

**Fabrication and Mechanical Properties of Iron Slag Matrix Composite  
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**ABSTRACT**

In recent years composites have attracted substantial importance as a potential structural material. Most basic and common attractive features of composites that make them useful for industrial applications are low cost, low weight, high specific modulus, renewability and biodegradability. In order to meet the dynamic desires of the design engineers the conventional materials are not alone enough. So, by combining these traditional materials with some non-traditional materials hybrid properties can be achieved which is the origin for the composite materials.

Slag, because of its high natural water content, low density, and poor strength characteristics in its natural state is considered unsuitable for engineering construction. However, when Slag was mixed with varying percentages of a polymers and other materials, it was found that the density of the admixtures increased and the permeability decreased with an increase in mechanical properties.

The objective of present work is to use this industrial waste i.e. Slag as particulate filler material to the epoxy matrix composites by moulding technique with different weight fractions ( 0%, 5%, 10%, 15%, 20% ) to study the mechanical behavior of reinforced polymer composite material. The change in weight is studied for Slag under different tests like, tensile, bending and impact for obtaining the result. The conclusion helps us to predict the mechanical behavior of various constituents of Slag had resulted in better mechanical properties. The composite can be regarded as a useful light weight engineering material.

**Key words:** composite materials, matrix phase, slag composition.

## PREPARATION OF SAMPLES

### 1. INTRODUCTION:

The Samples are prepared by reinforcing the pig iron slag to unsaturated polyester resin to improve the mechanical properties of resin. The industrial waste is collected from LANCO pig iron industry at Sri kalahasti. Various ingredients are added to the solution in order to improve the bonding properties and strength of the pure resin.

#### **Major ingredients:**

**The following are the major ingredients of the sample.**

- i. Resin – Unsaturated polyester and Epoxy
- ii. Catalyst – ketone peroxide
- iii. Hardener – cobalt (Accelerater)
- iv. Powder –slag.

#### **The Properties of these Ingredients are:**

**Resin: Polyester resins** are [unsaturated resins](#) formed by the reaction of [dibasic organic acids](#) and [polyhydric alcohols](#). Polyesters resins are used in [sheet moulding compound](#), [bulk moulding compound](#) and the [toner](#) of [laser printers](#). Unsaturated polyesters are [condensation polymers](#) formed by the reaction of [polyols](#) (also known as [polyhydric alcohols](#)), organic compounds with multiple alcohol or hydroxy functional groups. Typical polyols used are [glycols](#) such as ethylene acids used are [phthalic acid](#) and [maleic acid](#). Water, a by-product of esterification reactions, is continuously removed, driving the reaction to completion. The use of unsaturated polyesters lowers the viscosity of the resin.

Polyester resins are [thermosetting](#) and, as with other resins, cure exothermically. The use of excessive catalyst can, therefore, cause charring or even ignition during the curing process. Excessive catalyst may also cause the product the fracture or form a rubbery material.

Unsaturated polyester in maintaining the excellent performance of the processing technology at the same time, how to improve the heat-resistant unsaturated polyester, and mechanical properties of unsaturated polyester to improve the dimensional stability, resistance, chemical corrosion, moisture absorption, and improve the environment unsaturated polyester affinity is an important research direction.

#### **Catalyst:**

**Methyl ethyl ketone peroxide** (MEKP) is an [organic peroxide](#), a high explosive similar to [acetone peroxide](#). MEKP is a colorless, oily liquid whereas acetone peroxide is a white powder at [STP](#); MEKP is slightly less sensitive to shock and temperature, and more stable in

storage. Dilute [solutions](#) of 30 to 60% MEKP are used in industry and by hobbyists as the [catalyst](#) which initiates the [polymerization](#) of [polyester resins](#) used in [glass-reinforced plastic](#), and casting. For this application, MEKP is dissolved in [dimethyl phthalate](#), [cyclohexane peroxide](#), or [diallyl phthalate](#) to reduce sensitivity to shock. [Benzoyl peroxide](#) can be used for the same purpose.

MEKP is a severe skin irritant and can cause progressive corrosive damage or blindness.

### Cobalt:

Several cobalt compounds are used in chemical reactions as oxidation catalysts. Cobalt acetate is used for the conversion of [xylene](#) to [terephthalic acid](#), the precursor to the bulk polymer [Polyethylene terephthalate](#). Typical catalysts are the cobalt [carboxylates](#) (known as cobalt soaps). They are also used in paints, varnishes, and inks as "drying agents" through the oxidation of [drying oils](#). The same carboxylates are used to improve the adhesion of the steel to rubber in steel-belted radial tires.

Cobalt-based catalysts are also important in reactions involving [carbon monoxide](#). [Steam reforming](#), useful in [hydrogen production](#), uses cobalt oxide-base catalysts. Cobalt is also a catalyst in the [Fischer-Tropsch process](#), used in the conversion of carbon monoxide into liquid fuels. The [hydroformylation](#) of [alkenes](#) often rely on [cobalt octacarbonyl](#) as the catalyst, although such processes have been displaced by more efficient iridium- and rhodium-based catalysts, e.g. the [Captive process](#).

The [hydrodesulphurization](#) of [petroleum](#) uses a catalyst derived from cobalt and molybdenum. This process helps to rid petroleum of sulfur impurities that interfere with the refining of liquid fuels.

### Slag composition:

SiO <sub>2</sub>	19.95%
Al <sub>2</sub> O <sub>3</sub>	0.57%
CaO	32.40%
MgO	9.80%
FeO	0.32%
MnO	0.45%
Fe <sub>2</sub> O <sub>3</sub>	34.40%
SiO <sub>2</sub>	19.95%

### Special Features

- Improves adhesion
- Creates physico-chemical bond with inorganic substrates
- Increases tensile strength and modulus of composites

- Increases flexural strength and modulus of composites
- Increases compressive strength of composites

### Properties

Characteristic	Test Method	Unit	Specification
Appearance	Visual		Clear Liquid
Viscosity at 25°C	ASTM-D 445	M Pa	< 10
Density at 25°C	ASTM-D 4052	g/cc	1.05 - 1.09
Flash Point	ASTM-D 93	°C	122
Storage life		Years	1
Boiling point			120 <sup>0</sup> C
Refractive Index			1.428 – 1.43

### Method of preparation For Polyester

Sample	Resin	Catalyst	Acclerator	Flue dust/Sludge/Slag
Pure resin	96%	2%	2%	0
5%	91%	2%	2%	5%
10%	86%	2%	2%	10%
15%	76%	2%	2%	15%

- (a) The polymer matrix composites are made by simple casting technique. In which the Resin is mixed with Industrial Waste Like slag which is collected from the LANCO Pig Iron industry at Srikalahasthi. The Industrial Waste is mixed at different proportions as 5% ,10%, 15% and 20%. The catalyst is added at 2% in order to increase the reaction. The hardener is also added in 2% for proper reaction. The remaining is unsaturated polyester resin. All these ingredients are thoroughly stir by hand and then poured in the mould cavity.
- (b) The samples are prepared for different types of tests such as tensile, flexural and iM Pact.
- (c) The mould is prepared on smooth ceramic tile with rubber shoe sole to the required dimension. Initially the ceramic tile is cleaned with shellac (NC thinner) a spirituous product to ensure clean surface on the tile. Then mould is prepared by keeping the rubber sole on the tile. The gap between the rubber and the tile is filled with mansion hygienic wax. A thin

coating of PVA (polyvinyl alcohol) is applied on the contact surface of the specimen, using brush. The resulting mould is cured for 24 hours. The mixture is prepared as per the above mentioned percentage and poured into the mould.

(d) This is left for solidification for 24 hours and then removed from the sheet. .

(e) The specimens are post cured at 50<sup>0</sup>C for 2hrs in oven

## TESTING OF SPECIMENS

The specimens prepared are subjected to 3 types of tests

- 1) Tensile test – Uniaxial tensile test
- 2) Bending test – 3-point flexural test
- 3) IM Pact test – V- notched iM Pact test

## DENSITY OF COMPOSITE:

In order to find the density of the composites we have to find the volume of the composites using Archimedes principle.

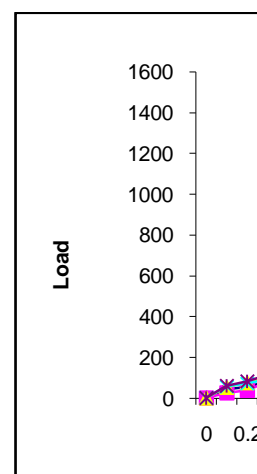
Take a graduated flask and fill it with water without air bubbles, up to a level (say 100ml). Now immerse the specimens (having same weight of fiber) into the water. Now the water is displaced to some extent and the water level in the flask is noted. The difference between the two levels gives the volume of the composites. Now average volume of each composite is calculated. The weights of all composites are noted using a digital weighing balance of 0.01gms least count. The average mass of each composite is then calculated.

$$\text{Density of composite} = \frac{\text{Average weight of each composite}}{\text{Average volume of each composite}}$$

## Load vs Elongation of Slag for Epoxy Resin

% weight Particulate	0 ( Pure)	5	10	15	20
Elongation	Load (N)				
0.0	0	0	0	0	0
0.1	44.88075	24.525	52.4835	55.67175	59.59575
0.2	54.20025	38.259	75.29175	71.1225	80.9325
0.4	82.64925	78.23475	107.6648	90.98775	111.834
0.6	113.5508	117.2295	133.1708	137.34	155.7338
0.8	131.9445	147.15	169.4678	166.77	199.3883
1.0	168.2415	178.0515	216.0653	199.6335	259.965

1.2	207.2363	213.6128	262.908	239.8545	351.198
1.4	260.946	277.1325	316.1273	278.3588	451.9958
1.6	346.293	348.5003	393.8715	316.863	559.17
1.8	417.906	428.1875	477.0113	359.046	692.8313
2.0	519.93	530.2305	572.903	416.6798	797.7983
2.2	631.764	621.7088	659.9678	479.4638	916.9898
2.4	727.1663	710.4893	748.0125	536.607	1020.485
2.6	831.3975	778.6688	832.6238	577.809	1085.313
2.8	932.6858	871.3733	903.9915	615.8226	1162.485
3.0	1013.658	950.0985	969.9638	642.555	1233.444
3.2	1079.836	1042.803	1013.618	671.2493	1445.994
3.4	1142.375	1115.642	1049.67	702.6413	
3.6	1206.63	1167.39	1081.798	721.035	
3.8	1297.373	1205.976	1105.587	745.805	
4.0	1334.16	1257.642	1138.451	752.1	
4.2	1354.107			777.606	
4.4	1388.442			781.857	
4.6	1436.184			786.762	
4.8	1434.222			790.686	



### Load Vs Elongation of Slag

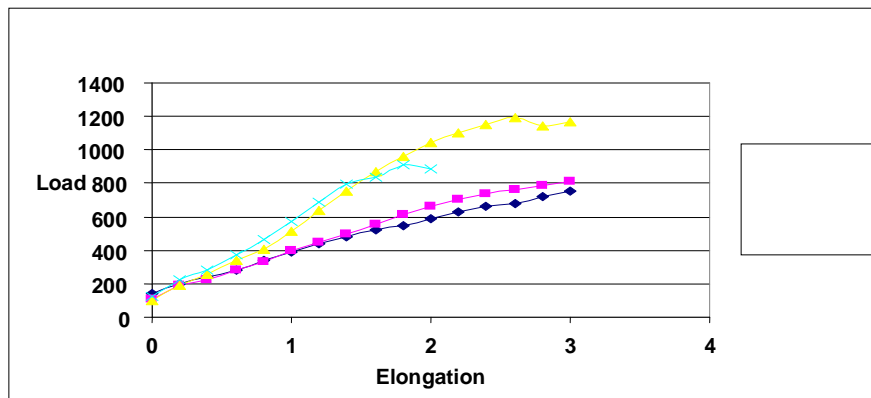
#### for Polyester

The tensile load versus elongation curve of Slag specimens is shown in fig 5.1. For pure particulate specimen as the load increases the elongation also increases gradually. It reached the peak at a load of 751.4460 N with a elongation of 3mm. For 5% particulate weight as the load increased the elongation also increased but the rate of deflection is slightly more than pure specimen. It reached the peak at a load of 808.1478 N. For 10% particulate weight as the load

increased the elongation also increased but the rate is greater than 15% particulate specimen, it reached the peak at a load of 1167.390 N with a elongation of 3 mm. For 10% particulate weight specimen the variation of the curve is similar to 20% particulate weight but it reached the peak at a load of 1056.79 N with a deflection of 2.4mm

**Table: 5.2 Load vs Elongation of slag for Polyester**

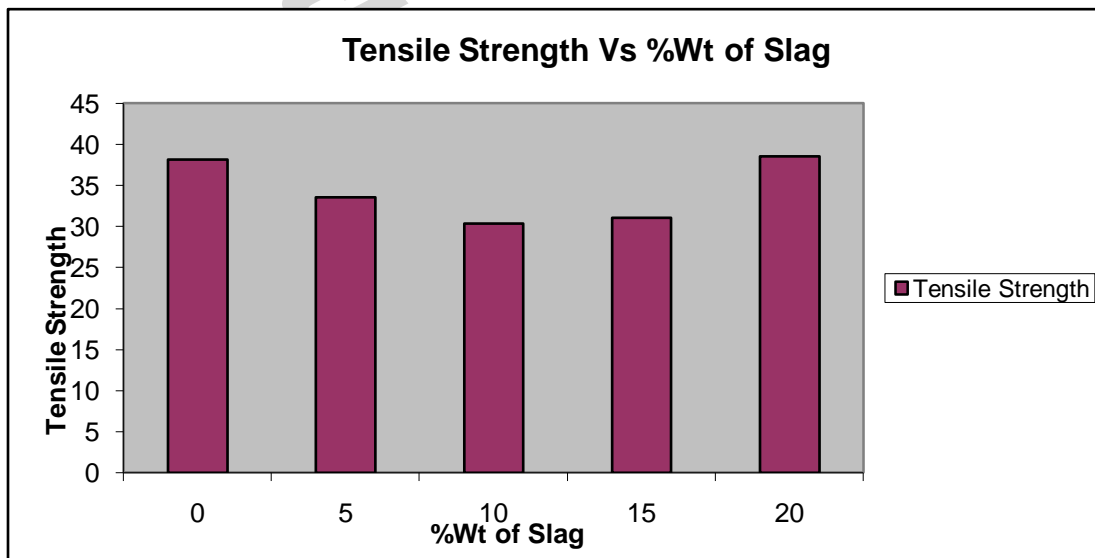
% weight Particulate	0 ( Pure)	5	10	15	20
Elongation	Load (N)				
0.0	141.7545	108.1062	97.90380	123.606	109.7815
0.1	168.4657	155.9098	177.1595	182.732	185.9786
0.2	197.6780	189.5292	193.4532	221.1174	187.1963
0.4	243.5332	226.8072	259.7688	283.3128	225.908
0.6	283.2637	281.9394	337.4640	374.5458	276.781
0.8	336.4830	333.3438	403.7796	461.2662	381.5167
1.0	390.1940	394.7544	517.5756	573.2964	473.501
1.2	437.7710	445.3740	634.7070	688.0734	499.259
1.4	480.9352	494.2278	754.7814	792.0594	548.913
1.6	518.9490	555.0498	870.7356	840.7170	625.458
1.8	548.3750	613.7136	961.5762	911.0220	711.714
2.0	587.8642	664.7256	1045.157	888.7860	825.668
2.2	627.3495	704.9466	1103.428		917.931
2.4	659.7225	737.3196	1154.637		1056.79
2.6	679.5878	762.2370	1191.130		
2.8	724.3040	785.7810	1142.211		



### Tensile Strength Vs Percentage Weight of Slag

The tensile strength versus percentage weight of Slag is shown in the fig 5.3. There is an increase in the graph which reached a maximum value at 20%. The value of tensile strength at 5% weight of particulate is 33.53MPa and there is an increase in the tensile strength at 10% weight of particulate to a value of 30.35MPa. The increment in the tensile strength has later decreased at 15% weight of particulate to an amount of 31.08MPa. The tensile strength at 20% weight of particulate to an amount of 38.55 Mpa. The values of the tensile strength and the percentage weight is given in the table

percentage wt of Slag	0%	5%	10%	15%	20%
Tensile strength(Mpa)	38.2	33.53	30.35	31.08	38.55



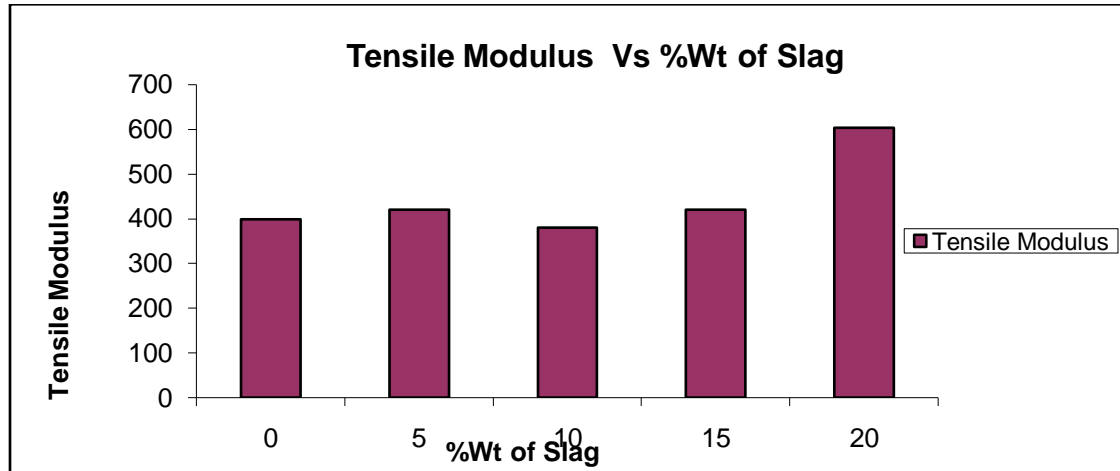
### Tensile Modulus Vs Percentage Weight of Slag

The tensile modulus versus percentage weight graph of Slag is shown in the figure 5.4. The tensile modulus reached maximum value at 20% and minimum value at 10%. The value of tensile modulus at 20% weight of slag is 602.34 MPa. The tensile modulus value decreased at 10% weight of slag to a value of 379.375MPa and there is again an decrease in the value at 5% and 15% weight of slag to a value of 419.12 MPa. The values of tensile modulus and the percentage weight of slag is shown in the table 5.4.

**TABLE 5.4 : Tensile Modulus Vs Percentage Weight of Slag**

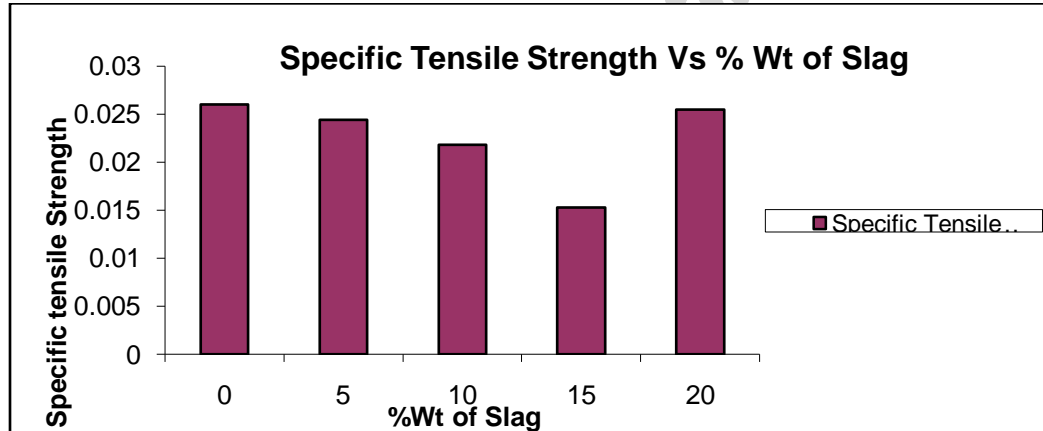
percentage wt of Slag	0%	5%	10%	15%	20%
Tensile modulus(Mpa)	397.916	419.12	379.375	419.58	602.34





**: Specific Tensile Strength Vs Percentage Weight of Slag**

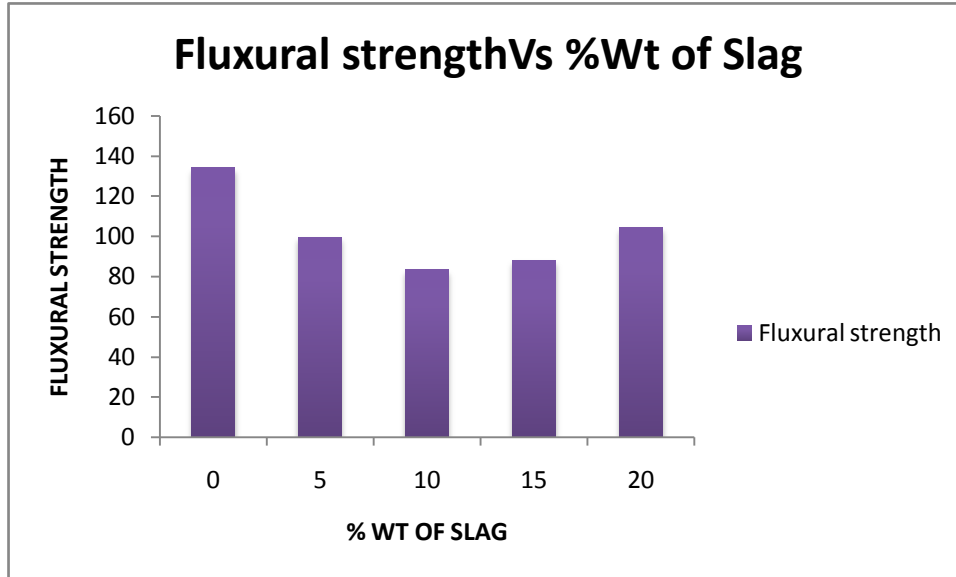
percentage wt of Slag	0%	5%	10%	15%	20%
Sp Tensile strength(Mpa/kgm-3)	0.026	0.0244	0.0218	0.0153	0.0255



**FIG 5.5 : Sp. Tensile Strength Vs Percentage Wt of Slag**

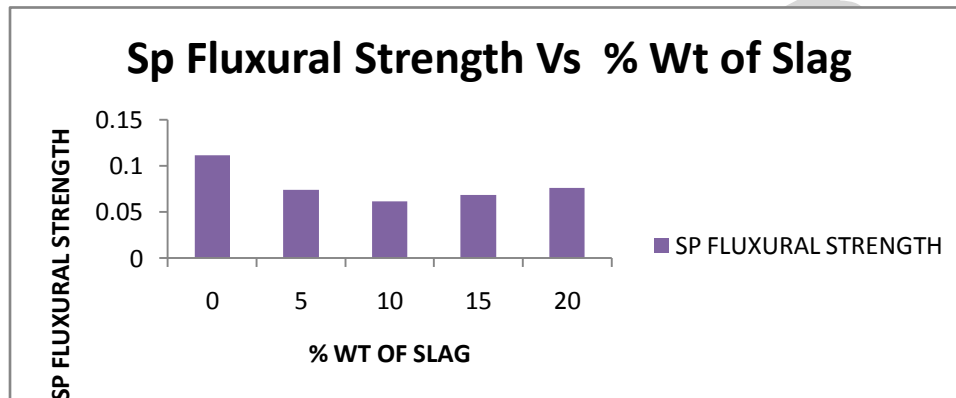
**Flexural Strength Vs Percentage Wt of Slag**

The flexural strength versus percentage weight of Slag is shown in the figure 5.7. The flexural strength reached a maximum value at 20%. The flexural strength at 20% weight of lime sludge is 104.3784 MPa. The flexural strength at 15% weight of slag is 88.145 Mpa. The flexural strength at 10% weight of slag is 83.205Mpa. The values of flexural strength and percentage weight of Slag is given in table



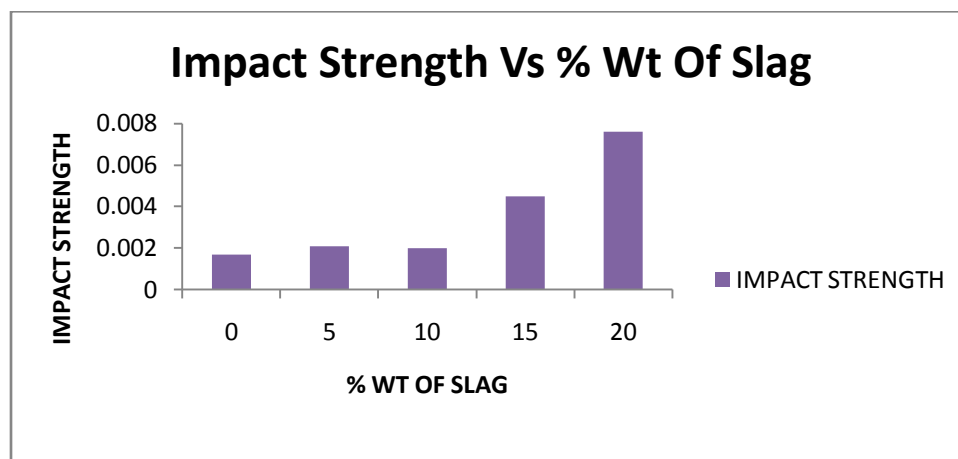
Specific Flexural Strength Vs Percentage Weight of Slag

percentage wt of Slag	0%	5%	10%	15%	20%
SpTensile strength(Mpa/kgm-3)	0.1114	0.0741	0.0615	0.0681	0.0759



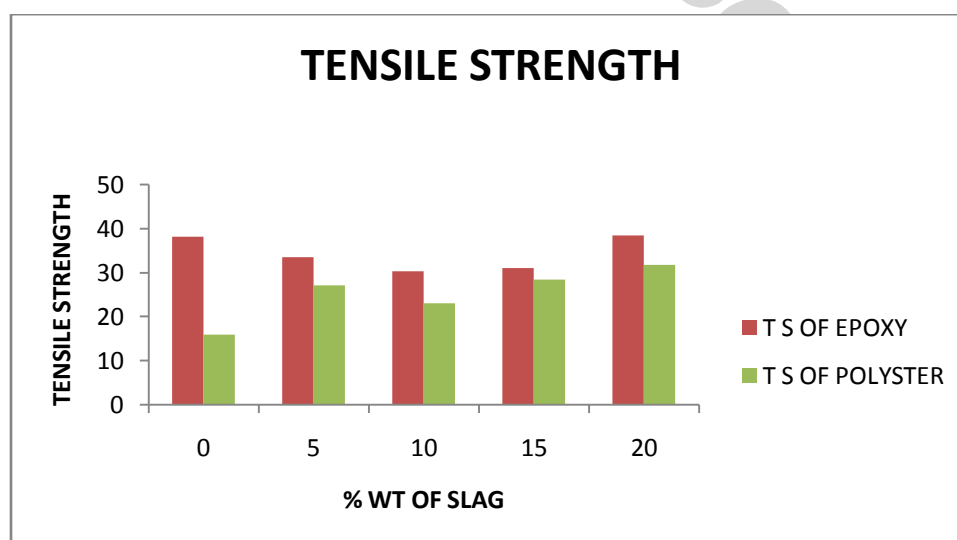
Impact strength Vs Percentage Weight of Slag

percentage wt of Slag	0%	5%	10%	15%	20%
Impact strength(Nm/mm2)	0.0017	0.0021	0.002	0.0045	0.0076



### Tensile Strength Vs Percentage Weight of Slag

percentage wt of Slag	0%	5%	10%	15%	20%
Tensile strength for (Epoxy)	38.2	33.53	30.35	31.08	38.55
Tensile strength for (Polyster)	15.96	27.12	23.156	28.45	31.763



### Specific Flexural Modulus Vs Percentage Weight of Slag

percentage wt of Slag	0%	5%	10%	15%	20%
SpFlexuralModulus(Epoxy)	2.7281	2.367	1.904	2.345	2.417
SpFlexuralModulus(Polyster)	2.44516	2.281	2,2508	2.301	1.936

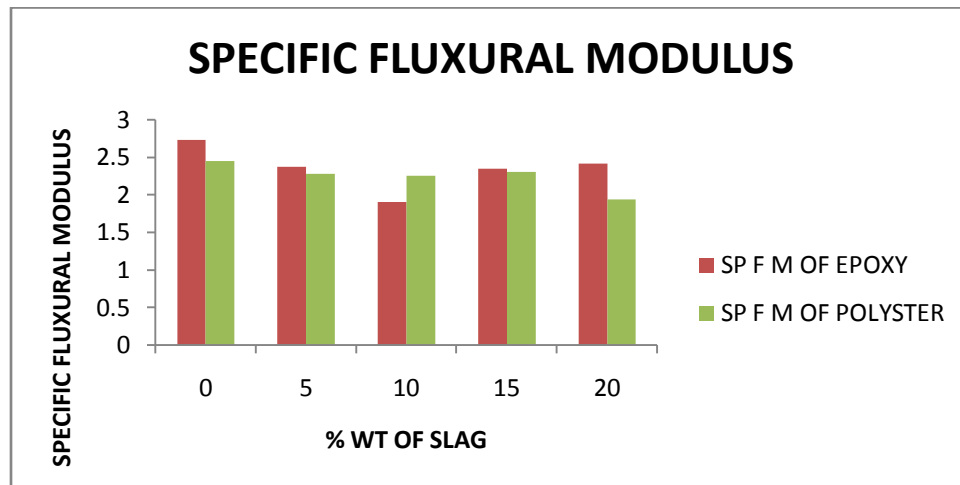


FIG: Specific Flexural Modulus Vs Percentage Wt of Slag

Impact strength Vs Percentage Weight of Slag

percentage wt of Slag	0%	5%	10%	15%	20%
Impact strength(Epoxy)	0.0017	0.0021	0.002	0.0045	0.0076
Impact strength(Polyster)	0.0022	0.0018	0.0011	0.0034	0.0052

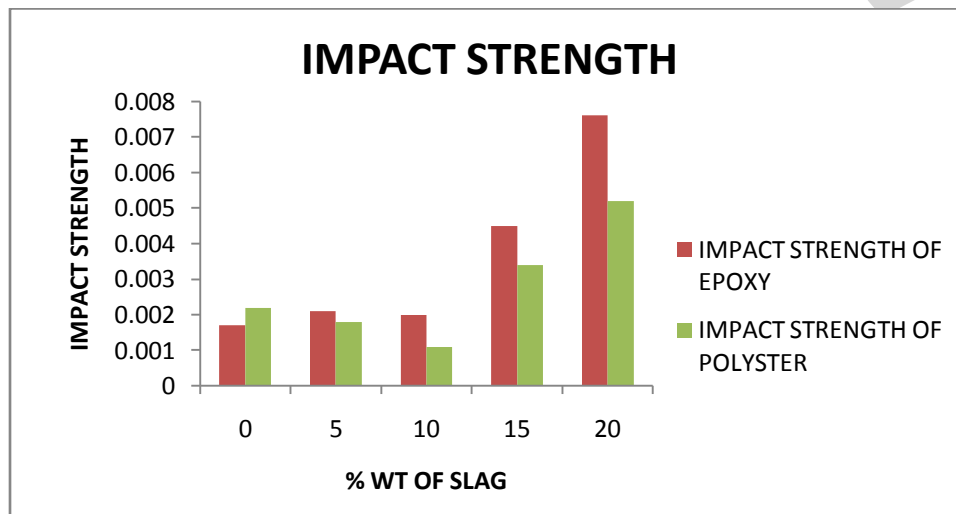


FIG Impact strength Vs Percentage Weight of Slag

## CONCLUSION:

Tensile, Flexural and impact tests are conducted on specimen in different compositions of Slag for epoxy and polyester. From the tensile and flexural test young's modulus of the specimen for different compositions are calculated. It can be observed that the young's modulus of the specimen get improved by reinforcing **Slag**.

- ❖ There is an increase in tensile and flexural properties up to 20% by reinforcing slag..
- ❖ Impact properties gradually decreased by increase in weight of Slag.

By using the mixture of cement and Slag as a reinforcing material the mechanical properties of the specimen increased

## SCOPE FOR FUTURE EXPERIMENTATION:

- Cement can be varied in different proportions for improving the mechanical properties of the specimen.
- Some other particulates like granite powder or any other industrial waste can be added for improving the mechanical behaviour
- The impact strength can be raised by improving the fineness of the particulate powder.
- Other tests like wear resistance test, die electric test can also be conducted to study mechanical behaviour.

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