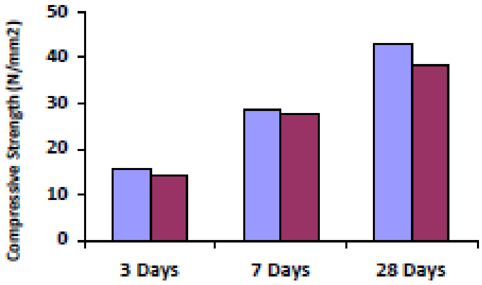
Author	Industrial Waste	W/C	% Replacement	Slump in mm/CF	Compressive Strength (MPa)	Split Tensile Strength (MPa)	Flexural Strength (MPa)
Devi and Gnanavel, 2014	Steel slag	0.55	0	35	20.67	2	1.8
			10	22	22.80		
			20	17	24.75		
			30	12	28.33	2.5	3.5
			40	8	27.02		
			50	3	25.06		
Thandavamoorthy 2016	Iron slag	0.5	0		49.25	1.98	
			25		42.50	2.12	
			50		48	2.12	
			75		50.33	2.26	
			100		48.33	1.98	
Sathwik et al., 2016	Ferrochrome slag	0.33	0	0.95	50.27	3.53	3.65
			25	0.98	52.49	4.03	3.76
			50	0.99	57.47	4.58	4.31
			75	0.99	70.24	5.26	6.24
			100	1	55.98	4.64	4.55
Panda and Bal 2012	Recycled Coarse aggregate	0.33	0		31	4.2	3.7
			10		30	4.05	3.6
			20		28.5	3.9	3.2
			30		27	3.75	3.15
			40		23	3.5	3.05
[illegible] et. al., 2017	Recycled aggregate	0.5	0	50	32.58		
			25	45	31.47		
			50	42	30.43		
			75	35	29.43		
			100	25	28.44		
Kore and Vyas 2015	Marble waste	0.55	0	0.86	15.29		
			20	0.88	16.86		
			40	0.88	17.92		
			60	0.97	18.68		
			80	0.98	21.29		
			100	0.99	19.94		
Senthamarai et al., 2010	Ceramic Waste	0.35	100	13	51	3.11	7.8
		0.4	100	24	45.75	3.19	7.08
		0.45	100	45	49.53	3.37	7.29
		0.5	100	64	47.24	3.12	6.4
		0.55	100	99	45.67	2.95	5.93
		0.6	100	155			
Rajendra et al., 2017	Stone waste	0.4	0		29.64	2.42	
			20		30.96	2.89	
			40		32.31	3.01	
			60		30.01	2.63	
[illegible] et al., 2015	Plastic Waste	0.5	0		27	2.4	
			5		18	2.48	
			10		17	2.25	
			15		16	2.2	
[illegible] et al., 2016	Electronic waste	0.5	0	27	42.85		
			5	31	40.51		
			10	38	39.42		
			15	47	36.85		
			20	61	38.87		
			25	70	36.77		
			30	73	35.41		
Anwar et al., 2016	Agricultural Waste	0.5	0		23.25		
			5		21.45		
			10		20.75		
			20		19.63		
			30		18.67		
			40		17.03		
			50		16.20		



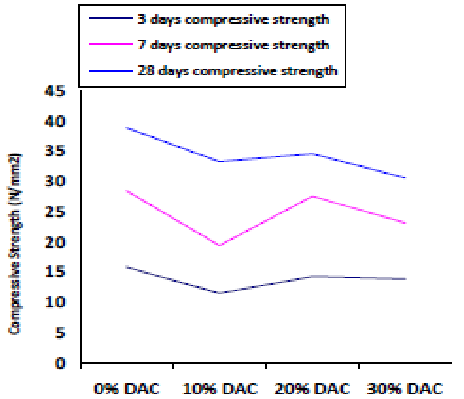


Flexural strength was found to after 28 days of curing 6.8, 7.14, 7.42, 7.68, 7.82, 6.32 and 6.54 respectively. Optimum percentage of replacement was found to be 20% of replacement by weight of coarse aggregate.

Somani et al., 2016 experimented to know use of demolished concrete waste in partial replacement of coarse aggregate in concrete with different percentages of replacement as 10%, 20%, 30% by weight of conventional coarse aggregate where optimum percentage of replacement of was found to be 20% by weight of coarse aggregate.

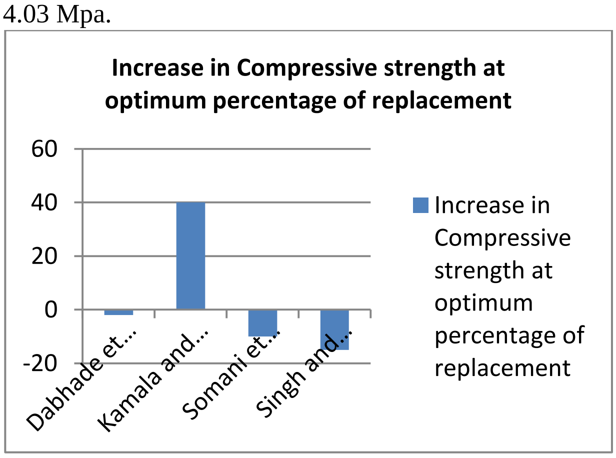


Fig(e) 20% DCA Compressive Strength



Fig(g) Compressive Strength of different percentage of DCA

Singh and Kumar 2014, experimented to know the utilization of demolished concrete and construction waste as coarse aggregate in concrete where compressive strength and flexural strength of concrete was studied. Optimum percentage of replacement was found to 15% partial replacement by weight of coarse aggregate. Compressive strength at 0% replacement for M40 design mix after 28 days of curing in MPa was found to be 42.81, at 10% replacement compressive strength was 19.40 MPa and at 15% replacement compressive strength was 36.37%. Flexural strength at optimum percentage of replacement was found to be 4.03 Mpa.



VI. CONCLUSIONS:

1. Not much study is done on Iron slag and Ferrochrome slag and much work is need for data analysis.
2. Recycled aggregate and Recycled coarse aggregate had average optimum percentage of replacement of 20% and 27% respectively where compressive strength was attained as per design mix without affecting the properties of conventional concrete.
3. As per IS 383 optimum percentage of replacement for plain concrete was found to 50%, 25%, and 25% for Iron Slag, Recycled aggregate and Recycled coarse aggregate respectively.
4. Experimental work of Recycled aggregate showed 20% replacement was average optimum replacement of natural coarse aggregate obtained fair results where in IS 383 it is allowed to use till 25% by weight of coarse aggregate.
5. Experimental work of Recycled coarse aggregate review shows 27% resulted optimum where in IS 383 it is allowed till 25% replacement by weight of coarse aggregate.

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