Experimental Study On Partial Replacement Of Fine Aggregate By Steel Slag And Coarse Aggregate By Pebble Stone In Concrete

Thilagavathy.C[1], Thenmozhi.S[2] Ph.D.

[1]M.E-Structural Engineering Student, Sree Sastha Institute of Engineering and Technology, Chennai.
[2]Professor, Dept. of Civil Engineering, Sree Sastha Institute of Engineering and Technology, Chennai..
Tamilnadu, India.
cthilagavathyc@gmail.com

---***---

Abstract - *Concrete has been proved to be a leading construction material for more than a century. Natural aggregates are becoming increasingly scarce and their production and shipment is becoming more difficult. Steel slag is an industrial by product obtained from the steel manufacturing industry. Steel slag can be used in the construction industry as aggregates in concrete by replacing natural aggregates. The primary aim of this research was to evaluate the strength of concrete made with steel slag as replacement for fine aggregates. For this present study M40 grade concrete shall be designed, Partial replacement of sand with steel slag will be made for varying percentages such as 10%, 20%, 30%, 40%, 50% by weight of sand. The river stone has got high potential for being a natural aggregate, it is been rarely used as a concrete material. The present investigation envisages the potential utilization of pebble stone as a coarse aggregate in replacement of crushed stone aggregate in concrete. The percentages of replacements were 25%, 50% and 75% by weight of coarse aggregate. Studies on compressive strength, tensile strength, flexural strength would be made the optimum percentage of steel slag and pebble stone replacement.*

Key Words**: Steel slag, Pebble stone, compressive strength, split tensile strength, flexural strength**

1. INTRODUCTION

The word concrete comes from the Latin word “concretus” (meaning compact or condensed), the perfect passive participle of “concrescere”, from “con” (together) and “crescere” (to grow). Perhaps the earliest known occurrence of cement was 12 million years ago. A deposit of cement was formed after an occurrence of oil shale located adjacent to a bed of limestone burned due to natural causes. These ancient deposits were investigated in the 1960s and 1970s.

The Romans used concrete extensively from 300 BC to 476 AD, a span of more than seven hundred years. Concrete, as the Romans knew it, was a new and revolutionary material. Laid in the shape of arches, vaults and domes, it quickly hardened into a rigid mass, free from many of the internal thrusts and strains that troubled the builders of similar structures in stone or brick. Concrete additives have been used since Roman and Egyptian times, when it was discovered that adding volcanic ash to the mix allowed it to set underwater. Similarly, the Romans knew that adding horse hair made concrete less liable to crack while it hardened, and adding blood made it more frost-resistant. In modern times, researchers have experimented with the addition of other materials to create concrete with improved properties, such as higher strength or electrical conductivity.

1.1 OBJECTIVES OF STUDY

This study is conducted to achieve the following objectives: This study was conducted to achieve the following objectives:

i. To evaluate mechanical properties by use of Steel slag in concrete specimens.
ii. To determine Strength, Workability, Durability by using Steel slag as partial replacement of fine aggregate using different proportion.
iii. To find the optimum proportion (20%, 30% & 40%) of Steel Slag that can be used as a replacement substitute material for fine aggregate in concrete.
iv. To study the strength developments hardened concrete with crushed pebble stone in coarse aggregate.
v. To determine the effect of various percentage of crushed pebble stone as partial coarse aggregates replacement towards compressive strength of concrete.
vi. To find the optimum proportion(10%, 20% & 30%) of Crushed pebble stone that can be used as a replacement substitute material for coarse aggregate in concrete
vii. To reduce the waste materials which comes from industries.

1.2 SCOPE OF STUDY

- Flexural Strength of structural members can be improved.
- Proper usage of waste materials from environment can be made.
- Basic strength characteristics, such as Compressive strength, Flexural strength, Tensile strength, and Density of concrete are the main

focuses in this project in order to study the quality and performance of concrete.

2. LITERATURE REVIEW

The usage of industrial by-products especially industrial wastes in making of concrete is an important study of worldwide interest. Many researchers have investigated the possible use of Steel slag, and Crushed pebbles as a concrete aggregate. For this investigation, some of the important literatures were reviewed and presented briefly.

2.1. STEEL SLAG

T. Subbulakshmi, et.al (2016), experiments were conducted to study mechanical properties of high performance concrete with different percentage replacement of mineral admixture and industrial by-products such as silica fume, bottom ash and steel slag aggregate. Presence of calcium hydroxide layer at the aggregate surfaces as reported extensively for conventional concrete is not seen in high performance concrete because of usage of combination mix of silica fume, bottom ash and slag by-products and presence of partially hydrated cement grains in conventional concrete matrix and the ITZ. It is widely reported that the permeability of concrete reduces drastically with inclusion of silica fume. Steel slag aggregate mix of concrete shows that the presence of ettringite in direct contact with aggregate of calcium hydroxide film in the ITZ of normal concrete. A combined model developed in ANN by using inputs from compressive strength of concrete predicts more accurately and it is recommended to be used alone to predict strength of concrete.

P.Sateesh Kumar, et.al (2015), this paper aims to study experimentally, the effect of partial replacement of fine aggregate by steel slag (ss), on the various strength and durability properties of concrete by using the mix designs. the optimum percentage of replacement of fine aggregate by steel slag is found. The compressive strength, flexural strength and split tensile strength of normal concrete and concrete with Steel slag as partial replacements are compared and observed that the strength of the normal concrete is slightly lower than the Steel slag replaced concrete. The compressive strength increases with increase in percentage of steel slag up to 40% by weight of fine aggregate. The enhancement in compressive strength is about 32% for 7 days curing and 27.2% for 28 days curing. The split tensile strength increases with increase in percentage of steel slag up to 40% by weight of fine aggregate. The enhancement in split tensile strength is about 48.2% for 7 days curing and 31.2% for 28 days curing.

P.S.Kothai, et.al (2014), this work relates the use of steel slag, a waste cheap material used as fine aggregates in M20 grade of concrete and recommends the approval of the material for use in concrete as a replacement material for fine aggregates. The partial substitution of natural aggregates with steel slag aggregates permits a gain of compressive, tensile and flexural strength and modulus of elasticity of concrete up to an optimum value of replacement .The following benefits can also be obtained: Cost reduction, Social benefits & Mass utilization of waste material is possible in construction by using steel slag as a partial replacement material for fine aggregates in concrete.

P. Vignesh Kumar, et.al (2014), in this study of partial replacement of coarse aggregate with iron slag in the cement concrete have greater strength than the conventional concrete. As the self-weight of this concrete is higher. The polypropylene fibres are free from water absorption. With improved understanding of the link between fibre characteristics and composite or structural performance. In 25 % iron slag used the compressive strength decreased 1% and split tensile strength also decreased. If the addition of 30% and 35% of the iron slag used. Increased compressive strength in concrete. The compressive strength of the concrete is increased 4%and 5% compared then the conventional concrete. 30and 35 % of the addition of iron slag is 6% increased split tensile strength and flexural strength compared than conventional concrete.

R.Kalpan, et.al (2014), this research has shown that replacing some percentage of natural aggregates by steel slag aggregates causes negligible degradation in strength. It is shown that as the amount of steel slag is increased beyond 75%. The results showed that replacing about 50 to 75% of steel slag aggregates by volume for natural aggregates will not do any harm to concrete and also it will not have any adverse effects on the strength and durability. Whole study was done by both the aggregates were replaced by crystallized & granular aggregates. The coarse aggregate were partially replaced by steel slag of about 10% and 20%. The fine aggregate were partially replaced by steel mill scale of about 40%and 50%. This partial replacement of coarse and fine aggregates with steel slag and steel mill scale will increases the strength of about 30% to 50%. The main aim of this research was to study the behavior of concrete and changes in the properties of concrete with steel slag and steel mill scale by replacing the use of natural aggregates.

2.2 CRUSHED PEBBLES

Pramodini Naik Gaonkar(2016) Workability of concrete mixes increases with the increase in percentage of river pebbles this is mainly because of smooth surface and round shape of river pebbles. If the workability had kept constant, the water content for some of the concrete mixes could have been reduced thus benefiting the mechanical properties of concrete. In fresh concrete , the slump test conducted for various trials, the result for that trials 60mm,120mm,120mm,140mm. In hardened concrete, the compression test conducted for various trials. The compression test was conducted using UTM on cubes at the age of 7 days, 14days and 28days of curing respectively and confirming to IS 516-1959. Cubes stored in water were not tested immediately on removal from water in damp condition. The actual dimension and weight of the specimen was noted. The specimen was placed on the testing platform of the compression testing machine in such a way that the load was applied to the top and bottom surface. The load was applied without shock and increase until the resistance of the specimen to the increasing load broke down and no greater load was sustained. The total load applied at failure was recorded. The maximum load applied divided by its cross sectional area given the cmpressive strength. Averages of two specimens were taken; provided the individual variation was not more than ± 15% of average. Cubes after curing were tested for compression for each trial after 7 days, 14 days and 28 days. It was observed that Compressive strength for all the trials is more than the minimum required strength of 26 Mpa, 36 Mpa and 40 Mpa roespectively at 7 days, 14 days and 28 days

Chandrashekhar.A,Maneeth P.D (2014) obtained the result of experimental investigation envisages the potential utilization of river stones as a coarse aggregate in the replacement of crushed stone aggregate in concrete. The main aim of their study was to determine fresh and hardened properties of concrete made with river stone and to compare with those using crushed stone aggregate and to ascertain whether river stone can be good aggregate for concrete. They have found through their investigations that river stones can be effectively used as partial replacement to coarse aggregates in concrete. Concrete made with river stone gains strength at the higher rate up to 28 days than the granite aggregate concrete but beyond 28 days there was a reduction in the rate of gain in strength of river stone concrete. The compressive strength for river stone concrete found to be less than crushed granite aggregate made from similar mix proportion. However, the compressive strength of the concrete mixes made using river stone exceeds the design strength of the concrete. The flexural tensile strength test result showed that addition of higher percentage of river stone will decrease the strength. This may be attributed to the smooth surface of the river stones, resulting in lower bonding strength with the matrix. The split tensile strength of cylinder specimen decreased with the increase in the percentage of river stone in concrete. Two different failure modes could be observed in split tensile testing of cylinders. In case of crush granite aggregates, the aggregate particles were found to split so as to form two equal halves. Where as in river stone, failure occurred at the aggregate– mortar matrix bonding interface. Even though the mechanical properties of concrete made using river stone decreased it was comparable with the standard aggregate concrete. Thus it can be concluded that the river stone which is abundantly available locally can be efficiently used as a coarse aggregate in concrete.

Goh Hee Chien (2009), The result of an experimental study on mechanical properties of concrete with different type of coarse aggregate and water/cementratios is presented. In this study concrete with 28 days target compressive strength of 30 N/mm^2 with workability at least 30mm were produce using pebble as aggregate and compare with the concrete using microtonalite as aggregate. The aims of the study were to investigate and determine the effect of pebble and microtonalite on mechanical properties of concrete and to determine the strength that can be achieved by both of the aggregates. The experimental focus on concrete mixes with a water binder ratio of 0.4, 0.45 and 0.50 without using admixture and superplasticizer. The mechanical properties of concrete were measured by conducted the cube compressive strength test. 28 days test result has indicated that the concrete mixture prepared with microtonalite produced the higher compressive strength, compare with concrete mixture prepared with pebble. However, concrete mixture prepared with pebble was able to reach the target compressive strength of 30 N/mm^2 by using water binder ratio of 0.45 and the result is 35.71 N/mm^2 with workability of 50mm.

2.3 LITERATURE SUMMARY

From all the above literature reviews, it was evident that Steel slag can be used as a cement replacement as well as fine aggregate replacement, and Crushed pebble stone can be used as a coarse aggregate replacement, individually in a concrete mix.

The optimum percentage of replacement was also identified for all materials individually. But there was no literature available on the utilization of all the two above mentioned replacement in the same concrete mix.

Hence it is planned to use Steel Slag and crushed pebble stone as fine and coarse aggregate respectively together as an ingredient of the concrete.

3. MATERIAL USED

The materials used for the project is collected and made sun dried before as initial testing and for further usage. The amount of material to be used should be noted in advance based on the preparation of mix design. From the results of mix design the quantity of each component such as cement, FA, CA and water will be finalized, then the collection of materials to be done and to be stored in a specified place free from impurities. Based on the availability of the materials and its condition the following tests were performed.

3.1 CEMENT

Ordinary Portland cement of 53 grade having specific gravity of 3.1 and fineness modulus of 4.62% was used. The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of IS 12269-1987.

3.2 FINE AGGREGATE

Fine aggregates are termed as "filler" which fills the voids in concrete. The fractions of aggregates less than 4.75mm are known as fine aggregates. The river sand is used as fine aggregate conforming to requirements of IS: 383-1970 comes under zone II.

3.3 COARSE AGGREGATE

Aggregates fractions larger than 4.75mm are termed as coarse aggregates. The fraction of aggregates used in the experimental work passed in 20mm sieve and retained on

10mm IS sieve comes under Zone II aggregates conforming to IS: 383-1970.

3.4 STEEL SLAG

Fig 3.1 Steel Slag

Steel slag is industrial waste resulting from steel refining plants in conversion process. There are two methods for steel slag production. Basic Oxygen Steel (BOS) and Electric Arc Furnace (EAF). BOS slag is obtained by blowing high pressure oxygen into a vessel containing molten iron, steel scrap and lime and EAF utilizes high voltage current to generate heat for doing the same process. The main utilization of BOF slag is as aggregate in road construction because of its suitable characteristics. In Europe about 65% of the produced steel slag is used as aggregate in road construction specially, as a substitute for high-quality natural aggregate in asphalt wearing courses. In china 40% of BOF slag production is used in BOF slag cement. Owing to the large production, the research work for last 30 years have shown that 65%of steel slag used today is for qualified field application. But remaining 35% of slag is still dumped. There are also few researches that have been performed regarding the utilization of steel slag in concrete as aggregate. This shows that it is advantageous to increase physical, chemical and mechanical properties of concrete.

3.5 CRUSHED PEBBLE STONE

Fig 3.2 Pebble Stone

Pebble stone is a clastic rock with particle size of 4 to 64 millimetres based on the Krumbein phi scale of sedimentology. Pebble stone is larger than gravel but smaller than cobble. A rock made predominantly of pebbles is known as a conglomerate. Pebble can come in a variety of different colours and textures, and can often have streaks of quartz and different colored sedimentary rock. Pebbles are mostly smooth, but dependent of how frequent they come in contact with the sea, can have marks of contact with other pebbles. Pebble left above the high water mark, may have the growth of organisms such as lichen on them, signifying the lack of contact with sea water. Pebble can easily found at riverbank, seashore and inland where ancient sea used to cover the land.

Table 3.1 Properties of cement materials

SI.NO.	DESCRIPTION	RESULT
1	Consistency%	30%
2	Initial setting time	30 min
3	Fineness%	3%
4	Specific gravity of cement	3.14

Table 3.2: Physical Properties of Fine Aggregate and Steel Slag

Materials	Specific Gravity	Finess Modulus (%)	Bulk Density (Kg/m3)	Water Absorption (%)
Fine Aggregate	2.64	2.66	1736.67	1
Steel Slag	2.93	2.97	1920	2

Table 3.3: Physical Properties of Coarse Aggregate and crushed pebble stone

Materials	Specific Gravity	Finess Modulus (%)	Bulk Density (Kg/m^3)	Water Absorption (%)
Coarse Aggregate	2.71	3.18	1612.67	0.50
Crushed pebble stone	2.63	3.85	1612.67	1.62

4. TESTING AND RESULT

Experimental Investigation comprises of test on cement, Fine aggregate and Coarse aggregate, concrete with partial replacement of Fine aggregate with Steel Slag and Coarse aggregate with Crushed pebbles.

4.1 MIX DESIGN

The mix proportion was done as per the IS 10262:2009 the target mean strength was 48.25 Mpa (40) for the OPC control mixture. Mix design is a term used for determining quantities of different constituents, which in our experiment was done with Indian standard method. The quantities of cement, fine aggregate, coarse aggregate, Rice Husk Ash, Copper Slag and Ceramic Tiles Waste were found out with help of this method. The proportions for normal mix of M40 Normal Mix were: - Cement: Sand: Coarse Aggregate: Water. After calculating the quantity, all constituents were weighed using electronic weighing machine.

Starts from cement, fine aggregate and Steel Slag were thoroughly mixed in dry state,. To the above mixture coarse aggregate and Crushed pebbles were added. Now the whole mixture was mixed manually. Water was finally added to the dry mixture.

After mixing operation, moulding was done and as the moulds were filled tamping was done simultaneously for compaction. After 24 hours demoulding was done and the specimen was placed in curing tank for 7, 14 and 28 days.

4.2 TESTING

Compressive Strength: To examine the compressive Standard cubical moulds of size 150mm × 150mm×150mm made of cast iron were used to cast concrete specimens to test compressive strength of concrete.

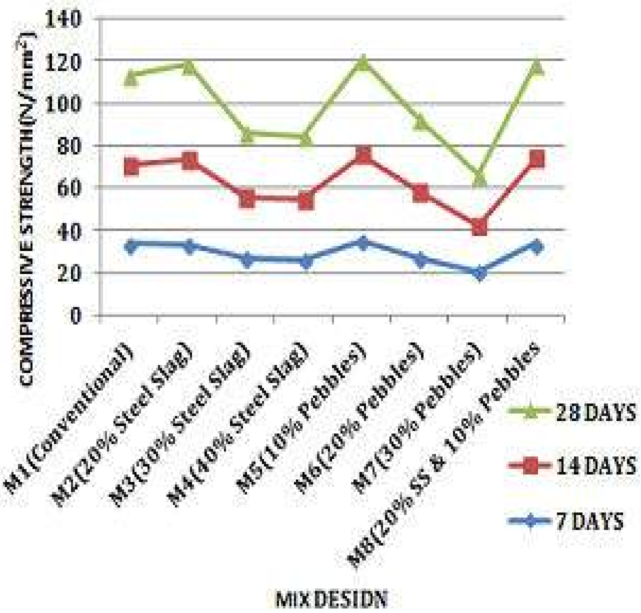
To determine the compressive strength we casted cubes with different percentage of Rice Husk ash, Copper slag and Ceramic tiles waste in the concrete. After that the specimen are tested at 7, 14 and 28 days at compression testing machine (CTM) as per I.S. 516-1959. The optimum percentage of RHA, Copper slag and Ceramic tiles waste were again casted and tested at 7, 14 and 28 days.

Fig 4.1 Compressive Strength Test

Table 4.1: Compressive Strength Result

MIX DESIGN	Compressive Strength(N/mm^2)		
	7 days	14 days	28 days
M1(Conventional)	33.78	37.26	42.51
M2(20% Steel Slag)	33.55	40.34	45.13
M3(30% Steel Slag)	27.05	28.75	30.44
M4(40% Steel Slag)	26.37	28.17	29.96
M5(10% Pebbles)	34.86	40.86	44.44
M6(20% Pebbles)	26.86	31.09	34.67
M7(30% Pebbles)	20.89	21.32	24.09
M8(20% Steel slag & 10% Pebbles)	33.68	40.28	44.68

Chart 4.1: Compressive Strength Result



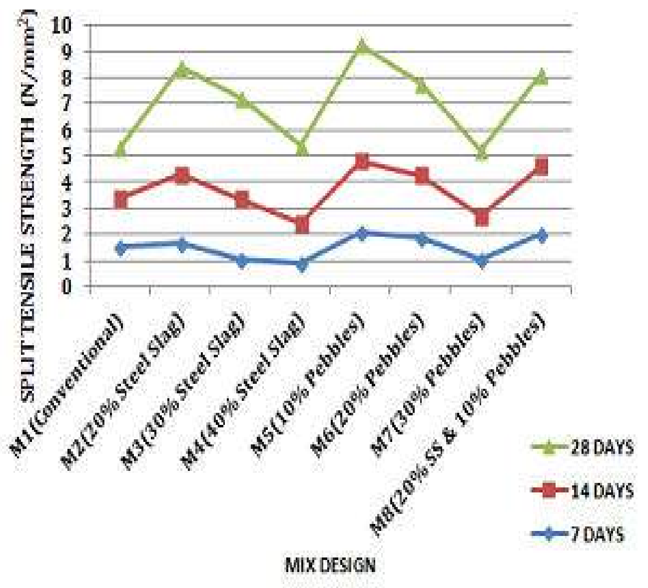
Split Tensile Strength: To examine the split tensile strength of plane mortar and mortar of various percentage of steel slag and crushed pebbles stones contents in concrete has been investigated by testing cylinders of 200mm x 100mm under CTM of 2000kN capacity.

Fig 4.2 Split Tensile Strength Test

Table 4.2: Split Tensile Strength Result

MIX DESIGN	Split Tensile Strength(N/mm²)		
	7 days	14 days	28 days
M1(Conventional)	1.55	1.82	2.01
M2(20% Steel Slag)	1.68	2.63	4.13
M3(30% Steel Slag)	1.02	2.34	3.87
M4(40% Steel Slag)	0.88	1.55	3.01
M5(10% Pebbles)	2.06	2.76	4.46
M6(20% Pebbles)	1.89	2.38	3.50
M7(30% Pebbles)	1.02	1.67	2.54
M8(20% Steel slag & 10% Pebbles)	2.02	2.60	3.54

Chart 4.2: Split Tensile Strength Result

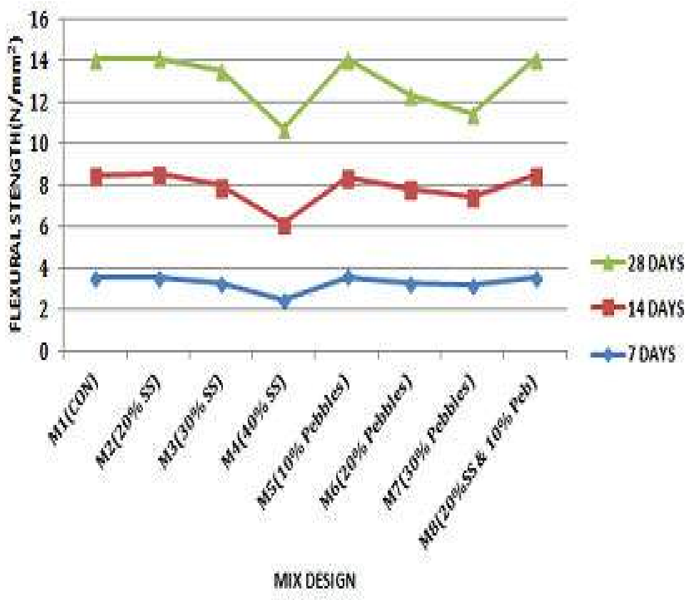


Flexural Strength: To examine the flexural strength of plane mortar and mortar with various percentages of Steel Slag and Crushed Pebbles content in concrete has been investigated by testing beams of 150mm × 150mm × 1000mm.

Table 4.3: Flexural Strength Result

MIX DESIGN	7 days	14 days	28 days
M_1(conventional)	3.53	4.96	5.58
M2(20% Steel Slag)	3.55	4.99	5.60
M3(30% Steel Slag)	3.30	4.68	5.56
M4(40% Steel Slag)	2.41	3.74	4.61
M5(10% Pebbles)	3.58	4.82	5.72
M6(20% Pebbles)	3.25	4.58	4.53
M7(30% Pebbles)	3.18	**4.28**	4.01
M8(20% Steel slag & 10% Pebbles)	3.56	4.91	5.59

Chart 4.3: Flexural Strength Result



5. CONCLUSIONS

The following conclusions are drawn from the study

1. Compressive strength increase with increasing the percentages of Steel slag and Crushed Pebbles upto replacement (20%SS & 10% Pebbles) of Fine Aggregate and Coarse Aggregate in concrete.
2. Flexural strength increase with increasing the percentages of Steel slag and Crushed Pebbles upto replacement (20%SS & 10% Pebbles) of Fine Aggregate and Coarse Aggregate in concrete.
3. Split Tensile strength increase with increasing the percentages of Steel slag and Crushed Pebbles upto

replacement (20%SS & 10% Pebbles) of Fine Aggregate and Coarse Aggregate in concrete.

4. From the results of compressive strength, split tensile strength and flexural strength of 7 days, 14 days and 28 days, 20% replacement of fine aggregate by steel slag and 10% replacement of coarse aggregate are the optimum percentage of replacement of M40 grade concrete and decreases considerably in further replacement of slag and pebbles in concrete.

5. The partial replacement of Steel Slag and Crushed Pebbles in concrete by waste material facilitates environmental friendly disposal of the waste which is generated in huge quantity in industries.

REFERENCES

1. Abdul-Aziz, Al-Negheismish, Faisal Al-Sugair and Rajeh Al-Zaid, "Utilization of Local Steelmaking Slag in concrete", Journal of Environmental science of sustainable society, Vol. 1, pp. 39-55. (1996)
2. Beshr.H, Almusallam.A.A Maslehuddin.M "Effect of Coarse Aggregates Quality on the Mechanical Properties of High Strength Concrete" - Construction and Building Materials (2003).
3. Brahim M, Qasrawi, Hishma Y, Shalabi, Faisal I - "Use of steel slag in asphalt concrete mixes" ASI, – Canadian Journal of Civil Engineering, Vol.34, Number 8, pp.902-911, NRC Research Press, 1st August (2007).
4. Carlo Pellegrino, Vittorio Gaddo, Mechanical and durability characteristics of concrete containing EAF slag as aggregate, Cement & Concrete composites 31(2009) 663 – 671.
5. Chandrashekar. A , Maneeth.P.D , Performance Appraisal of River Stone as a coarse Aggregate in Concrete/ Maneeth.P.D et al Int. Journal of Engineering Research and Applications January 2014.
6. Chinnaraju1,Ramkumar, Study On Concrete Using Steel Slag As Coarse Aggregate Replacement And Eco sand As Fine Aggregate Replacement , International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 3. (2013).
7. Deborah M. Proctor, Erinc, Shay, Kurt A. Fehling & Brent L. Finley -"Assessment of human health and ecological risks posed by the uses of steel industry slag in the environment" –– Journal of Human Ecological and Risk Assessment, Vol.8, Issue4, pp.681-711,(2002).
8. Dr.T.Ch.Madhavi1, L.Swamy Raju2, Deepak Mathur Polypropylene Fiber Reinforced Concrete International Journal Of Emerging Technology And Advanced Engineering June (2014).
9. Erhan Guneyisi Et Al "A Study On Durability Properties Of High-Performance Concretes Incorporating High Replacement Levels Of Slag", Journal Of Materials And Structures, 6 June (2007).
10. Furlani.E, Tonello.G, Maschio.S, Recycling of steel slag and glass cullet from energy saving lamps by fast firing production of ceramics. Waste management 30 (2010) 1714 – 1719.
11. Goh Hee Chien, Concrete Mix Design Using Crushed Pebble as Replacement Material in Concrete Mixture This project is submitted to Faculty of Engineering,University Malaysia Sarawak,2009
12. International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol 2, issue 6, june (2013).
13. Ilangovana.R, et al., "Strength and durability properties of concrete containing Quarry rock dust as fine Aggregate" ARPN Journal of Engineering and Applied Sciences, (2008),3, 20-26.
14. Khalid Raza, Sharda Sharma, Ritesh Mall and Patel, Comparative Strength Analysis Of Concrete By Using Steel Slag As An Alternative To Normal Aggregates (Coarse) In Concrete, - International Journal of Civil Engineering ISSN 2347 – 8527 Volume 3, Issue 5. (2014).
15. Khidhair J. Mohammed, et al., "Using of steel slag in modification of concrete properties" Eng. & Tech. Journal, (2009), 27.
16. Mohammed Nadeem, Arun Pofale,Experimental Investigation Of Using Slag As An Alternative To Normal Aggregates (Coarse And Fine) In sssConcrete ,International Journal Of Civil And Structural Engineering, Volume 3, No 1.(2012).
17. Mohammed Nadeem and Arun D.Pofale "Utilization of Industrial waste slag as aggregate in concrete applications by Adopting Taguchi‟s for Optimization" Open Journal of civil Engineering (2012), 2, 96-105.
18. Mohanraj.E.K. et al., "Study on concrete using waste materials by partial replacement of aggregates to reduce global warming gases" Indian journal of science and technology, 2011, 4, (1899-1905).
19. Narasimha Raj, Suresh Patiland and Bhattacharjee Concrete Mix Design By Packing Density Method, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 2 Ver. I (Mar- Apr. 2014), PP 34-46.
20. Pramodini Naik Gaonkar, Green Concrete using GGBS, River Pebbles and CRF as Partial Replacementto Cement and Aggregates, International Journal of Engineering Research, Jan (2016).
21. Priyanka, et al., " An Experimental investigation on the properties of concrete containing manufactured sand" International Journal of Advanced Technology, (2012),3,101-104.
22. Southararajan.V.M, Anshul Jain, Abhishek Kumar Singh, S. Thirumurugan Evaluation Of Composite Polypropylene Fibre Reinforced Concrete/ International Journal Of Engineering And Technology (Ijet)(2014).
23. Sultan Tarawneh, Emhaidy Gharaibeh and Falah M. Saraireh, Effect Of Using Steel Slag Aggregate On Mechanical Properties Of Concrete, American Journal of Applied Sciences 11 (5): 700-706. (2014).