Evaluation of Mechanical Properties of Slag Reinforced Polymer Composite

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Abstract: 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 nontraditional materials hybrid properties can be achieved which is the origin for the composite materials. Huge amount of minerals are released from the many industries as a waste materials, by appropriate usage of these industrial waste to enhance the physical and mechanical properties of the conventional polymer materials

The objective of present work is to use this industrial waste i.e. slag which is generated during the production of pig iron in the blast furnace as particulate filler material to the organic resin at different weight fractions to study the mechanical behavior of reinforced polymer composite material. Unsaturated ortho- phthalic polyester resin is selected as a matrix material due to its availability, low cost and easy to mould at room temperature. The slag is reinforced in different proportions with resin along with the accelerator (cobalt) and hardener (methyl ethyl ketone peroxide) and Silane as a coupling agent to prepare samples. Uni-axial tensile test, 3-point loaded flexural test and V-notched impact tests are carried out to study the mechanical properties experimentally.
The slag is mixed with resin and poured in a mould to form specimen of required dimensions as per ASTM standards. 10%, 20%, 30% of slag wt% and t 0.3% and 0.5% Silane wt is taken to make the specimen. It is observed that load carrying capacity is increased with increase in wt% of slag.
The tensile Strength of pure resin, the Specific tensile strength the average tensile modulus is improved and flexural strength is 2.4675 times more than that of pure polyester but the value is decreased gradually with addition of coupling agent. Similarly the flexural modulus obtained is also as high as approximately 5 times more than that of pure polyester resin. The impact strength is decreased with increase in wt% of slag, gradually The impact strength of particulate composite can be improved by increasing the fineness of the powder.

I. INTRODUCTION

Composite materials are engineering materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure.A composite material is a microscopic or macroscopic combination of two or more distinct materials with a recognizable interface between them. The most common composite is concrete. It consists of a binder (cement) and reinforcement (gravel). The individual materials that make up composites are called *constituents* as *matrix* and reinforcement. The reinforcement is usually much stronger and stiffer than the matrix, and gives the composite its good properties. The matrix holds the reinforcements in an orderly pattern.
Matrix phase: The primary phase, having a continuous character, is called matrix. Matrix is usually more ductile and less hard phase. It holds the dispersed phase particle or fibers and shares a load with it. The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal
Dispersed phase: The second phase is embedded in the matrix in a discontinuous form. This secondary phase is called dispersed phase. Dispersed phase is usually stronger than the matrix, therefore it is sometimes called reinforcing phase. The reinforcement is usually much stronger and stiffer than the matrix, and gives the composite its good properties. The matrix holds the reinforcements in an orderly pattern. Because the reinforcements are usually discontinuous, the matrix also helps to transfer load among the reinforcements. Reinforcements basically come in three forms: *particulate, discontinuous fiber,* and *continuous fiber*. A particle has roughly equal dimensions in all directions, though it doesn't have to be spherical. Gravel, micro balloons, and resin powder are examples of particulate reinforcements. Reinforcements become fibers when one dimension becomes long compared to others. Discontinuous reinforcements (chopped fibers, milled fibers, or

whiskers) vary in length from a few millimeters to a few centimeters. Most fibers are only a few microns in diameter, so it doesn't take much length to make the transition from particle to fiber. With either particles or short fibers, the matrix must transfer the load at very short intervals. Thus, the composite properties cannot come close to the reinforcement properties. With continuous fibers, however, there are few if any breaks in the reinforcements. Composite properties are much higher, and continuous fibers are therefore used in most high performance components, be they aerospace structures or sporting goods.

Comparison of Resin Properties:

The choice of a resin system for use in any component depends on a number of its characteristics, with the following probably being the most important for most composite structures:

- Adhesive Properties
- Mechanical Properties
- Micro-Cracking resistance
- Fatigue Resistance
- Degradation from Water Ingress

Adhesive Properties: The adhesion of the resin matrix to the fiber reinforcement or to a core material in a sandwich construction is important. Polyester resins generally have the lowest adhesive properties. Vinyl ester resin shows improved adhesive properties over polyester but epoxy systems offer the best performance of all due to their chemical composition and the presence of polar hydroxyl and ether groups. As epoxies cure with low shrinkage and adherents are not disturbed during the cure.

Mechanical Properties: Two important mechanical properties of any resin system are its tensile strength and stiffness. Tests carried out on commercially available polyester, vinyl ester and epoxy resin systems cured at 20°C and 80°C. After a cure period of seven days at room temperature it can be seen that a typical epoxy will have higher properties than a typical polyester and vinyl ester for both strength and stiffness. composite exhibits considerable amount of shrinkage that occurs in a resin during and following its cure period. Shrinkage is due to the resin molecules rearranging and re-orientating themselves in the liquid and semi-gelled phase and can show shrinkage of up to 8%.

Micro-Cracking: The strength of a laminate is usually thought of in terms of how much load it can withstand before it suffers complete failure. This ultimate or breaking strength is the point at which the resin exhibits catastrophic breakdown and the fiber reinforcements break. However, before this ultimate strength is achieved, the laminate will reach a stress level where the resin will begin to crack away from those fiber reinforcements not aligned with the applied load, and these cracks will spread through the resin matrix. This is known as ‘transverse micro-cracking’ and, although the laminate has not completely failed at this point, the breakdown process has commenced.

Fatigue Resistance: Generally composites show excellent fatigue resistance when compared with most metals. However, since fatigue failure tends to result from the gradual accumulation of small amounts of damage, the fatigue behavior of any composite will be influenced by the toughness of the resin, its resistance to micro cracking, and the quantity of voids and other defects, which occur during manufacture.

Degradation from Water Ingress: An important property of any resin, particularly in a marine environment, is its ability to withstand degradation from water ingress. All resins will absorb some moisture, adding to a laminate’s weight, but what is more significant is how the absorbed water affects the resin and resin/fiber bond in a laminate, leading to a gradual and long term loss in mechanical properties. Both polyester and vinyl ester resins are prone to water degradation due to the presence of hydrolysable ester groups in their molecular structures. As a result, a thin polyester laminate can be expected to retain only 65% of its **Inter-laminar shear** *strength* after immersion in water for a period of one year, whereas an epoxy laminate immersed for the same period will retain around 90%.

Osmosis: All laminates in a marine environment will permit very low quantities of water to pass through them in vapour form. As this water passes through, it reacts with any hydrolysable components inside the laminate to form tiny cells of concentrated solution. Under the osmotic cycle, more water is then drawn through the semi-permeable membrane of the laminate to attempt to dilute this solution. This water increases the fluid pressure in the cell to as much as 700psi. Eventually the pressure distorts or bursts the laminate or gel coat, and can lead to a characteristic ‘chicken-pox’ surface. A polymer chain having an epoxy backbone is substantially better than many other resin systems at resisting the effects of water. Such systems have been shown to confer excellent chemical and water resistance, low water transmission rate and very good mechanical properties to the polymer.

II. EXPERIMENTAL APPARATUS AND PROCEDURE

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 Srikalahasti. Various ingredients are added to the solution in order to improve the bonding properties and strength of the pure resin.

Major ingredients: i. Resin – Unsaturated polyester, ii. Catalyst – ketone peroxide, iii. Hardener – cobalt (Accelerater), iv. Powder –slag and v. Silane – A 187 – Glycidoxy propyl trimethoxyl Silane

Slag composition: SiO_2 - 19.95%, $Al2O_3$ - 0.57%, CaO - 32.40%, MgO - 9.80%, FeO - 0.32%, , MnO - 0.45%, Fe_2O_3- 34.40%, SiO_2 - 19.95%.

Method of preparation:

Table2.1 different proportions of resin, catalyst, saline, slag and accelerator

Sample	Resin	Catalyst	Cobalt	Saline	Slag
Pure resin	100%	0	0	0	0
L10%	86%	2%	2%	0.3,0.5%	10%
L20%	76%	2%	2%	0.3,0.5%	20%
L30%	66%	2%	2%	0.3,0.5%	30%

The polymer matrix composites are made by simple casting technique. In which the Resin is mixed with slag remaining is unsaturated polyester resin. All these ingredients are thoroughly stir by hand and then poured in the mould cavity. The samples are prepared for different types of tests such as tensile, flexural and impact.

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 mixtures is prepared as per the above mentioned percentage and poured into the mould. Silane is added as coupling agent to reinforce the interfacial bonding of the particulate material which intern improves the mechanical properties of the polymer composite materials. The specimens are post cured at 50^0C for 2hrs in oven.

Fig:2.1 Adhered Sheet to the tile

Fig:2.2 Pouring the prepared solution into cavity

Fig:2.3 Mould after pouring

Fig:2.4 Final Specimens for tensile test

The specimens prepared are subjected to 3 types of tests as 1. Tensile test – Uniaxial tensile test, 2. Bending test – 3-point flexural test and 3.impact test – V- notched impact test

TENSILE TEST: A 2 ton capacity - Electronic tensometer, METM 2000 ER-I model (Plate II-18), supplied by M/S Microtech, Pune, is used to find the tensile strength of composites. Its capacity can be changed by load cells of 20Kg, 200Kg & 2000 Kg. A load cell of 200 Kg. is used for testing composites. Self-aligned quick grip chuck is used to hold composite specimens. A digital micrometer is used to measure the thickness and width of composites.

BENDING TEST: The bending test is conducted on the specimen using the same machine

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress.

IMPACT TEST: An analog Izod/ charpy impact tester supplied by M/S International Equipments, Mumbai was used to test the impact properties of fiber Reinforced composite specimen. The Equipment with a minimum resolution on each scale of 0.02 J, 0.05 J, 0.1 J and 0.2 J respectively .Four scales and corresponding hammers (R1,R2,R3,R4) are provided for all the above working ranges.

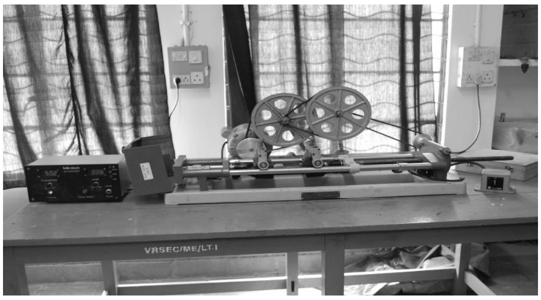

Fig:2.5Tensometer

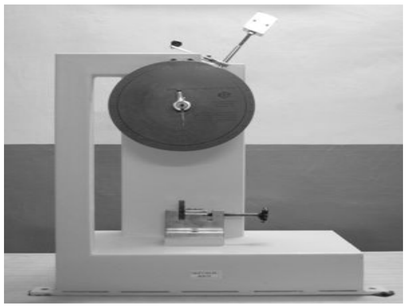

Fig:2.6 Impact Testing Machine

Standard test method, ASTM D256-97, for impact properties of particle-resin composites has been used to test the unidirectional composite specimens. The specimens are prepared to dimension of 63.5*12.7*10mm width. A V-notch is provided with a sharp file having an included angle of 45^0 at the centre of the specimen, and at 90^0 to the sample axis. The depth of the specimen under the notch is 10.16+0.05mm or 10.16-0.05mm.

III. RESULTS AND DISCUSSIONS

The behavior of different composite specimen for various weight fraction of filler material under bending is plotted.The tables and graphs shows the detailed analysis of varying deflection at different load conditions.

Table 3.1 Load and Deflection Tensile Testing With 0.3% Silane

% weight Particulate	0 (Pure)	10	20	30
Deflection	Load (N)			
0.0	141.7545	61.2144	78.48	57.2904
0.2	197.678	146.9538	163.2384	144.9918
0.4	243.5332	200.3202	223.0794	203.6556
0.6	283.2637	232.1046	262.1232	247.212
0.8	336.483	281.3508	336.8754	310.5846
1.0	390.194	340.2108	408.096	378.2736
1.2	437.771	401.4252	488.7342	471.4686
1.4	480.9352	463.6206	560.5434	547.0056
1.6	518.949	521.6958	628.2324	622.935
1.8	548.375	584.2836	694.3518	685.3266
2.0	587.8642	635.688	743.0094	738.693
2.2	627.3495	680.2254	786.762	763.6104
2.4	659.7225	720.054	828.945	776.1672
2.6	679.5878	758.5092	860.5332	789.705
2.8	724.304	787.1544	888.786	
3.0	751.446	812.0718	920.9628	

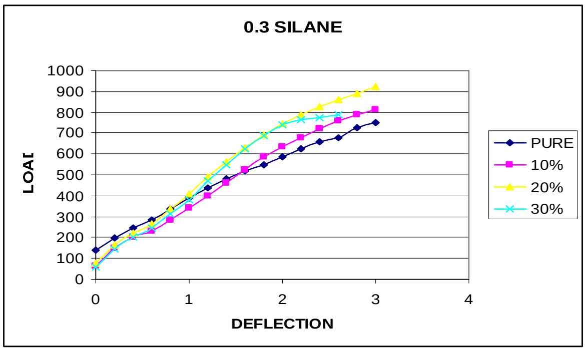

Fig: 3.1: Load and Deflection Tensile Testing With 0.3% Silane At Different wt % Of Particulate Material

Table: 3.2 Load and Deflection Tensile Testing With 0.5% Silane

% weight Particulate	0 (Pure)	10	20	30
Deflection	Load (N)			
0.0	141.7545	71.8092	73.3788	71.0244
0.2	197.678	162.4536	171.2826	134.0046
0.4	243.53322	209.7378	227.9844	198.9468
0.6	283.2637	271.3446	281.1546	247.6044
0.8	336.483	331.3818	349.4322	299.9898
1.0	390.194	400.248	409.6656	400.248
1.2	437.771	456.5574	485.0064	488.7342
1.4	480.9352	521.1072	550.9296	584.0874
1.6	518.949	590.9544	612.9288	657.6624
1.8	548.375	652.1688	671.7888	719.4654
2.0	587.8642	707.301	714.168	780.0912
2.2	627.3495	769.4964	749.8764	825.4134
2.4	659.7225	829.5336	780.0912	868.7736
2.6	679.58775	871.9128	796.7682	894.0834
2.8	724.304	902.3238	809.7174	910.9566
3.0	751.446	944.5068	808.5402	918.4122

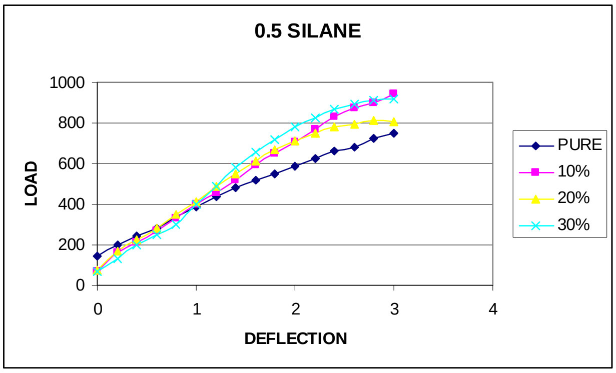

Fig: 3.2 Load and Deflection Tensile Testing With 0.5% Silane at Different wt % Of Particulate Material

From the fig 3.3 and 3.4 it is clear that max. load bearing capacity is 1191.13 at 10% particulate material with .03% saline. max. tensile strength is 31.7635 at 20% particulate material without saline.

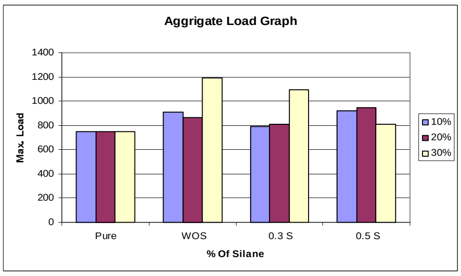

Fig: 3.3 Max. load bearing capacity at different Wt % slag material with Different % of Silane

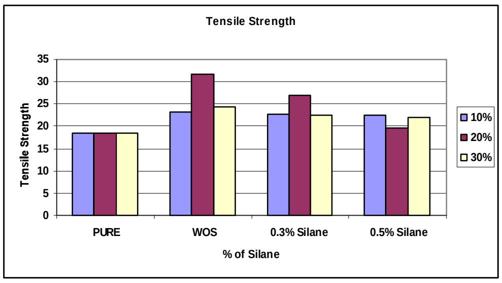

Fig:3.4: Maximum Tensile Stress at different wt % slag with Different % of Silane

From the fig 3.5 it is clear that max. tensile modulus is 769.306 at 30% particulate material without saline.

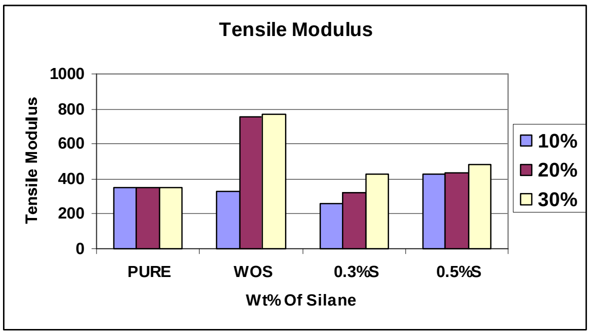

Fig:3.5: Maximum Tensile Modulus at different wt % particulate material with Different % of Silane

From the fig: 3.6 &3.7 it is clear that max. specific tensile strength is 0.0264 and max. tensile modulus 0.62708 at 20% particulate material without saline

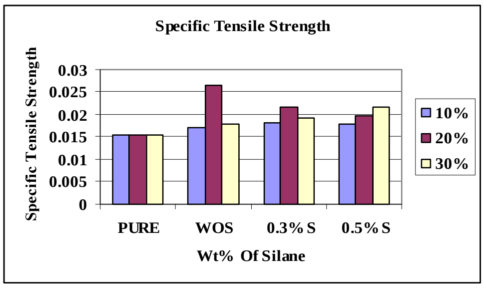

Fig: 3.6: Specific Tensile Strength at different wt % particulate material with Different % of Silane

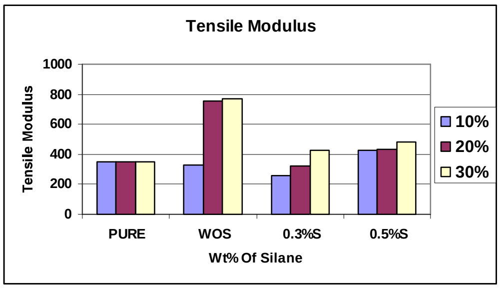

Fig:3.7: Specific Tensile Modulus at different wt % particulate material with Different % of Silane

Table: 3.3 Load and Deflection for Flexural testing at different Wt% particulate material and Different wt % of Silane

%weight of slag	0	10% 0.3S	10% 0.5S	20% 0.3S	20% 0.5S	30% 0.3S	30% 0.5S
Elongation(mm)	Load (N)						
0	10.79	8.91	16.284	13.9302	14.715	10.044	4.1202
0.2	14.715	18.0504	30.803	30.2148	24.9174	20.050	10.0062
0.4	19.62	31.1958	43.360	42.5754	32.9616	33.195	20.4048
0.6	23.544	49.4424	57.879	56.7018	41.0058	51.442	31.9806
0.8	27.468	64.5498	71.416	67.1004	48.2652	66.549	46.8918
1	30.411	75.9294	84.366	77.1066	53.5626	77.929	61.2144
1.2	33.354	85.347	97.315	85.9356	58.4676	87.347	72.0054
1.4	37.278	96.7266	105.751	93.5874	63.5688	98.726	80.8344
1.6	40.221	106.144	113.992	100.062	68.4738	108.14	89.8596
1.8	43.164	113.403	122.625	107.125	73.3788	115.40	99.0613
2	45.126	119.289	129.492	112.030	76.518	121.28	107.713
2.2	47.08	127.137	136.555	118.112	82.6002	129.13	113.207
2.4	50.031	136.947	141.460	126.156	85.5432	138.94	118.112
2.6	53.95	142.048	145.580	133.808	89.4672	144.04	123.017
2.8	56.898	148.523	148.327	139.694	92.8026	150.52	129.884
3.0	59.841	154.409	150.485	145.384	95.7456	156.40	135.378

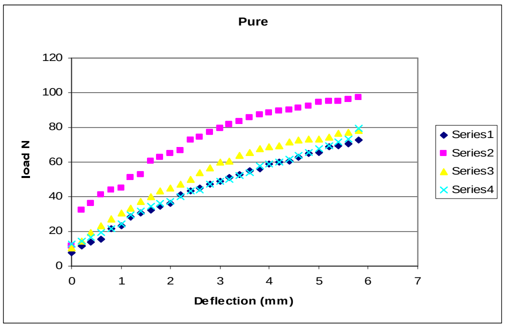

Fig 3.7: Load Vs Deflection curves for different Specimens

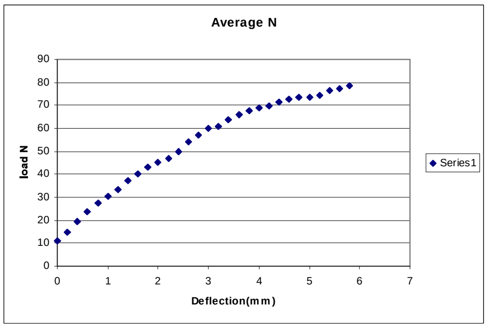

Fig: 3.8: Load Vs Deflection curves for Average of five different Specimens

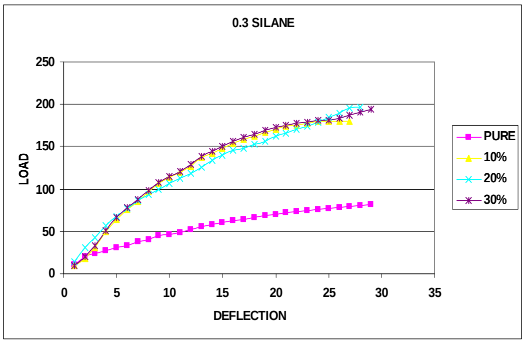

Fig: 3.9: Load Vs Deflection curves for Flexural testing at different wt% slag at 0.3 % of Silane

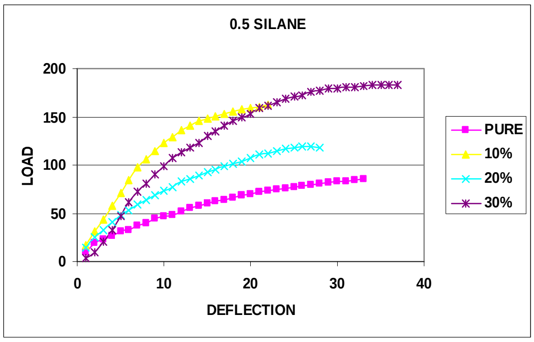

Fig: 3.10: Load Vs Deflection curves for Flexural testing at different wt% slag at 0.5 % of Silane

From the fig: (bar chart) 3.11 &3.12 it is clear that average flexural stress is max. 121.571 and avg. flexural strength is 3065.69 at 20% and 10% particulate material without saline

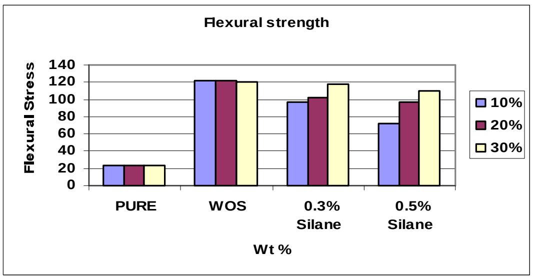

Fig:3.11: Average Flexural Stresses at different wt% slag and Different wt % of Silane

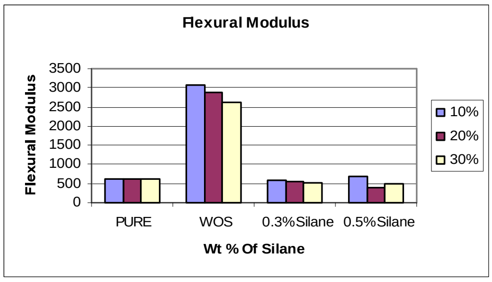

Fig:3.12: Average Flexural Modulus at different wt% slag and Different wt % of Silane

From the fig: (bar chart) 3.13 &3.14 it is clear that sp flexural stress is max. 2.2508 at 10% particulate without saline and sp. flexural strength is 0.10813 at 30% particulate and 0.5% saline

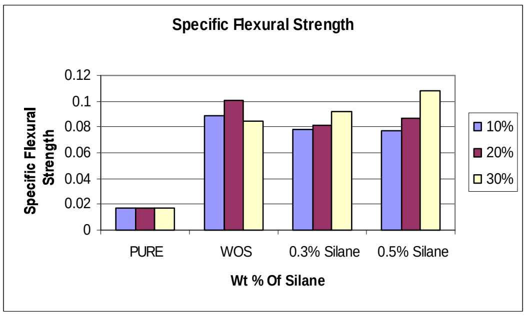

Fig:3.13: Specific Flexural Strength at different wt% slag and Different wt % of Silane

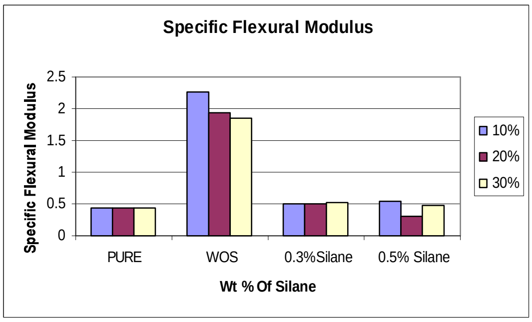

Fig:3.14: Specific Flexural Modulus at different wt% slag and Different wt % of Silane

Impact test: Notched Izod Impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Izod impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. Izod specimens are notched to prevent deformation of the specimen upon impact. This test can be used to determine if a material meets specific impact properties or to compare materials for general toughness.

Test Procedure:

The specimen is clamped into the pendulum impact test fixture with the notched side facing the striking edge of the pendulum. The pendulum is released and allowed to strike through the specimen. Many materials (especially thermoplastics) exhibit lower impact strength at reduced temperatures, it is sometimes appropriate to test materials at temperatures that simulate the intended end use environment. So the test is carried at controlled temperature.

Table:5 Impact Strength at different wt% particulate material and Different wt % of Silane

Wt %	10	20	30
PURE	22	22	22
WOS	11.2	10	9.6
0.3	18	12.4	11.6
0.5	15.4	12.4	7.6

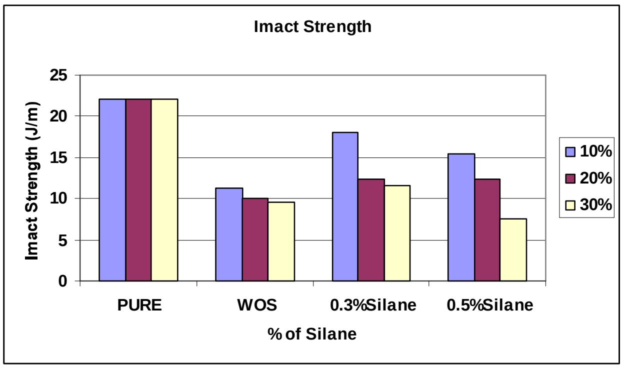

Fig:3.15: Impact Strength at different wt% and Different wt % of SilanFig:5.22 Specimens after Impact test conducted

Fig:3.16 Specimens after impact test conducted

Fig:3.16 Specimens after flexural test conducted

5.4 Mechanical Behavior Of Composites:

1. The mechanical behavior can be observed from the graph 3.1 shows the maximum tensile load bearing capacity of resin at different % of particulate and 0.3% and 0.5% of Silane coupling agent. It is observed that the load carrying of carrying capacity increased to 812.718N at 10% slag from that of pure polyester resin 352.27N, further it is increased to 1091.68N at 0.3% Silane but reduced to 789.705 N with 0.5% silane

2. Graph 3.2 shows the tensile strength of pure resin 18.54M Pa. It is increased to 23.15M Pa at 10% slag there after reduced with increase in wt% of slag and silane

3. It is observed from the graph 3.3 that the tensile modulus of pure resin 352.27M Pa is improved to 754.387M Pa for 20% slag without silane, but this value is reduced with the addition of silane.

4. Fig 3.4 shows that the Specific tensile strength of pure 0.01545 M Pa/Kg/$m^{3\ is}$ increased with increase in wt% of slag and silane. The value is maximum 0.0264 M Pa/Kg/m^3 at 20% slag and 0.3% silane.

5. From the graph 3.5 it can be observed that Specific tensile modulus of pure 0.2939 M Pa/Kg/m^3 is increased to 0.62708 M Pa/Kg/m^3 without silane, but this value is reduced by adding the coupling agent.

6. It is observed from the graphs 3.7 that there is significant increase in the load bearing capacity of the flexural specimen with increase in weight % of the particulate. But the strength is reduced by adding the silane.

7. It can be observed from the graph 3.8 that flexural strength of pure resin (23.44M Pa) is increased to 97.143M Pa at 10% slag and 0.3 % Silane, it is further increased to 117.42M Pa at 30% slag.

8. From the graph 3.9, it can be observed that Flexural modulus of pure resin 622.84M Pa is increase with increase in weight% of slag with out Silane to 3065.69M Pa but the flexural modulus is drastically reduced by adding the silane.

9. Fig 3.10 shows that the Specific Flexural strength of pure resin 0.01677 M Pa/Kg/m^3 is increase to 0.10813M Pa/Kg/m^3 with 30% slag with 0.5% Silane and from the graph 5.20Flexural modulus also reduced with increasing the slag and silane.

10. The impact strength of the pure specimens 22J/m is decreased it increase of the weight percentage of the composite as 11.2 J/m at 10% 10J/m at 20% 9.6J/m at 30% slag but it is improved to 11.6J/m at 0.3% silane and once again it is drop down to 7.6J/mwith 0.5% slag.

IV. CONCLUSION

The main objective of this investigation is to gauge the possibility of industrial waste i.e. slag is an alternative filler material in a polymer matrix. Following conclusion are made from the investigation.

These tests tensile, bending, impact are conducted on specimen in different compositions. From the tensile test and bending test are conducted on the specimen and the young's modules of the specimen for different compositions are calculated .It can be observed that the young's modules of the specimen gets improved by reinforcing the resin with ingredients and it is varied with the variation of silane coupling agent. The impact strength reduced by reinforcing the pure resin with ingredients.

- It is observed that the load carrying of carrying capacity increased to 812.718N at 10% slag from that of pure polyester resin 352.27N, further it is increased to 1091.68N at 0.3% Silane but reduced to 789.705 N with 0.5% silane.
- The Specific tensile strength of pure 0.01545 M Pa/Kg/$m^{3\ is}$ increased with increase in wt% of slag and silane. The value is maximum 0.0264 M Pa/Kg/m^3 at 20% slag and 0.3% silane.
- Flexural strength of pure resin (23.44M Pa) is increased to 97.143M Pa at 10% slag and 0.3 % Silane, it is further increased to 117.42M Pa at 30% slag.
- Flexural modulus of pure resin 622.84M Pa is increase with increase in weight% of slag with out Silane to 3065.69M Pa but the flexural modulus is drastically reduced by adding the silane.
- The impact strength of the pure specimens 22J/m is decreased it increase of the weight percentage of the composite as 11.2 J/m at 10% 10J/m at 20% 9.6J/m at 30% slag but it is improved to 11.6J/m at 0.3% silane and once again it is drop down to 7.6J/mwith 0.5% slag.

REFERENCES

[1] Alok Satapathy, Amar patnaik, "Analysis of dry sliding behavior of red mud filled polyester composites using taguchi method"

[2] Pongdhorn sae-oui , Chakrit Sirisinha , Uthai Thepsuwan , kannika Hattapanit. "Roles of Silane coupling agents on properties of silica filled polycholoroprene"

[3] P.Mareri, S.Bastide, N.Binda, & A.Crespy "Mechanical behavior of poly propylene composites cantaining fine mineral filler: effect of filler surface treatment"

[4] H. Weibeck, D.F. borrely, C. Xavier, "The effect of silane coupling agent on a composite polyamide-6/talc", Barz. J. Chem, Eng. Vol. 15 n.4 Sao Paulo Dec 1998.

[5] T. Chaowasakoo, N. Sombatsompop, " Mechanical and morphological of fly/epoxy composites using conventional thermal and microwave curing methods", composites science and technology 67(2007) 2282-2291.

[6] Soon-Chul Kwon, Tadaharu Adachi, Wakako Araki, Akihiko Yamaji, " Effect of composing particles of 2 sizes on mechanical properties of spherical silica-particulate reinforced epoxy composites".

[7] K. Zhu, S. Schmauder, " Prediction of failure properties of short fiber reinforced composites with metals and polymer matrix".

[8] I.H. Tavman, " Thermal and mechanical properties of copper powder filled poly(ethylene) composites".

[9] H. Ku, W. Jacobson, M. Trada, F. Cardona, D. Rogers " Tensile tests of formaldehyde SLG reinforced composites: Pilot study", journal of composite materials, vol.42, No.26/2008.

[10] S.F. Hassan and M. Gupta " Effect of Nano-ZrO2 particulates reinforced on microstructure and mechanical behavior of solidification processed elemental Mg", journal of composite material, Vol.41, No. 21/2007.

[11] V. Alvarez, A. Vazquez and O. De La Osa, " Cyclic Water Absorption Behavior of Glass-vinylester and glass-epoxy composites", journal of composite materials, Vol.41, No. 10/2007.

[12] M.A. Aboudzadeh. S.M. Mirabedini, M. Atai, " Effect of silane based treatment on the adhesion strength of acrylic lacquers on the PP surfaces".

[13] Pongdhorn Sae-oui, Chakrit Sirisinha, Uthai Thepsuwan, Kannika Hatthapanit " Roles of silane coupling agents on properties of Silica- filled Poychloroprene"

[14] H.F.Wu, D.W.Dwight & N.T.Huff " Effects of silane coupling agents on the interphase and performance of glass- fiber reinforced polymer composites.