Experimental Study on Concrete with Limestone Powder and Copper Slag

P. Anusha, K. Sai Ramya

Abstract— **Concrete is composite material, it is used as construction material due to good compressive strength and durability. Most of cement plants consume more energy and produce large amount of undesirable products, which effects of environment. Nearly 7% of the total global CO_2 emission is contributed by cement industries. In the recent attempts have been made for the prosperous utilization of various cement mineral additions such as copper slag, pozzolan, sand and limestone powder. The limestone powder is used as the concrete productions for its very low cost and high workability of concrete.**

The main aim of this project is to investigate the compressive strength, flexural strength and split tensile strength of M40 grade of concrete. The limestone powder and copper slag are used as replacing material for cement and fine aggregate to improve its mechanical properties. For 10%, 15%, 20% of lime stone powder with 0%, 20%, 40%, 60%, 80% and 100% with interval of 20% of copper slag are consider for concrete mix and compared with conventional concrete.

Index Terms — **Limestone powder, Copper slag, Compressive strength, Flexural strength, Split tensile strength, Soundness test.**

I. INTRODUCTION

The industrial waste materials have aided the production of cement in construction works. The new products and waste materials are generate by different industries. Dumping and destruction of waste material is causes environmental and health problems. The recycling of waste material is used the construction field. And it is gives great potential in industry. For so many years byproducts such as flyash, silica flume and lime powder were consider waste material. The concrete mix prepared with different materials as improvement in workability and durability compared with normal concrete. It has been used the construction of powder, chemical plants and under water structures and researchers study the decades, intensive in recently to all possible methods are reuse. The construction waste, blast furnace, steel slag, coal flyash and bottom ash has been use the replacement by aggregate in roads, pavements, building constructions, embankments and foundations. This raw material is manufacture of ordinary Portland cement pointed by Teikthyeluin et al (2006).

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The ordinary Portland cement (OPC) is mostly used the constructions material. The cement is expected requirement will grow threefold about 3.5 billion tons per year. The cement becoming an energy exhaustive production of concrete. Therefore, the raw material required for cement production is relatively less. Manufacturing the cement produce the high amount of undeliverable products.

Present day's limestone powder is widely used to replacement of ordinary Portland cement to produce composite cement. The lime stone is calcareous sedimentary rock consist of $CaCO_3$. Limestone powder is additive in cement and replacing of limestone powder into cement in so many years. The limestone powder is increase the strength in early ages and hydration rate of cement improved.

The construction industry mostly used good quality of concrete by mixes of cement, sand, coarse aggregate, water and admixtures as need. Sand is important material for concrete mix. In this work sand is replacement by copper slag and it is by product of smelting and refining copper. Slag less than 0.8% of copper is the waste and low cost and to obtained waste the property of pozzolanic and high density can used replacing of all concrete materials. Experimental study on M40 grade of concrete is replacement of fine aggregate with copper slag produce angular granules. The material is used in construction the strength is increases of concrete and reduce the dumping. The copper slag percentages increase water absorption reduce and resist the seismic force of earth.

Limestone powder is made by grinding the limestone in different mills. It is used the construction field and as raw material angular granules with the binder. The limestone powder is very low cost and it is environmental load of cement production. Grinding process the lime is ground to fines powder, this material move the storage hopper by elevator and feeder. Feeder is move the main grinding mill. Limestone is one of the major wastes material it is used the constructions and also many other uses of limestone. Limestone is sedimentary rock. Steel, plastic, constructions, neutralizers and other uses of the limestones.

Copper slag by product of smelting and slag produces angular disposed of waste material. The slag is used other purpose and the copper slag is replaced for fine aggregate. To provide the alternative materials is sand and cement. Copper slag is used the building material and blasting media manufactured from copper slag bring less harm to peoples and environment than sand. It is most rigid health and ecological. Copper slag is by-product obtained the smelting and refining of copper. The major consistutents of a smelting charge are sulphides, iron oxides and copper, SiO_2, Al_2O_3, CaO and MgO, present in original concentrate or added flux iron, copper, sulphur, oxygen and oxides largely control the

chemical and physical properties of smelting system. The copper slag is used the cement clinkers production and reduce the calcinations temperature of clinkers. The use of copper slag replace by iron powder as adjusting material of cement production. Cement produce by copper slag performed even better than iron powder.

II. LITERTURE REVIEW

Chao-Lung Hwang and Jaw-Chang Laiw (1989) properties of concrete using copper slag as a substitute for fine aggregate in this paper copper slag is by product of copper productions it contains of iron oxide and silicate. The copper slag is similar to the natural sand. The copper slag is chemically stable and physical properties are also similar to fine aggregate. The amount of copper slag is 20%, 40%, 60%, 80%, 100%, was replacement of fine aggregate in cement mortar and concrete. Fine aggregate and copper slag fineness modulus was roughly 2.6 for concrete mix design. At these values the workability was found to be with minimal bleeding and addition of copper slag strength of concrete was improved. When the replaced amount 80% is exceeding, lower strength is obtain. It is possible to formations of ettringite. The effect of copper slag on long term strength is development was dependent on the used amount and the fines are also founded. It was the copper slag can be use as fine sand replaced for ordinary reinforced concrete.

Khalifa S.AI-Jabri, MakotoHisada, Salem K.AI-Oraimi and Abdullah H.AI-sandy (2009) studied on copper slag as sand replacement for high performance concrete. In this paper present experimental process investigate the effect of copper slag using by replacement of sand of the properties of HPC. The concrete mixes prepare the different percentages like 0% to 100% rang of copper slag. The concrete mixture to determine the workability, density, compressive strength, flexural strength, split tensile strength and durability. The HPC density is slightly increase nearly 5% with increase the copper slag content. The workability increase and also increase copper slag percentages. However, additions of copper slag caused attrition in the strength increase the free water content in the mix. The mixes 80% to 100% copper slag replaced the strength is decrease approximately 80Mpa, and 16% lowest strength of control mix. The copper slag quantity increase 40% of replacement the surface water absorption is decrease. Therefore 40% copper slag use as replacement of sand to get HPC with good strength and durable properties.

B Ganesh, Ch Bhaskara rao, K Rajesh (2017) studied on experimental study on lime stone powder & copper slag strength of concrete with partial replacement of cement and fine aggregate. In this paper the copper slag and lime powder is waste material to use the construction industries. The experimental investigate to determine the compressive strength, flexural strength and split tensile strength of concrete mix. For different replacement of cement and sand using lime and copper slag that are 0%, 10% & 10%, 10% & 20%, 10% &30%, 10% & 40%, 10%& 50 %, 10% &60%, 10% &80% and 10% &100%. Lime powder and copper slag by weight. The result improvement in strength properties of concrete composition up to 10% and 80% lime and copper slag replacement cement and sand can be effectively used the structural concrete. The max compressive strength obtained at 10% &60% at 7 and 28 days. Split and flexural Strength obtain higher strength at 10% &80% replacement period is 28 days. In these percentages increase the density. And also increase the workability of concrete with increase the % of lime and copper slag.

Tamil selvi P, Lakshmi Naravani P and Ramya G (2014) studied on the experimental study on concrete using copper slag as replacement of fine aggregate. In this paper the copper slag is as replacement of fine aggregate and the slag is industry waste product. In this work M40 grade of concrete was selected to calculate the mix proportions of concrete. In this work used material is cement, sand, coarse aggregate. To determine the different strength like compressive strength, flexural strength, split tensile strength, rebound hammer, ultrasonic pulse velocity and non-destructive test. In this work followed percentages is 0%, 20%, 40%, 60%, 80% and 100%. Maximum compressive strength is 40% of copper slag in 7 and 28 days. The split and flexural strength test is 40% replacement of fine aggregate at 28 days and also pulse velocity higher at 40%. To obtained the good result in this experiment.

Neethu Susan Mathew, S.Usha (2014) studied on the effect of copper slag as partial replacement for fine aggregate in geopolymer concrete. In this paper the cement and fine aggregate as replace the industrial waste material its reduce the cost and control the environmental pollution. The cement is replacement of flyash and GGBFS. The copper slag is replacement of fine aggregate. Flyash and GGBFS strength, durability and bond strength is based on the geopolymer concrete with and without fine aggregate is compared. The experiment result the geopolymer with 40% replacement of copper slag improve the 17.5%, 13.94% and 22.72% at 28 days compressive strength, split tensile and flexural strength is comparison the geopolymer concrete without copper slag. The water is absorbent durability of geopolymer concrete.

P. Meenaksh (2017) studied on partial replacement of cement by barites and lime powder in concrete in this paper design concrete mix is M30 grade of concrete is use. The cement is partial replacement of barites and limestone powder as the percentages are 0%, 10%, 20% and 30% were used the experimental work. The replaced ingredients are increase the compressive strength in early period at 7 days and 14 days also same result obtained. The replacement for concrete not show increases the compressive strength in 28 days.

S. Sudha (2016) studied on durability and strength character of concrete using lime sludge and flyash as partial replacement of fine aggregate in this paper design the concrete mix. Present the construction use the waste materials like flyash, lime sludge etc. these material is very low cost. The cement is replaced b lime sludge and the fine aggregate is replacement by flyash. The percentages of lime sludge are

0%, 5%, 10% and 15%. Flyash are 0% and 5%. To determine the compressive strength, flexural and split tensile strength at 7 days and 28 days.

Swati Chadel, Ajay K Duggal and Naiyara Khan (2016) studied on to study the effect of partial replacement of lime by cement in mastic asphalt. In this paper investigate the mastic asphalt is grained material it is use the construction work because it's high durability, higher stability and low cost. The effect of partial replacement of lime b cement at percentages are 3%, 6%, 9%, 12% and 15% in the mix. The mastic asphalt sample was prepared with and without coarse aggregate to given percentages. Industrial grade bitumen was used the binder, stone dust was used as fine aggregate size from 2.36mm to19mm used the coarse aggregate in this work. It observed the specimens without coarse aggregates the values satisfy the proposition < 9% nor <12%. With coarse aggregate the maximum replacement possible is 12%.

Pranshu saxena, Ashish Simalti (2015) studied on scope of replacing fine aggregate with copper slag in concrete. In this paper copper slag is used the replacing process it is b product of smelting and it is waste material of industries. The copper slag is used the construction work. To elevate the compressive strength, tensile and flexural strength is obtained maximum strength 40% copper slag is replaced with sand. The copper slag is also replace the cement in the future construction works it gives good strength.

James Mohammadi, Warren south (2016) studied on the effect of up to 12% substitution of clinker with limestone on commercial grade concrete containing supplementary cementitious materials. In this paper cement content 12% limestone addition minor difference in concrete properties. Air content, bleed propensity and initial setting time were reduced when the final setting time reduced with increase the lime content. 10% limestone addition of concrete mix the strength is noted 56 days. 12% replacement satisfies significant reduction in strength at 28 and 56 days.

Mostafa Khanzadi, Ali Behnood (2009) studied on the mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate. In this paper copper slag is the by-product obtained during the smelting. This slag are recycling, recovering of metal production of value added products. This paper investigate using copper slag as coarse aggregate in HPC and replacing the lime stone coarse aggregate by copper slag coarse aggregate on the compressive strength, split tensile and flexural strength, rebounded hammer to determine the HPC. The silica fume was prepared with w/c ratios of 0.40, 0.35 and 0.30. The cement is replacement by silica fume with different percentages 0%, 6%, and 10% respectively. The copper slag aggregate compared to limestone aggregate values in 28 days compressive strength increase the 10-15% and split tensile increase 10-18%. Study the results using copper slag as coarse aggregate in HPC is very useful for these exterminate.

M.V.Patil (2015) studied on the properties and effects of copper slag in concrete in this paper investigate the effect of copper slag as replacement of fine aggregate. The concrete mixes prepared the different percentages of copper slag 0%-100%. To find the compressive strength, split tensile and flexural strength of concrete mixes. All concrete specimens curing period is 7, 28, 56 days. After complete specified period the strength test was conducted. The strength is increase to high toughness of copper slag.

W. Gudissa and A. Dinku studied on the use of limestone power as an alternative cement replacement material an experimental study. In this paper investigate the limestone powder addition of physical and chemical properties of the cement paste and harded concrete. The OPC replacement of limestone powder is 5% to 10% satisfied the standard compressive strength of high early strength of cement is 42.5Mpa. The replacement of cement clinkers b limestone filter is 15%-20% satisfied the compressive strength of early strength of 32.5Mpa. Limestone powder is weight to the clinker from 25%-32% in slightly higher at 28 days of standard compressive strength.

III. METHODOLOGY

The main objective of this project work is to study the mechanical properties of concrete containing the cement is replacement of limestone powder and fine aggregate replaced by copper slag. Basic properties of concrete is consists of limestone and copper slag.

In this project M40 grade of concrete was used to evaluate mechanical properties of concrete. The cement is partial replaced by limestone powder and fine aggregate partial replaced by copper slag. The cement replacement three test groups the percentages are 10%, 15%, 20% limestone powder with cement and fine aggregate replaced by copper slag six test groups the percentages are 0%, 20%, 40%, 60%, 80% and 100% in test series. Casting the concrete cubes, beams and cylinders and 7, 28 days were tested. The following tests were conducted.

1. Specific Gravity Test
2. Sieve Analysis Test
3. Soundness Test
4. Compressive strength test for cubes
5. Flexural strength for beams
6. Split tensile strength test for cylinders

IV. MATERIAL AND MIX PROPORTIONS

The materials used in the investigation and their properties are explain below.

A. Cement: Ordinary Portland cement of 53 grades from Sri Bhavya cement brand conforming to IS: 8112-1989 and IS: 12269-1987 is used in this experimental work.

B. Limestone powder: The Limestone powder is used for the replacement of cement is brought from Guntur, Andhra Pradesh, India. The performance of concrete mass with

limestone powder is replacement for cement. The percentages of limestone powder are 10%, 15% and 20%.

C. Fine aggregate: Fine aggregates generally consist of natural sand or crushed stone with most particles passing through 9.5 mm sieve. Fine aggregate fine sand were purchased from a nearby crusher in Guntur area, typically the same material used in normal concrete mixture.

D. Copper slag: The copper slag is used for the replacement of fine aggregate. The copper slag used in this work was bought from Sri Srinivasa metalizers (Hyderabad), India. To determine the chemical and physical properties of copper slag.

E. Coarse aggregate: The coarse aggregate are stones retained 4.75mm sieve. Nearly all natural aggregate originate from bed rock. Coarse aggregate are different shapes like rounded, irregular or partly rounded, angular, flaky etc. rounded particles full irregular and sometimes shaped on coarse aggregate.

F. Water: The water helps from the strength giving cement and required workability to the concrete. Portable water is used the concrete mix. The quality and quantity of water is used the concrete mix to check carefully.

Mix design:

In this process selecting suitable material of concrete and determine relative amount to produce the concrete to required strength, durability and workability economically possible it is concrete mix design.

Mix proportion:

The M40 grade of concrete was prepared the mix design IS: 10262-2009 recommendations are taken. The mix proportions are 1:1.305:2.768 with water-cement ratio is 0.43.

Mixing: The individual mix ingredients are weighed with their proportions and then the material is place the tray. The materials are mixed thoroughly mixed in dry conditions before added all ingredient. The prepared mix was immediately used for testing fresh mix for workability. In the properties of fresh concrete and tensile strength of hardened concrete were examined.

1. Conventional concrete.
2. Cement replacement by lime powder by 10%, 15%, 20% and sand replacement by copper slag by 0%, 20%, 40%, 60%, 80%, 100% respectively.
3. The lime powder each percentage constant the copper slag vary the percentages and above samples was test for compressive strength, split tensile strength, flexural strength test.

V. RESULTS AND DISCUSSION

A. Specific gravity

The specific gravity of copper slag conducted the different percentages 0%, 20%, 40%, 60%, 80% and 100%of copper slag, it is replaced for fine aggregate the percentage of copper slag increase and also increase the specific gravity.

Table 1: specific gravity of copper slag

Percentage of copper slag	Specific gravity
0	2.620
20	2.777
40	2.845
60	3.092
80	3.410
100	3.610

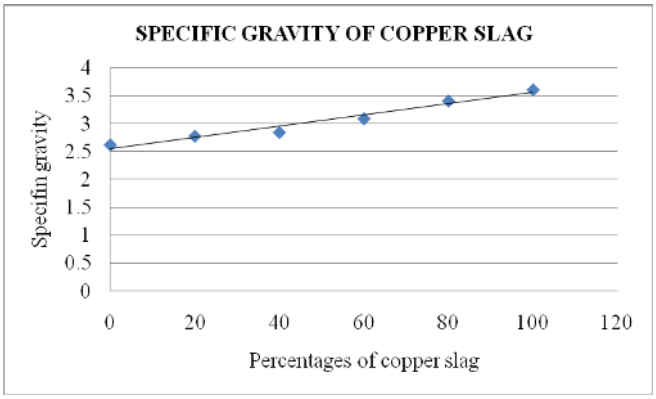

Fig 1: specific gravity of copper slag graph

B. Sieve analysis of sand

Sieve analysis of fine aggregate conducted different sieve sizes of the test. The sieve are 4.75, 2.63, 1.18, 600µm, 300µm and 150µm. its increase the cumulative percentage of sand retained.

Table 2: Sieve analysis of sand

Sieve sizes	Cumulative % of sand retained
4.75	1.5
2.63	8.2
1.18	28.14
600 µm	67.85
300 µm	91.25
150 µm	98.68

Fineness modulus of sand = 2.95

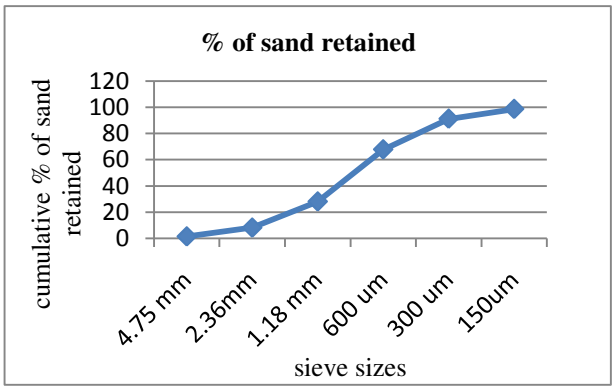

Fig 2: sieve analysis for sand graph

C. Sieve analysis of copper slag

The copper slag is replacement of fine aggregate the specific gravity test is conducted the copper slag and to take the different size of sieves.

Table 3: Sieve analysis of copper slag

Sieve sizes	Cumulative % of copper slag retained
4.75	18
2.63	5.36
1.18	50.78
600 µm	87.52
300 µm	95.28
150 µm	98.2

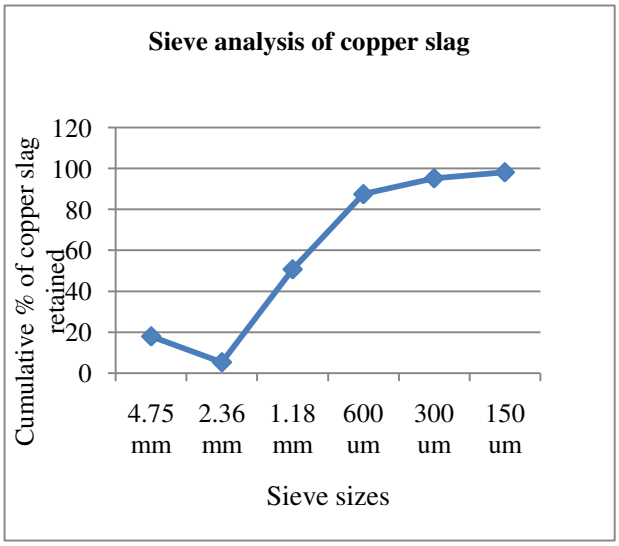

Fig 3: Sieve analysis for copper slag graph

D. Slump cone test

Different mixes of freshly mixed concrete were tested for workability by slump cone test. The percentage of copper slag increases with decreases the workability. The limestone powder increases with workability also decrease.

Table 4: slump cone values

Percentages of copper slag	Slump cone test values in cm		
	10%LP	15%LP	20%LP
0%	28.6	29.1	28.5
20%	28.8	29.4	28.7
40%	29.5	29.4	29
60%	29.8	29.6	29.8
80%	0	0	0
100%	0	0	0

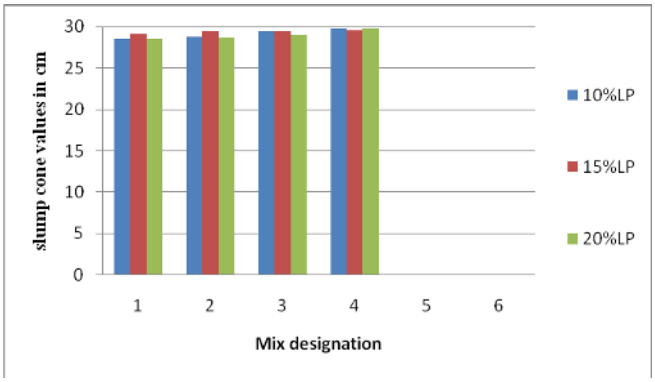

Fig 4: Slump cone test values graph

E. Compressive strength test for cubes:

Compressive strength values of the cube specimens were tested at 7 and 28 days for all the six different mix. It is observed that the compressive strength of concrete increase when percentage of copper slag increase and then decrease. So, 60% quantity of copper slag can be replaced in sand with 15% of lime stone powder at a time increase the compressive strength. The results obtained are tabulated below with proper graphs.

Table 5: Compressive strength test values for cubes

Percentages of copper slag	Compressive strength in N/ mm^2					
	10% LP		15%LP		20%LP	
	7 days	28 days	7 days	28 days	7 days	28 days
0%	28.51	36.32	29.86	42.16	27.22	39.49
20%	29.98	38.29	32.35	43.84	31.20	36.93
40%	34.86	41.28	36.22	47.48	32.93	39.25
60%	42.90	50.80	44.27	65.19	40.78	46.96
80%	34.85	45.04	38.03	47.76	33.82	41.91
100%	34.66	45.84	36.31	43.57	31.96	40.24

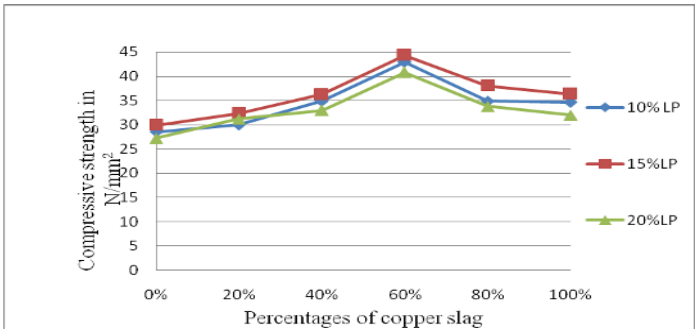

Fig 5: 7 Days compressive strength of concrete

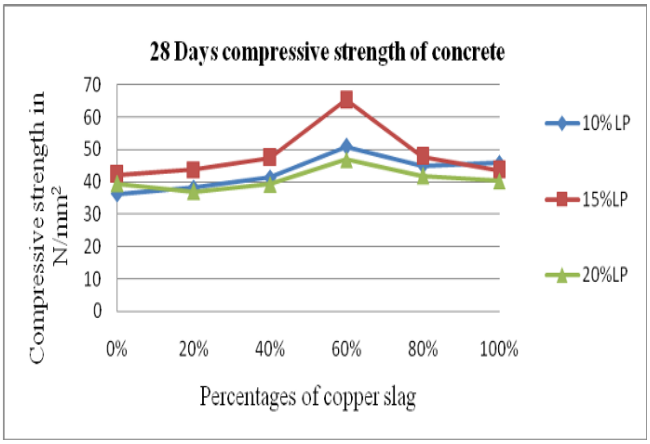

Fig 6: 28 Days compressive strength of concrete

F. Flexural strength for beams

Flexural strength for the beam specimens are tested on Universal testing machine (UTM) at 28 days for all the different mix. Average modulus of rupture at 28 days increased with 15% limestone powder and 80% copper slag concrete mix.

Table 7: Flexural strength test values for beam

Percentages of copper slag	Flexural strength in N/ mm^2		
	10% LP	15% LP	20% LP
0%	5.24	5.34	4.82
20%	5.66	5.87	5.37
40%	5.94	6.33	5.71
60%	6.68	7.07	6.50
80%	7.16	7.63	6.75
100%	5.43	4.98	5.77

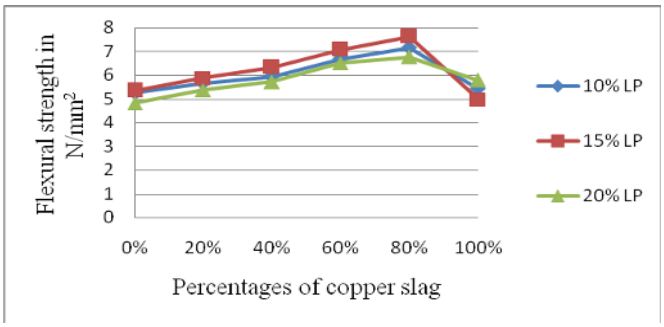

Fig 7: 28 Days flexural strength of concrete graph

G. Split tensile strength test for cylinders

Split Tensile strength of the cylinder specimens were tested at 28 days for all the six different mix. It is observed that the tensile strength of concrete increase when 80% of copper slag and 15% of limestone powder and then decrease. The results obtained are tabulated below with proper graphs.

Table 8: Split tensile strength values

Percentages of copper slag	Split tensile strength in N/mm^2		
	10%LP	15%LP	20%LP
0%	2.64	2.77	2.34
20%	2.70	2.92	2.52
40%	3.01	3.23	2.88
60%	3.31	3.72	3.13
80%	4.20	4.75	3.87
100%	3.37	3.83	3.32

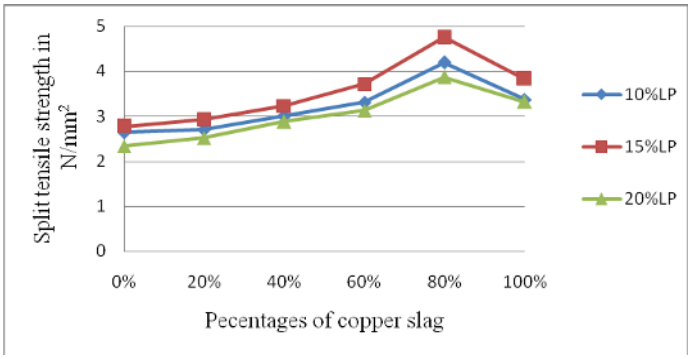

Fig 8: 28 Days split tensile strength of concrete graph

VI. CONCLUSIONS

Based on the experimental following conclusions can drawn:

- The cement partially replaced by limestone powder and the fine aggregate is replaced by copper slag. The percentages of copper slag increases, workability decrease.
- The compressive strength of concrete increases as percentages of copper slag increase with 60% and limestone powder increase with 15% and then decreases.
- 60% of copper slag with 15% of limestone powder shows 25.05% higher compressive strength than nominal concrete for 28 days.
- The flexural strength of concrete increases as percentages of copper slag increases with 80% and limestone powder increases with 15% and then decreases.
- 80% of copper slag with 15% of limestone powder shows 33.73% higher flexural strength than nominal concrete for 28 days.
- The split tensile strength of concrete increases as percentages of copper slag increases with 80% and limestone powder increases 15% and then decreases.
- 80% of copper slag with 15% of limestone powder shows 6.9% higher split tensile strength then nominal concrete for 28 days.
- Utilize these two waste material in concrete provides additional environmental and technical benefits. And also reduce the cost to making concrete and improve the mechanical properties.

REFERENCES

[1] Chao-Lung Hwang and Jaw-Chang Laiw studied on "properties of concrete using copper slag as a substitute for fine aggregate", Special publication, Volume : 114 (1989)1677-1696.

[2] Khalifa S.AI-Jabri, MakotoHisada, Salem K.AI-Oraimi and Abdullah H.AI-sandy (2009) studied on "copper slag as sand replacement for high performance concrete, Journal of cement and concrete composites", Volume 31 (2009) 483-488.

[3] B Ganesh, Ch Bhaskara rao, K Rajesh (2017) studied on "experimental study on lime stone powder & copper slag strength of concrete with partial replacement of cement and fine aggregate", International journal of mechanical engineering and computer applications, Volume 5 (2017) 2320-6349.

[4] Neethu Susan Mathew, S.Usha (2014) studied on "the effect of copper slag as partial replacement for fine aggregate in geopolymer concrete",

IOSR Journal of Mechanical and Civil engineering, PP73-77 (2014) 2278-1684.

[5] James Mohammadi, Warren South studied on **"**Effect of up to 12% substitution of clinker with limestone on commercial grade concrete containing supplementary cementitious materials", Construction and Building Materials 115 (2016) 555–564.

[6] Tamil selvi P, Lakshmi Naravani P and Ramya G (2014) studied on the "experimental study on concrete using copper slag as replacement of fine aggregate", Journal of Civil and environmental engineering 4: 156.

[7] M.V.Patil (2015) studied on this paper investigate the "properties effect of copper slag as replacement of fine aggregate". Proceedings of 18th IRF International Conference, 11th January 2015, Pune, India, ISBN: 978-93-84209-82-7.

[8] Omar M.Omar, Ghada D.Abd Elhameed, Mohamed A. Sherif, Hassan A. Mohamadien (2012) studied on "influence of limestone waste as partial replacement material for sand and marble powder in concrete properties", HBRC Journal, Volume 8 issue 3, pages 193-203.

[9] W. Gudissa and A. Dinku studied on the "use of limestone power as an alternative cement replacement material an experimental study", Journal of EEA. Vol. 27, 2010.

[10] P. Meenaksh (2017) studied on "partial replacement of cement by barites and lime powder in concrete", International Journal of ChemTech Research CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555 Vol.10 No.3, pp 143-148,

[11] S. Sudha (2016) studied on "durability and strength character of concrete using lime sludge and flyash as partial replacement of fine aggregate", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 03 Issue: 07 | July-2016 p-ISSN: 2395-007.

[12] Swati Chadel, Ajay K Duggal and Naiyara Khan (2016) studied on to "study the effect of partial replacement of lime by cement in mastic asphalt", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 ,Volume: 03 Issue: 11 | Nov -2016 p-ISSN: 2395-0072.

[13] Al-Jabri (2009) studied on the "effect of using copper slag as a replacement of sand on the properties of high performance concrete (HPC)", construction and Building Materials Volume 23, Issue 6, June 2009, Pages 2132-2140.

[14] Pranshu saxena, Ashish Simalti (2015) studied on "scope of replacing fine aggregate with copper slag in concrete– A review", International Journal of Technical Research and Applications e-ISSN: 2320-8163, Volume 3, Issue 4 (July-August 2015), PP. 44-48.

[15] Mostafa Khanzadi, Ali Behnood (2009) studied on the "mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate" Construction and Building Materials 23(6):2183-2188.