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Strength and Cost Analysis of Various Mix Design of Concrete Using Steel Slag, Coconut Shell and Rubber Aggregate

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ABSTRACT— Due to growing environmental awareness, as well as stricter regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial waste and finding solutions on using its valuable component parts so that those might be used as secondary raw material in other industrial branches. Although iron and steel slag is still today considered waste and is categorized in industrial waste catalogues in most countries in the world, it is most definitely not waste, neither by its physical and chemical properties nor according to data on its use as valuable material for different purposes. Moreover, since the earliest times of the discovery and development of processes of iron and other metals production, slag as by-product is used for satisfying diverse human needs, from the production of medicines and agro-technical agents to production of cement and construction elements. Considering the specificity of physical and chemical properties of metallurgical slags and a series of possibilities for their use in other industrial branches and in the field of civil constructions, this report demonstrates the possibilities of using iron slag as partial replacement of sand in concrete.

Iron and steel making slag are by products of the iron making and steelmaking processes. To date, these types of slag have been widely used in cement and as aggregate for civil works. The report presents an investigation of mechanical and durability properties of concrete by adding iron slag as replacement of sand in various percentages. The X-ray diffraction analysis carried out in this paper gives a deeper insight in the mineralogical constitution and behavior of such slags when used for construction purposes. The results show that the strength properties of concrete increase significantly when sand is partially replaced by iron slag.

KEYWORDS- Environmental Awareness, Industrial Waste, iron and steel slag, metallurgical slags.

I. INTRODUCTION

1. Introduction To Coconut Shell Used As An Aggregate In Concrete-

There were many experimental work conducted to improve the properties of the concrete by putting new materials, whether it is natural materials or recycle materials or synthetic materials in the concrete mix. The additional material can be replacing the aggregate, cement or just as additive is natural material.

Following a normal growth in population, the amount and type of waste materials have increased accordingly. Many of the non-decaying waste materials will remain in the environment for hundreds, perhaps thousands of years. The non-decaying waste materials cause a waste disposal crisis, thereby contributing to the environmental problems. However, the environmental impact can be reduced by making more sustainable use of this waste. This is known as the Waste Hierarchy. Its aim is to reduce, reuse, or recycle waste, the latter being the preferred option of waste disposal.

Fig.1 Coconut Shell **Fig.2 Coconut shell as aggregates.**

2. Introduction to rubber aggregate used in concrete-

Cement and aggregate, which are the most important constituents used in concrete production, are the vital materials needed for the construction industry. This inevitably led to a continuous and increasing demand of natural materials used for their production. Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are either recycled or discarded as a waste. Concrete strength is greatly affected by the properties of its constituents and the mix design parameters. Because aggregates represent the major constituent of the bulk of a concrete mixture, its properties affect the properties of the final product. An aggregate has been customarily treated as inert filler in concrete. However, due to the increasing awareness of the role played by aggregates in determining many important properties of concrete, the traditional view of the aggregate as inert filler is being seriously questioned. Aggregate was originally viewed as a material dispersed throughout the cement paste largely for economic reasons. It is possible, however, to take an opposite view and to look on aggregate as a building material connected into a cohesive whole by means of the cement paste, in a manner similar to masonry construction.

The other part of the problem is that aggregate production for construction purpose is continuously leading to the depletion of natural resources. Moreover, some countries are depending on imported aggregate and it is definitely very expensive. For example, the Netherlands does not possess its own aggregate and has to import. This concern leads to a highly growing interest for the use of alternative materials that can replace the natural aggregates.

Fig. 3 Rubber sample (before cutting)

Fig. 4 Chipped rubber samples

3. Introduction to steel slag used as an aggregate in concrete-

SLAG- Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminum silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slags required for various end-use consumers. Although, the chemical composition of slag may remain unchanged, physical properties vary widely with the changing process of cooling. The blast furnace (BF) is charged with iron ore, fluxing agents (usually limestone and dolomite) and coke as fuel and the reducing agent in the production of iron.

4. Utilization of metallurgical slags in construction industry

Slag is by-product formed in smelting, and other metallurgical and combustion processes from impurities in the metals or ores being treated. During smelting or refining slag floats on the surface of the molten metal, protecting it from oxidation or reduction by the atmosphere and keeping it clean. In iron and steel production slag phases are generated, formed mainly from the addition of mixture of oxides and fluxes and are also composed of reaction products like those resulting from the oxidation of charge materials and the dissolution of refractories. Primary purpose is to refine the liquid metal by removing impurities.

II. LITERATURE REVIEW

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space between the aggregate particles and glues them together. Numerous advances in all areas of concrete technology including materials, mixture proportioning, recycling, structural design, durability requirements, testing and specifications have been made. Innovative contracting mechanisms have been considered, explored and tried. Some progresses have been made in utilizing some of these technology innovations.

The main concrete making materials are discussed below.

1. Constituents of Concrete

i) Cement

Cement is a generic name that can apply to all binders. The chemical composition of the cements can be quite diverse but by far the greatest amount of concrete used today is made with Portland cements. For this reason, the discussion of cement in this thesis is mainly about the Portland cement.

ii) Aggregates

Aggregates generally occupy 70 to 80 % of the volume of concrete and can therefore be expected to have an important influence on its properties. They are granular materials derived for the most part from natural rock and sands. Moreover, synthetic materials such as slag and expanded clay or shale are used to some extent, mostly in lightweight concrete.

iii) Water

Water is a key ingredient in the manufacture of concrete. Attention should be given to the quality of water used in concrete. The time-honored rule of thumb for water quality is “If you can drink it, you can make concrete with it.” A large amount of concrete is made using municipal water supplies. However, good quality concrete can be made with water that would not pass normal standards for drinking water.

iv) Chemical Admixtures

Admixtures are ingredients other than water, aggregates, hydraulic cement, and fibers that are added to the concrete batch immediately before or during mixing. A proper use of admixtures offers certain beneficial effects to concrete, including improved quality, acceleration or retardation of setting time, enhanced frost and sulfate resistance, control of strength development, improved workability, and enhanced finish ability. It is estimated that 80% of concrete produced in North America these days contains one or more types of admixtures.

2. Coconut Shell-

There were many experimental work conducted to improve the properties of the concrete by putting new materials, whether it is natural materials or recycle materials or synthetic materials in the concrete mix.

i. Vishwas P. Kulkarni and Sanjay Kumar B. Gaikwad

Concrete is the widely used structural material in the world today. The demand to make concrete lighter has challenged scientists and engineers all over world. The challenge is to make lightweight concrete which decreases the concrete density while maintaining strength and without adversely affecting the cost. A common way is to introduce a new aggregates into the mix design to lower the concrete density.

ii. GopalCharan Behera and Ranjan Kumar Behera

The rapid urbanization and industrialization have increased the consumption of aggregates. So the researchers have to find the alternative for the coarse aggregate. The increase in population increases the industrial by-products, domestic wastes etc. In India that coconut shell (CS) is an agricultural waste, which requires high dumping yards and also is environmental polluting agent.

iii. Kulkarni Parag P. and Sanap Santosh T.

The effective way of utilizing crushed coconut shell aggregate in concrete is presented in this paper. As coconut shell is available at a low price in most of the tropical countries. The concrete obtained using coconut shell aggregates satisfy the minimum requirements of lightweight concrete.

3. Rubber aggregate

Recycled waste tyre rubber is a promising material in the construction industry due to its lightweight, elasticity, energy absorption, sound and heat insulating properties. The Literature available reveals that used rubber tyre can be effectively used in concrete to enhance the various properties of concrete and to protect environment.

i. ***Sara Sgobba et al, (2010)*** **-** The study explores the ameliorative effects of rubber particles on some properties of concrete. The result presented shows that the incorporation of rubber aggregates in concrete, obtained from waste tires, is a suitable solution to decrease the weight in some engineering manufactures.

ii. ***El-Gammalet al, (2010)*** **-** The application of recycled waste tire rubber by replacing fine and coarse aggregate in concrete has been performed at different percentages to study the change in compressive strength & density of concrete. Two different forms of waste rubber tier (i.e. chipped & crumb) have been used in the study.

iii. ***Malek K. Batayneh et al, (2008)-*** A research was carried out to find a positive method for disposing non-decaying materials, such as reuse in concrete mixes. Crumb rubber was used in the concrete mix to partially substitute for fine aggregate (sand) in various percentages of 20%, 40%, 60%, 80%, 100%. For each mix, cubes of 100x100x100 mm, cylinders of 150mm diameter by 300mm height, and small beams of 100x100x400 mm were prepared. All specimens were fabricated and then cured in water for 28 days in accordance with ASTM/C192M-06 Standard practices.

Table 1: Indian tyres industry general details

Consumption world ranking	4th
Total number of Tyre Companies	36
Total number of Tyre Factories	51
Tyre Production 2013-14 (Estimated)	110 Million
Industry Turnover (Estimated)	Rs.31000 crores
Capacity Utilization (Estimated)	84%
Growth in Truck & Bus tyre production	15%

4. Composition of a Tyre

A tire is an assembly of numerous components that are built up on a drum and then cured in a press under heat and pressure. Heat facilitates a polymerization reaction that crosslink's rubber monomers to create long elastic molecules. These polymers create the elastic quality that permits the tire to be compressed in the area where the tire contacts the road surface and spring back to its original shape under high-frequency cycles.

Table 2: Percentage Composition of Materials for a Passenger car and a Truck.

Material	**passenger car**	**Truck car**
Natural rubber	14 %	27 %
Synthetic rubber	27 %	14 %
Carbon black	28 %	28 %
Steel	14-15 %	14-15 %
Fabric, fillers, accelerators,		
antiozonants, etc.	16-17 %	16-17 %

5. Steel slag

Slag is used as substitute to previous clinker. The slag otherwise would have been a waste and used as a filler material slag, if used properly, will conserve valuable limestone deposits required for production of cement. Portland Slag Cement (PSC) has advantages of better performance, durability and optimal production cost, besides being eco-friendly. A brief review of the work carried out by various researchers on use of slag in concrete is presented below.

i. **K.G. Hiraskar and Chetan Patil (2013),** investigated the use of blast furnace slag as aggregates in concrete. The results showed that it has properties similar to natural aggregates and it would not cause any harm if incorporated into concrete. The research was encouraging, since they show that using blast furnace slag as coarse aggregates in concrete has no negative effects on the short term properties of hardened concrete.

ii. **Mohammed Nadeem1, Arun D. Pofale (2012),** studied on replacement of coarse and fine aggregate in concrete by slag. Concrete of M20, M30 and M40 grades were considered for a W/C ratio of 0.55, 0.45 and 0.40 respectively for the replacements of 0, 30, 50, 70 and 100% of aggregates (Coarse and Fine) by slag. Whole study was done in two phases, i.e. replacement of normal crushed coarse aggregate with crystallized slag and replacement of natural fine aggregate with granular slag.

iii. **Anastasiou and Papayianni, (2006),** investigated on using steel slag aggregates in concrete and found out that the 28 day strength was increased by 21% with replacement of natural aggregates, while there was no increase in the setting time of concrete mixtures.

iv. **Manso and Gonzalez (2004),** studied on durability of the concrete made with Electric Arc Furnace slag as an aggregate was done and the results showed that it was acceptable. The concrete mixes using conditioned EAF slag showed good fresh and hardened properties and acceptable behavior against aggressive environmental conditions.

v. **Maslehuddin, et al, (2003),** compared steel slag and crushed limestone aggregate. They studied the mechanical properties and durability characteristics of steel slag aggregate concrete in comparison with limestone aggregates. Abrasion resistance, specific gravity, water absorption, chemical soundness, alkalinity, concentration of chloride and sulfates were tested and compared with lime stone aggregates.

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III. METHODOLOGY

The ingredients of concrete i.e. cement, fine aggregate, fine aggregate, coconut shells are tested before producing concrete. As per Indian standard codes various test are conducted on ingredients materials of the concrete. Firstly the dry ingredients cement, coarse aggregate, fine aggregate and coconut shells are fed in mixer and thoroughly mixed to ensure even distribution. Then the Water is added and the mix is continued. Production of mix (normal concrete of grade M- 20) in the laboratory is carried out by IS method of concrete mix design (IS 10262-1982). Coconut shell concrete is produced by adding coconut shells in different percentage (i.e. 25% and 50%) replacement for coarse aggregate.

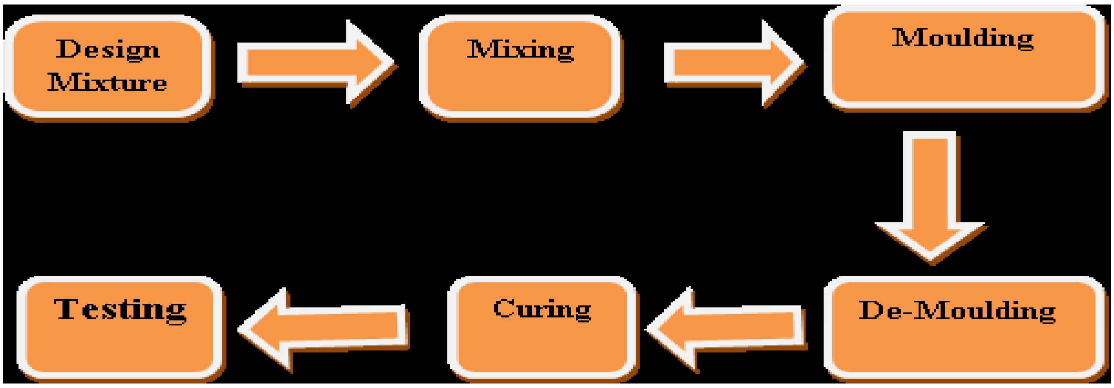

Fig. 5. Preparation of specimen

Step 1) To find the characteristics properties like sieve analysis, bulking, specific gravity, hardness, water absorption of materials such as sand, cement, coconut shell, steel slag, etc.

Step 2) Preparation of mix design using the properties of material which are found in step 1.

Step 3) Partial replacement of coarse aggregates with steel slag, coconut shells & rubber aggregates.

Step 4) Casting of 6 cubes for each mix design for each material, and test them on Compression Testing machine for compressive strength at 7 days and 28 days respectively.

Step 5) Analysis of compression test result and prepare comparative chart.

Step 6) Analysis and comparison of cost for getting economical mix design.

IV. RESULTS

4.1 Strength analysis:-

4.1.1 For coconut shell:

Table 3: Compressive strength results for M20 (1:1.3:2.67) grade concrete using coconut shell

% replacement of aggregates	Trial no.	compressive strength (MPa)		average compressive strength (MPa)	
		7 days	28 days	7 days	28 days
0	1	14.3	22.8	15.05	22.3
	2	15.6	23.6		
	3	15.25	20.5		
10	1	16.15	24.4	15.85	24.34
	2	15.78	23.8		
	3	15.62	24.9		
30	1	14.2	16.2	13.43	15.44
	2	13.16	14.8		
	3	12.92	15.3		

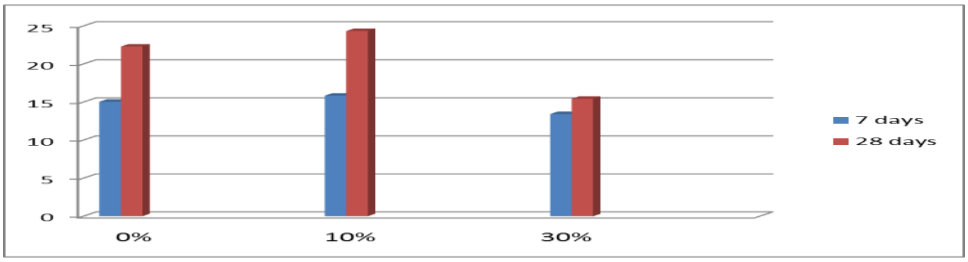

Fig. 6 Comparative graph of M20 (1:1.3:2.67) grade concrete for 7 days & 28 days curing for 0%, 10%, 30% replacement of coarse aggregates with coconut shells

Table.4 Compressive strength results for M25 (1:1.15:2.35) grade concrete using coconut shell

% replacement of aggregates	Trial	compressive strength (MPa)		average compressive strength	
		7 days	28 days	7 days	28 days
0	1	19.64	22.65	19.94	23
	2	20.22	23.25		
	3	19.96	23.1		
10	1	21.34	27.81	21.53	26.08
	2	21.2	26.25		
	3	22.05	26.34		
30	1	18.32	21.42	18.73	21.13
	2	18.8	20.66		
	3	19.08	21.32		

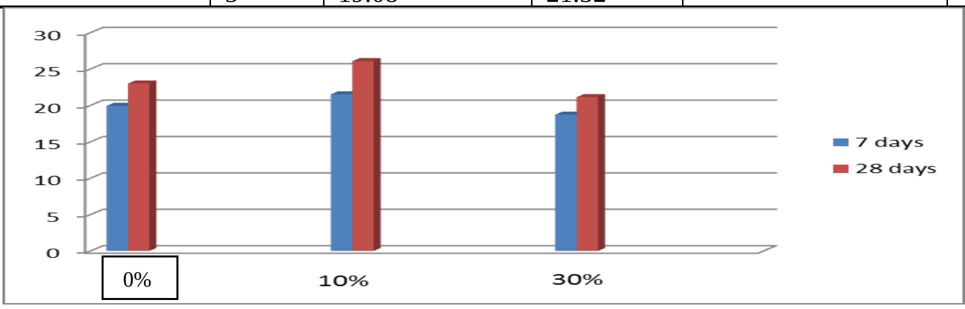

Fig. 7 Comparative graph of M25 (1:1.15:2.35) grade concrete for 7 days & 28 days curing for 0%, 10%, 30% replacement of coarse aggregates with coconut shells

4.1.2 For rubber aggregates:

Table .5: Compressive strength results for M20 (1:1.3:2.67) grade concrete using rubber aggregate

% replacement of	Trial	compressive strength (MPa)		average compressive strength	
		7 days	28 days	7 days	28 days
0	1	17.77	25.77	17.33	26.42
	2	16.89	26.66		
	3	17.32	26.82		
10	1	13.33	14.67	13.73	15.37
	2	14.22	16		
	3	13.62	15.45		
30	1	10	12.56	10.74	12.1
	2	10.6	11.55		
	3	11.62	12.12		

Fig. 8 Comparative graph of M20 (1:1.3:2.67) grade concrete for 7 days & 28 days curing for 0%, 10%, 30% replacement of coarse

Table.6: Compressive strength results for M25 (1:1.15:2.35) grade concrete using rubber aggregate

% replacement of aggregates	Trial no.	compressive strength (MPa)		average compressive strength (MPa)	
		7 days	28 days	7 days	28 days
0	1	20.52	29.6	21.17	29.12
	2	21.68	28.95		
	3	21.3	28.83		
10	1	15.35	17.2	15.76	18.27
	2	16.25	18.6		
	3	15.67	19.01		
30	1	13.42	15.6	13.52	15.62
	2	14.2	15.2		
	3	13.86	16.05		

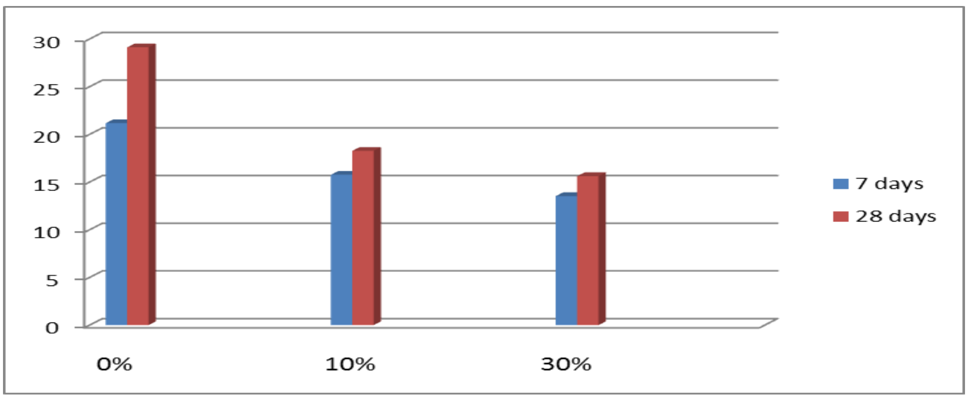

Fig. 8 Comparative graph of M25 (1:1.15:2.35) grade concrete for 7 days & 28 days curing for 0%, 10%, 30% replacement of coarse aggregates with rubber aggregate

4.1.3 For steel slag:

Table.6: Compressive strength results for M20 (1:1.3:2.67) grade concrete using steel slag

% replacement of aggregates	Trial no.	compressive strength (MPa)		average compressive strength (MPa)	
		7 days	28 days	7 days	28 days
0	1	18.26	23.58	19.54	23.75
	2	20.64	23.6		
	3	19.72	24.08		
10	1	20.74	24.52	21.71	23.31
	2	21.87	25.66		
	3	22.51	25.73		
30	1	23.5	26.8	23.99	27.46
	2	24.12	28.34		
	3	24.35	27.25		

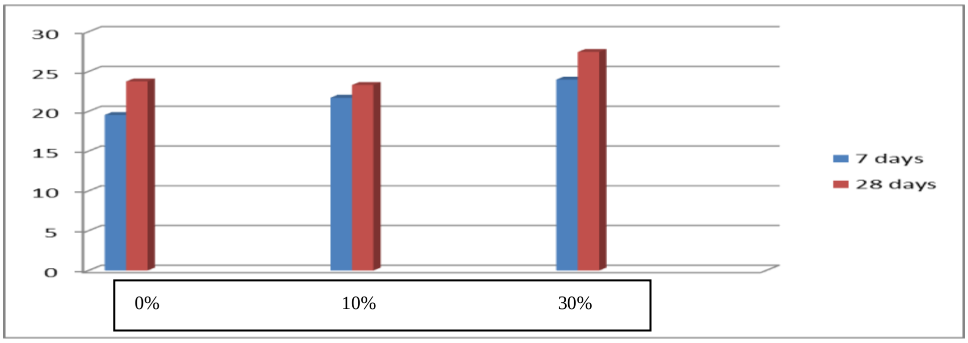

Fig. 9 Comparative graph of M20 (1:1.3:2.67) grade concrete for 7 days & 28 days curing for 0%, 10%, 30% replacement of coarse aggregates with steel slag

Table.7: mpressive strength results for M25 (1:1.15:2.35) grade concrete using steel slag

% replacement of aggregates	Trial no.	compressive strength (MPa)		average compressive strength (MPa)	
		7 days	28 days	7 days	28 days
0	1	20.4	25.9	21.45	26.72
	2	22.60	26.58		
	3	21.35	27.67		
10	1	21.63	26.95	21.63	27.8
	2	24.52	27.83		
	3	233.8	28.61		
30	1	18.32	21.42	18.87	21.86
	2	18.8	20.66		
	3	19.5	23.5		

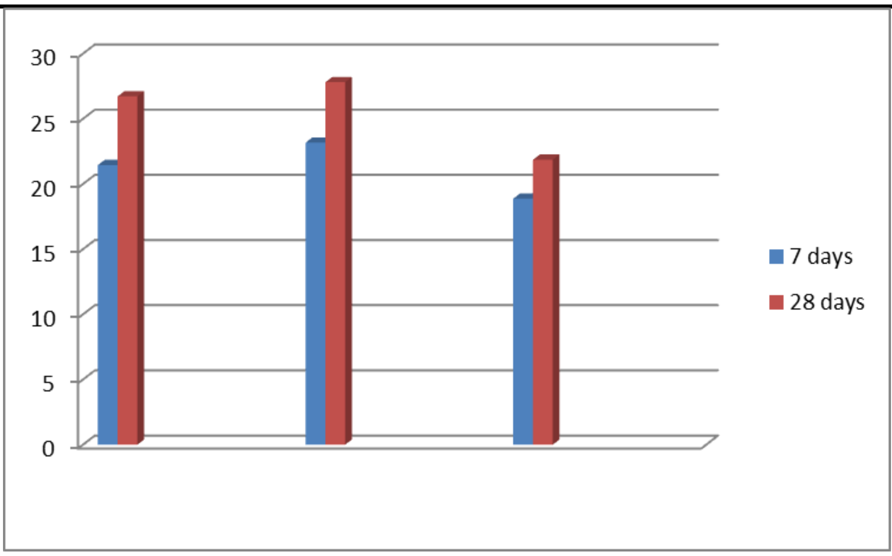

Fig. 10 Comparative graph of M25 (1:1.15:2.35) grade concrete for 7 days & 28 days curing for 0%, 10%, 30% replacement of coarse aggregates with steel slag

4.2 Cost analysis-

4.2.1 For coconut shell-

Table.8: Cost analysis for M20 (1:1.3:2.67) grade concrete using coconut shell

Material	Rate (Rs.)	Cost of Concrete (Rs.)		
		PCC	10% CS replace concrete	30% CS replace concrete
Cement	6.5/kg	1885	1885	1885
Crushed sand	990/cum	432	432	432
10 mm aggregate	815/cum	204	184	143
20 mm aggregate	815/cum	525	525	525
Coconut shells	0/kg	0	0	0
	Total (Rs.)	**3046**	**3026**	**2985**

Table.9 analysis for M25 (1:1.15:2.35) grade concrete using coconut shell

Material	Rate (Rs.)	Cost of Concrete (rs.)		
		PCC	10% CS replace concrete	30% CS replace concrete
Cement	6.5/kg	2080	2080	2080
Crushed sand	990/cum	466	466	466
10 mm aggregate	815/cum	194	175	136
20 mm aggregate	815/cum	499	499	499
Coconut shells	0/kg	0	0	0
	Total (Rs.)	**3239**	**3220**	**3181**

4.2.2 For Rubber Aggregates:

Table. 10: Cost analysis for M20 (1:1.3:2.67) grade concrete using rubber aggregate

Material	Rate (Rs.)	Cost of Concrete (rs.)		
		PCC	10% RA replace concrete	30% RA replace concrete
Cement	6.5/kg	1885	1885	1885
Crushed sand	990/cum	432	432	432
10 mm aggregate	815/cum	204	184	143
20 mm aggregate	815/cum	525	525	525
Rubber Aggregate	12/kg	0	480	1440
	Total (Rs.)	**3046**	**3506**	**4425**

Table.11: Cost analysis for M25 (1:1.15:2.35) grade concrete using rubber aggregate

Material	Rate (Rs.)	Cost of Concrete (rs.)		
		PCC	10% RA replace concrete	30% RA replace concrete
Cement	6.5/kg	2080	2080	2080
Crushed sand	990/cum	466	466	466
10 mm aggregate	815/cum	194	175	136
20 mm aggregate	815/cum	499	499	499
Rubber Aggregate	12/kg	0	456	1368
	Total (Rs.)	**3239**	**3676**	**4549**

4.2.3 For Steel Slag:

Table.12 Cost analysis for M20 (1:1.3:2.67) grade concrete using steel slag

Material	Rate (Rs.)	Cost of Concrete (rs.)		
		PCC	10% CS replace concrete	30% CS replace concrete
Cement	6.5/kg	1885	1885	1885
Crushed sand	990/cum	432	432	432
10 mm aggregate	815/cum	204	184	143
20 mm aggregate	815/cum	525	525	525
Steel slag	17/kg	0	680	2040
	Total (Rs.)	**3046**	**3706**	**5025**

Table.13 Cost analysis for M25 (1:1.15:2.35) grade concrete using steel slag

Material	Rate (Rs.)	Cost of Concrete (rs.)		
		PCC	10% CS replace concrete	30% CS replace concrete
Cement	6.5/kg	2080	2080	2080
Crushed sand	990/cum	466	466	466

10 mm aggregate	815/cum	194	175	136
20 mm aggregate	815/cum	499	499	499
Steel slag	17/kg	0	646	1938
	Total (Rs.)	**3239**	**3866**	**5119**

V. CONCLUSION

1. The coconut shell aggregates have higher water absorption because of higher porosity in its shell structure. The aggregate impact value of coconut shell aggregates are much lower compared to crushed stone aggregate which indicates that this aggregates have good absorbance to shock.
2. The 28 days compressive strength for M20 grade concrete of coconut shell concrete was found to be 24.05 for 10% replacement by coconut shell aggregate under full water curing and it satisfies the requirement for structural lightweight concrete.
3. The 28 days compressive strength for M25 grade concrete of coconut shell concrete was found to be 27.03 for 10% replacement by coconut shell aggregate under full water curing and it can be used for less important work.
4. This can be useful for construction of low cost housing society.
5. The coefficient of permeability was found to be negligible in all the samples of concrete mixes containing furnace slag whereas the coefficient of permeability was more in concrete mixes without furnace slag.
6. The presence of furnace slag in concrete mixes acts as pore fillers and causes reduction in the pores, resulting fine and discontinuous pore structures and thereby increases the impermeability of concrete.
7. Compressive strength of steel slag concrete increases in 12 % compared to the conventional coarse aggregate concrete.
8. The Compressive strength tends to increase with increase percentages up to 30% of iron slag in the mix.
9. At 30% replacement of coarse aggregate with Iron slag aggregate gives desirable compressive strength.
10. Hence, it could be recommended that the Iron slag aggregate could be effectively utilized as coarse as coarse and fine aggregate in all concrete applications.
11. Introduction of recycled rubber tyres into concrete mix leads to decrease in slump and workability for the various mix samples.
12. Rubberized concrete can be used in non-load bearing members i.e. lightweight concrete walls, other light architectural units, thus rubberized concrete mixes could give a viable alternative to where the requirements of normal loads, low unit weight, Medium strength, high toughness etc.
13. The overall results of this study show that it is possible to use recycled rubber tyre aggregates in concrete construction as partial replacement to mineral coarse aggregates
14. Fine and coarse aggregates of rubber increased workability of fresh concrete. .
15. The compressive strength of concrete with rubber decreased with increase of curing time.

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