IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 3 Ser. II (May – June 2021), PP 01-12
www.iosrjournals.org

AnExperimentalInvestigationonGlass Reinforced Polymer as a formworkmaterial

Dr.Binu Sukumar[*], R.Aframariam[**], Anuja.S[**], Buwnaswari.S[**], Durgadevi.D[**]

[*]*Professor & Head, Department of Civil Engineering, R.M.K Engineering College, Kavaraipettai, Tamil Nadu, India*

[**] *U.G. Student, Department of Civil Engineering, R.M.K Engineering College, Kavaraipettai, Tamil Nadu, India*

Abstract - *Formwork systems are among the key factors determining the success of a construction project in terms of speed,quality,costandsafetyoftheworks.Itoccupiesaround 25% of the cost and 60% of time in the entire construction project.The rapid advancement in thefield of formwork along with the innovation in concrete as a material has to lead to a revolutionary change where safer, quicker, sustainable and more efficient construction is possible these days. Glass reinforced plastic (GRP) formwork, is a form of plastic formwork which is being used in the construction industry as a permanent formwork. Instead of using GRP as a permanent formwork for bridges and casting pipes it's usage as a temporary formwork for construction is studied by carrying outvariousrequiredtestsofformwork.Thestudiesshowsthat when GRP is used as a formwork material the cost of constructionhasbeengreatlyreduced.Itprovidesbetterfinish and increases the quality ofconstruction.*

Index Terms - *Glass reinforcement plastic panels, tensile strength, flexural strength, breaking load of manufactured panels, mechanical properties, chemical resistance.*

Date of Submission: 29-05-2021 Date of Acceptance: 12-06-2021

I. Introduction

Formwork is temporary or permanent mould into which fresh concrete is poured and formed. They are temporary structures that are built to support parts or the whole of a permanent structure until it is self supporting.. Formworkplays the vital role of a skeleton for construction , without which it will fail as a system. Many materials have been used as formwork material since the beginning of construction in civilisation. The rapid advancementinthefieldofformworkalongwiththeinnovation in concrete as a material has to lead to a revolutionary change where safer, quicker, sustainable and more efficient construction is possible these days. Glass reinforced plastics panels(GRP)isaformofplasticformworkwhichisbeingused as permanent formwork for bridge construction, as well as mould for pipe casting. In this project we will discuss the possibility of GRP panels to be used as a temporary formwork for building construction , its techniques along with various different tests of formwork material.

Mechanical properties of GRP matrix Composites:

Aramide et al.[1] investigated the mechanical properties of woven-mat GF-reinforced unsaturated polyester composite with different fiber Vfs like 5, 10, 15, 20, 25 and 30%. The tensile strength, Young's modulus and elastic strain increased with increase of the GF Vf. Impact strength decreased with increase of the GF Vfof 25%. The maximum tensile and flexuralpropertieswerefoundat30%VfofGF.Themaximum strain was found at 25%Vf.

Erden et al.4 investigated the mechanical behaviour of woven roving E-GF-reinforced unsaturated polyester composites with matrix modification technique. The oligomericsiloxane was added to polyester resin in different levels like 1, 2, and Wt% respectively. Incorporation of oligomericsiloxane into the polyester resin increased the mechanical properties such as inter-laminar shear, flexural and tensile strength, modulus of elasticity and vibration values. Glass/polyester with 3 wt% of oligomericsiloxane composite was found to be better mechanical properties compare to other combinations. The tensile strength increased from 341.5 to 395.8 MPa while the. Flexural Strength increased from 346.1 MPa to 399.4 MPa, Interlaminar Shear strength increased from 25.5 to 44.7 MPa, natural frequency increased from 6.10 to 7.87 Hz.

Al-alkawi et al.[9] investigated the fatigue behaviour of woven strand mats E-GF reinforced polyester composites under variabletemperatureconditionssuchas40C,43Cand60C.The S-N curve reported that the tensile and fatigue strength decreased with increasing temperature up to 60C at 33% fiber Vf.The24percentagereductionfactorforfatiguestrengthwas higher than the percentage reduction factor for tensile strength for all temperaturelevel.

Awan et al.[5]investigated the tensile properties of GF- reinforced unsaturated polyester composite with various cross sections of fibers at various ply of 1-ply,2-ply and 3-ply . The higher weight percentage of GF in composites gives stronger reinforcement. The number of layers, thickness and the cross sectional area was different for each specimen. Maximum tensilestrengthobservedinthreeplyreinforcement.HigherVf of fibers increased the strength and stiffness of thecomposite.

Puticetal.[10]investigatedtheinterlaminarshearstrengthofthe random/woven GF mat-reinforced polyester matrix composite with three-layer and eight combinations of the composition patterns. The glass fabric with various densities, various polyesterresinslikebisphenolicresin,water-resistantresinand acid resistant resin were used to analyse the strength. Outer layers were short GF and inner layers were woven mat fiber and thickness of outer layers 1 mm, middle layer 0.5–0.8 mm. The P6 [Glass mat (240 g/m2)/woven mat (0/90) (800 g/m2)/Glass mat (240 g/m2)] pattern model bisphenolic resin- based composites had higher interlaminar shear strength compared to other patterns.

Alam et al.[6] investigated the effect of orientation of chopped strand and roving GFRP composites with different fiber orientation such as 0, 45 and 90. Fiber orientation was not affectedbythedensityandhardnessofcomposites.At90fiber orientation the maximum tensile strength was obtained. The short fiber was found to be reducing the impactstrength.

Aktas et al.[13] investigated the impact and post impact behaviour of E-glass/epoxy eight plies laminated composites with different knitted fabrics such as Plain, Milano and Rib. Different impact energy levels were ranging from 5 J to 25 J. The experimental result showed that the Rib knitted structure had maximum mechanical properties for irregular fiber architecture, Milano knitted structure showed maximum performance in transverse direction and as well as better mechanical properties than Plain knitted structure.

Karakuzu et al.[14] investigated the impact behaviour of unidirectional E-glass/epoxy composite plates with the stacking sequence of plates selected as [0/30/60/90]. Four differentimpactenergieswere10J,20J,30Jand40Jandfour impact masses were selected like 5 kg, 10 kg, 15 kg and 20kg. Absorbed energy versus impact energy curve reported that the energy absorption capability of the specimen subjected to 25 equal mass was lower than the specimen subjected to equal velocity for the same impact energy. Delamination area versus impactor mass curve reported that the delamination area in the sample was subjected to a lower impact mass with higher velocity was lower than the delamination area in the sample was subjected to higher impact mass with lower velocity for same impactenergy

Liu et al. [11]investigated interlaminar shear strength of woven E-GF reinforced/epoxy composites with unmodified and modified matrix modification technique. Initial epoxy matrix was diglycidyl ether of bisphenol-F/diethyl toluene diamine systemandmodifiedmatrixwasmultiwalledcarbonnanotubes (MWCNT) and reactive aliphatic diluent namen-butylglycidyl ether system. The three-point bending result showed that the modified epoxy/GF composites inter-laminar shear strength was higher than the unmodified epoxy/GF composite; 0.5wt% MWCNTs and 10 phr butyl glycidyl ether (BGE)addingepoxy/GF composite was 25.4% increased the inter laminar shear strength (41.46 MPa) than unmodified composites

Vibration characteristics of GRP

Erden et al.[4]investigated vibrational properties of glass/polyester composites via matrix modification technique. To achieve this, unsaturated polyester was modified by incorporationofoligomericsiloxaneintheconcentrationrange of1–3wt%.Modifiedmatrixcompositsreinforcedwithwoven roving glass fabric were compared with untreated glass/polyester in terms of mechanical and interlaminar properties by conducting tensile, flexure and short-beam shear tests. Furthermore, vibrational properties of the composites were investigated while incorporating oligomericsiloxane. From the experiment it was found that the natural frequencies of the composites were found to increase with increasing siloxane concentration.

Yuvaraja et al.[15] investigated the vibration characteristics ofa flexibleGFRPcompositewithshapememoryalloy(SMA)and piezoelectricactuators.Infirstcase,thesmartbeamconsistsof a GFRP beam modelled in cantilevered configuration with externally attached SMAs. In second case, the smart beam consists of a GFRP beam with surface-bonded lead zirconatetitanate (PZT) patches. To study the behaviour of the smart beam a mathematical model is developed. Using ANSYS the vibration suppression of smart beam was investigated. The experimental work is carried out for both cases in order to evaluate the vibration control of flexible beam for first mode, also to find the effectiveness of the proposed actuators. As a result of the vibrational characteristic, GFRP beam is more effective when SMA is used as an actuator. SMA actuator was more efficient than the PZT actuator because very less voltage is required for actuation of SMA.26

Environmental behaviours of GRP matrix composites

Botelho et al.[16] investigated the environmental behaviour of woven mat GF reinforced poly ether-imide thermoplastic matrix composites. The testing was conducted with varying temperature at relative humidity of 90% for 60 days under sea water. The moisture absorption behaviour was mostly dependent on temperature and relative humidity. The moisture absorption curve reported that the weight gain was initially increasedlinearlywithrespecttotime.Themaximummoisture absorption of 0.18% was found after 25days.

Renaudetal.[17]investigatedtheenvironmentalbehaviourofE- GF-reinforced isophtalic polyester composites with different GFs such as boro-silicate and boron-free at different environmental conditions such as strong acids, cement extract, salt water, tap water and deionized water. The test was conducted at 60C for lifetime of 43 years; the boron-freeE-GFcompositeincreasedtheresistanceofmoistureabsorptioninall environmentalconditions.

Agarwal et al.[18] investigated the environmental effects of randomly oriented E-GF-reinforced polyester composites with differentenvironmentalconditionssuchasbrine,acidsolution, ganga water, freezing conditions and kerosene oil. The test conducted at different interval of time such as 64 h, 128 h and 256 h. The percentage reduction in tensile strength decreased aftereveryintervaloftime,themaximumpercentagereduction was found on NaOH solution and minimum percentage reduction was found on freezercondition.

J.G. Ferreria and F.A. Branco(2005) [20] In this paper, the results of a research project were presented where glass fibres wereappliedtothefabricationofstructuralelements,30mhigh telecommunication towers. The lightness and tensile strength advantages of the GRC were associated with carbon and stainless-steel reinforcement, leading to an innovativematerial with highdurability.

It concluded, The use of GRC reinforced with carbon fibers or stainless steel bars can be used as a structural material, with reduced weight and good durability properties. GRC application in telecommunication towers is viable and confers strength and deformability levels adequate for the needs of these structures. The numerical models that have been developed for the determination of the strength, deformability and dynamic behavior of the towers show a good correlation with the experimental behavior and may be used for thedesign of this type oftower

Dr. P. Perumal and Dr. J. Maheswaran(2006)[21] examined that the mixes with 1.5% volume of fibres gave optimum composite properties in terms of compressive strength with 25.39% strength 27 improvement. The highest increase insplit tensile strength was observed in mixes with 1.5% of volumes of fibres and found to be 5.76% higher strength than reference concrete. Similarly, the highest flexural strength was observed in mixes with 1.5% of volume of fibre and found to be 72.5% more than referenceconcrete.

Chawla and Tekwari(2012) [24]outlines the experimental investigation conducted on the use of glass fibres with structural concrete. CEM-FILL anticrack high dispersion, alkali resistance glass fibre of diameter 14 micron, having an aspect ratio 857 was employed in percentages varying from

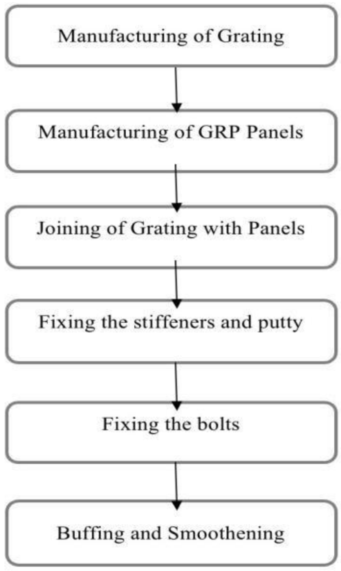
0.33 to 1 percent by weight in concrete and properties of this FRC, like compressive strength, flexural strength toughness, modulus of elasticity, were studied.

Muthuswamy and Thirugnanam(2013)[22] described the experimental work on Hybrid Fibre Reinforced High Performance concrete using three types of fibres namely,steel, glass and polyester fibres of a reputed brand. Silica fume was added as a mineral admixture to partially replace the cementin concrete and a super plasticizer was used to get the desired workability. A comparison with steel fibre reinforcedconcreteand plain concrete showed significant improvement in the strengths of the hybrid fibre reinforced concrete due to the inclusion of both fibres and silica fume.

Sinha et al (2013) [23]studied the effect of ternary blends on the strength characteristic of steel fibers reinforced concrete. Both binary and ternary blends were made using SCMs such as fly ash, ground slag, silica Glass Fibre Concrete: Investigation on Strength And Fire Resistant Properties fume, granulated blast furnace,andmetakaolin.Thirtypercentofcementwasreplaced by one SCM or combination of two SCMs. The results of compressive strength and tensile strength are presented.

Chandramouli et al (2010) had conducted experimental investigation to study the effect of using the alkali resistance glass fibres on compressive, split tensile and flexural strength on M20, M30, M40 and M43 grades of concrete. The mechanical properties of glass fibre reinforced polyester polymer concrete were evaluated. The author observed thatthe modulus of rupture of polymer concrete containing 20 percent polyester resin and about 79 per cent fine silica aggregate is about20MPa.Theadditionofabout1.5percentchoppedglass fibres (by weight) to the material increases the modulus of rupture by about 20 per cent and the fracture toughness by about 55 percent

II. ManufacturingProcedure



A Manufacturing of FRP Gratings

GRP gratings are processed in two different manufacturing methods. Generally, gratings are classified according to type of manufacturing process. They are:

1.Molded Fiber Glass Grating ManufacturingProcess

2.Pultruded Grating ManufacturingProcess**:**

In our project we used pultruded FRP Grating method for the manufacturing of our FRP Panels.

Molded Fiber Glass GratingManufacturing Process:

A grating is any regularly spaced collection of essentially identical, parallel, elongated elements. Gratings usually consist of a single set of elongated elements,butcanconsistoftwosets,inwhichcasethe second set is usually perpendicular to the first (as illustrated). When the two sets are perpendicular, this isalsoknownasagridoramesh.Fiberglassgratingis an integral construction single piece fiberglass roving reinforced with Isophthalic resin typically composed of 60-65% resin by weight and immensely strong continuous glass fibers manufactured by a specially designed process that provides a property of good mechanical and corrosion resistance. These are safe& ideal for chemically corrosive environment having long maintenance freelife.

Molded grating is manufactured in an open, heated mold that resembles a large waffle iron. Continuous glassfibersareplacedinthemoldinalternatinglayers and thoroughly wetted out with resin. This continuous process produces an integral, one-piece construction, which offers excellent corrosion resistance as well as bi-directional strength. When the weaving process is completed, the mold is heated to cure the panel. If the gratingistohaveembeddedgrit,themoldwillreceive the grit at this time before the part is cured. After curing, the part is extracted from the mold. The standard part would have a meniscus (concave) top surface for slip resistance. Should a standard grit surface be specified, the grit would be bonded to the top of the completed grating panel as a secondary operation.

Liquid resin and continuous fiberglass rovings systematically laid in a mold, layer after layer manually, to produce the desired thickness and panel dimensions. The finished molds are set aside for a predetermined time to allow the panel to cure. The panel is then ejected from the mold. The molds are cleanedandprepareforthe processtobeginagain.

Figure1 Display of Grating Smoothside

The high percentage of resin (65%) in molded fiberglass grating offers superior corrosion resistance and optimal impact resistance. Molded fiberglass gratings with a square mesh pattern offer increased load capacity and panel utilization due to its bi- directional trait. Numerous cut-outs for piping, valve access, and column penetrations can be made without the need for additional structural framing. Being of

one- piece construction, the fiberglass grating performs as a plate, distributing loads throughout the fiberglass grating section and around cut-outs. Cutting access holes in the molded fiberglass grating does not weaken the panel and does not generally require additional or costly supports (unlike pultruded fiberglass grating that will require additional supports at cutouts).

B Pigmentation:

Manufacturing the fiberglass:

To make glass fibers that are suitable for GRP, materialssuchassilicasand,clay,limestoneandother minerals are gradually melted in a furnace until they are liquefied. This liquid is then pushed through bushings, creating tiny little strands of the filament whicharethencoatedwithaspecialchemicalsolution.

Once this process is complete, the individual strands are then bundled together to produce what is called a roving. The diameter of each strand and number of strands in each bundle determine the weight of the roving.

The rovings are either used in the composite application or are used to make chopped strand mats, which are the basis for many GRP products we use today. Different weaves of fiberglass can be manufactured for a range of differentpracticalapplications.Thepatterndeterminesthe weight and strength of GRP, so depending on your needs a different type of strand mat will beused.

Figure 2*Isophthalic Resin used for pigmentation (Color Yellow)*

C Making the GRP product:

Once enough of these chopped strand mats have been made, they can then be used in moulds to create a range of products. Moulds are first treated with a special chemical mix which consists of resin, a hardener, a catalyst and pigment to ensure nothing sticks it. Once this has dried and cured, thefirst strand mat layer is fitted to themould.

This process is then continued, with a layer of resin and a catalyst added after each new strand mat. Like before, it is then left to cure before another is placed on top. It’s this process that gives GRP its signature strength and the more layers that are added to the mould, the stronger the end product will be.This glass used in this material is made from gradually heating a mixture including limestone and silica sand, amongst other ingredients. It is very important at the heating stage that its temperature is managed carefully to ensure a smooth and robust end material which does not have any defects.

GRP polymeres are thin fine strands of glass fibres whichareusedinmakingthepanelsuptotherequired. thickness. Creating GRP is a time-consumingprocess, simply due to the curing time in between layers but the end result is well worthit.

Figure 3 Display of Fiber through Pigmentation

GRP can then be sanded and painted, and used to make enclosures, housings, covers and a number of other useful products. According to the Fiber Reinforced Plastic Resource Centre, thethinstrands of glass fiber is made from passing the heated material through fine brushing machines while the mixtureiscooling.Theresultingmaterialcaneitherbe made into glass fiber matting or woven cloth. Once the fiberglass stands have been made, these can then be used to build up the structure of a product, for example,acanoe–usuallyfromamold–withanouter made of polyester plastic. The fiberglass is secured with resin. It is the multiple thin layers of fiberglass whichgivethefinalstrengthanddurability;especially when laid in multi-directions across themold.

D Fixing grating with panels

In his process the panels and Grating which are manufactured in the above-mentioned process is now joined together in order to increase the efficiency of load carried by the Panels. It is donein accordance with the plywood formwork where an external putty is placed above the panels to increase the strength of the plywood which is holding the concrete.

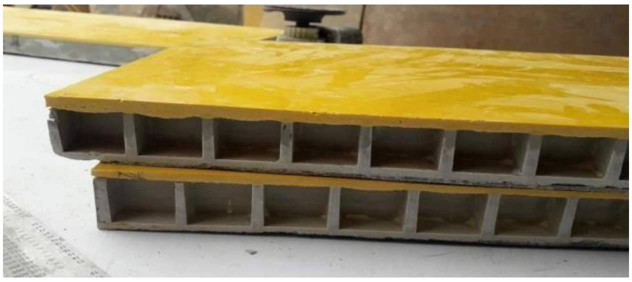


Figure 4 GRP Panel with Grating attached

Figure 5 Display of all four GRP panels

E Align the forms with nuts and bolts

This is the final step in the manufacturing of the Grp formwork. In this process the panels and Gratings which are fixed together are now additionally fixed with the provision of nuts and bolts which is to help in aligning them in position and also in the required angle. After this the Formwork is ready to cast the concrete in the Residential Building.

Figure 6 Completed GRP Panels with Finished Bolted ends

III. Experiments AndResults

Tensile Test: Tensile test is carried out on molded fiber glass gratingtoknowtheultimatetensilestrengthandcrossbreakingstrength. The mechanical properties of materials are determined by performing carefully designed laboratory experimentsthat replicate as nearly as possible the service conditions. In real life, there are many factors involved in the nature in which loads are applied on a material. The following are some common examples of modes in which loads mightbe applied: tensile, compressive, and shear. These properties are important in materials selections for mechanical design. Other factors that often complicate the design process include temperature and timefactors.

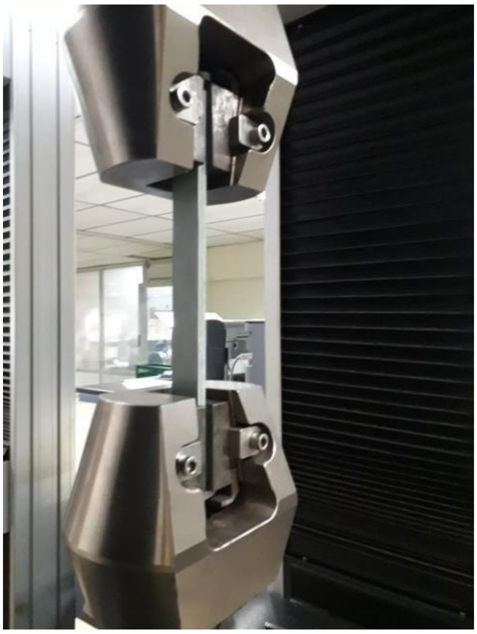
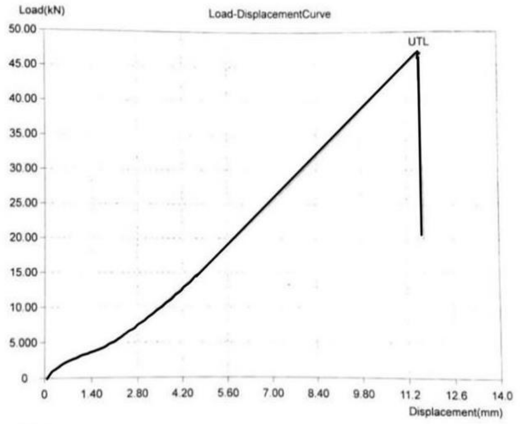


Figure 7 Tensile Load specimen in UTM

Table 1.1 Tensile test

Test Parameters	Observed Values	
Size:25mm*243mm	Test 1	Test 2
Gauge width(mm)	24.04	24.48
Gauge Thickness(mm)	6.40	6.81
Original cross-sectional area(mm2)	160.26	172.45
Ultimate tensile load(kN)	46.91	32.10
Ultimate tensile strength(N/mm2 or Mpa)	293.00	184.00



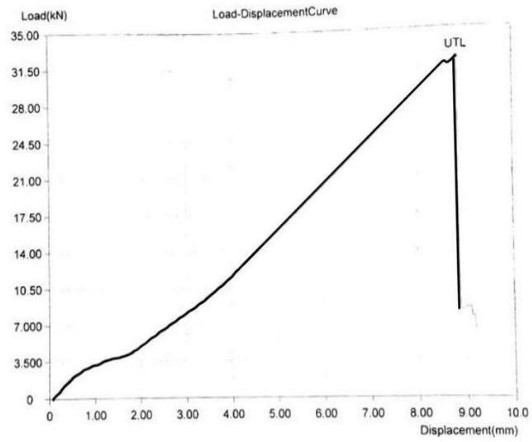


Figure 8 Graph representing Load vs Displacementspecimen1 Figure 9 Graph representing Load vs Displacement specimen2

Flexural Test: These test methods cover the determination of flexural properties of unreinforced and reinforced plastics, including high-modulus composites and electrical insulating materials in the form of rectangular bars molded directly or cut from sheets, plates, or molded shapes. These test methods are generally applicable to both rigid and semi rigid materials.
However, flexural strength cannot be determined for those materials that do not break or that do not fail in the outer surface of thetest specimen within the 4.0 % strain limit of these testmethods.

Table 1.2 Flexural test

Test parameters	Observed values	
Size: 20mm*20mm	Specimen1	Specimen2
Flexural strength(N/mm2 or Mpa)	258.00	264.00

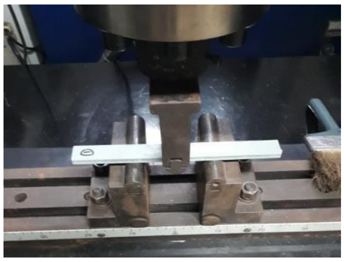
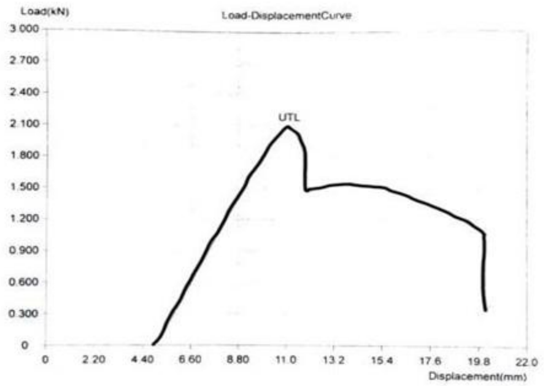


Figure 4.8 Flexural test Specimen beforeapplication of load



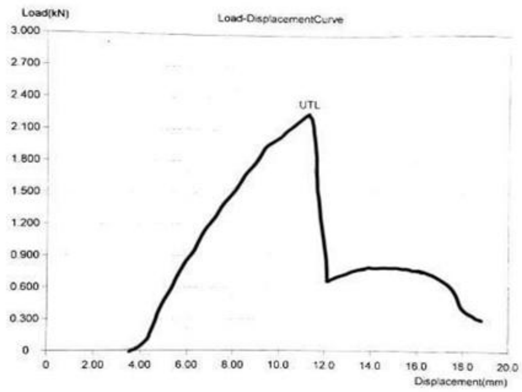


Figure 10 Graph representing Load vs Displacement specimen 1 Figure 11 Graph representing Load vs Displacement specimen 2

ChemicalResistanceTest: StandardTestMethodsforEvaluatingResistanceofPlasticstoChemicalReagents,outlines testprocedures for determining resistance of the grating to various chemical reagents by means of reporting weight, dimensions, appearance, and strength properties, after a set duration period of immersion. does not specify the types or concentrations of reagents, duration of the test, or properties to be reported. The test method consisted of soaking test laminated coupons cut from the glass fiber laminate in the following chemical reagents for a seven-day period. For a 100ml of solution, the %of chemicals taken was 5% Caustic Soda, 10% SulphuricAcid.

Table 1.3 Chemical Resistance Test

Chemicals used	**Initial weight**	**Final weight**	**%Change in weight**
10% Sulphuric Acid	9.555	9.565	0.18
5% Caustic Soda	9.232	9.243	0.119

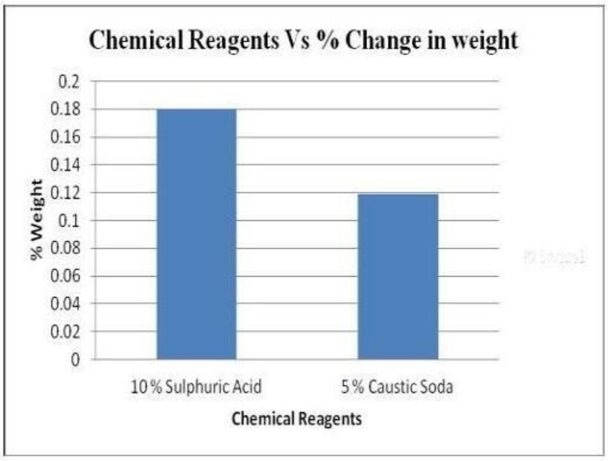


Figure 12 GraphrepresentingChemical ReagentsVs % Change in weight ofspecimen

Load Bearing Capacity: Molded high load capacity (HLC) grating is yet another product in the arsenal ofengineeredfiberglassreinforced plastic (FRP) solutions by fiber grate. While capitalizing on most of the traditional benefits of the molded grating products

– high strength, corrosion resistance, fire retardancy, non-conductivity and low miniatous this is specially manufactured by molded as well as pultruded process in FRP composite materials

Table 1.4 Load Bearing Capacity

Test parameters	Observed values
Breaking load in (kN)	27.55

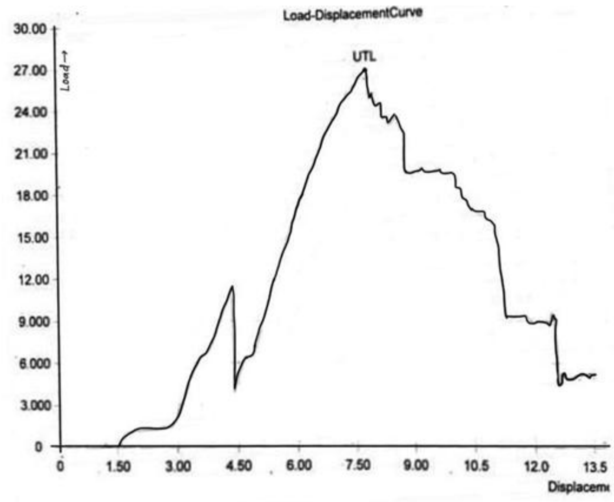


Figure 13 Graph representing Load Vs Deflection for Breaking Load Test on Grating Sample

Figure 14 Grating Sample Before Testing

Hardness Test(Digital Rockwell Harness Test):
A hardness test is used to find the hardness of a material .

A hardness test is typically performed by pressing a specifically dimensioned and loaded object (indenter) into the surface of the material you are testing. The hardness is determined by measuring the depth of indenter penetration or by measuring the size of the impression left by an indenter.

Table 1.5 Hardness Test

Test parameters	Observed values	
Size: 43mm*43mm	ID1	ID2
HRR	123,120,121	119,122,110

Impact Test (Charpy Impact Test):
The Chary Impact Tester is used on machines capable of measuring less than one foot-pound to three hundred foot-pounds at temperatures ranging from -320°F to over 2000°F. It is a high strain- rate test where a notched specimen is hit with a controlled weight pendulum swung from a set height.

Table 1.6 Impact Test

Specimen size(mm)	Notch type	Test temperature	Size:10mm*75mm	Absorbed energy – Joules
10*6.7*75	Un Notched	24	ID-1	16
10*6.7*75	Un Notched	24	ID-2	20

IV. Conclusion

An Experimental investigation on GRP panels as a formwork material has been presented . According to the experiments and analysis of the GRP panels the following concluding remarks can be listed.

1. The results of the tensile test obtained gives an averagevalueof239N/mm2whichismorethan the standard tensile strength [17]of the GRPpanels
2. TheBreakingLoadthuscarriedoutgivesavalue of 27.55 KN ,which is more or less equal to Plywood [25] with value28-31KN.
3. The flexural test gives the value of 261 Mpa which is better than plywood of the same thickness([25]).

4. The hardness test thus carried out gives an average value of 120(Hardness number) which is more than mildsteel(110).
5. The chemical resistance test shows us that GRP does not gets affected by the chemicals exposed in suchenvironments[17].

The results obtained from the GRP panels shows that the value obtained are more or less equal to the value of conventional formwork(Plywood) which help us to conclude that GRP panels can be used as a Formwork material in Building Construction.

References

[1]. Aramide FO, Atanda PO and Olorunniwo OO Mechanical properties of a polyester fiber glass compos iite. Int J Compos Mater 2012; 2: 147– 144.

[2]. Mathew MT, Naveen Padaki V, Rocha LA, et al.Tribological properties ofthedirectionallyorientedwarpknitGFRPcomposites.Wear2007;263: 930–938.

[3]. Lopez FA, Martin MA, Alguacil FJ, et al. Thermolysis of fibreglass polyester composite and reutilisation of the glass fibre residue to obtain a glass ceramic material.J Anal Appl Pyrolysis 2012; 93:104–112.

[4]. Erden S, Sever K, Seki Y, et al. Enhancement of the mechanical properties of glass/polyester composites via matrix modification glass/polyester composite siloxane matrix modification. Fibers Polym 2010;11:732–737.

[5]. AwanGH,AliL,GhauriKM,etal.Effectofvariousformsofglass fiber reinforcements on tensile properties of polyester matrix composite. J Faculty Engtechno 2009;16:33–39.

[6]. Alam S, Habib F, Irfan M, et al. Effect of orientation of glass fiber on mechanical properties of GRP composites. J ChemSoc Pak 2010; 32: 265–269.

[7]. Mohan N, Natarajan S, KumareshBabu SP, et al.Investigation on sliding wearbehaviourandmechanicalpropertiesofjatrophaoilcake-filledglass- epoxy composite. J Am Oil ChemSoc 2011; 88:111–117.

[8]. Hussain Al-alkawi J, Dhafir Al-Fattal S and Abdul-Jabar Ali H. Fatigue behavior of woven glass fiber reinforced polyester under variable temperature. Elixir mechEng 2012; 46:12045–12043

[9]. Putic S, Bajceta B, DraganaVitkovic, et al. The interlaminar strength of the glass fiber polyester Composite. Chem Indus ChemEng Q 2009; 15: 45–48.

[10]. Liu Y, Yang JP, Xiao HM, et al. Role of matrix modification on interlaminar shear strength of glass fibre/epoxy composites. Compos Part B 2012; 43: 95–98. 49

[11]. Mohammad Torabizadeh A. Tensile, compressive and shear properties of unidirectional glass/epoxy composites subjected to mechanical loading and low temperature services. Ind J Eng Mater Sci 2013; 20:299–309.

[12]. Aktas A, Tercan M, Aktas M, et al. Investigation of knitting architecture on the impact behavior of glass/epoxy composites. Compos Part B 2013; 46:81–90.

[13]. KarakuzuR,ErbilEandAktasM.Impactcharacterizationofglass/epoxy composite plates: an experimental and numerical study. Compos Part B 2010; 41:388–395.

[14]. Botelho EC, Bravim JC, Costa ML, et al. Environmental effects on thermal properties of PEI/glass fiber composite materials. J Aerosp Techno Manag Sao Jose dos Campos 2013; 5: 241–247.

[15]. Claude Renaud M and Mark Greenwood E. Effect of glass fibres and environments on long-term durability of GFRP composites. Battice, Belgium: Owens Corning Composites Publications,2009.

[16]. Agarwal A, Garg S and Rakesh PK. Tensile behavior of glass fiber reinforced plastics subjected to different environmental conditions. Ind J Eng Mater Sci 2010;17:471–476.

[17]. IOSR Journal of Mechanical and Civil Engineering (IOSR- JMCE) e- ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 8, Issue 6 (Sep. - Oct. 2013), PP34-39

[18]. IS 14856:2000 A Codebook on Glass Fibre Reinforced Plastic panels- Specification.

[19]. IS 1734-1 Methods of test forPlywood.

[20]. Dr. P. Perumal and Dr. J. Maheswaran, "Behavioural study on the effect of AR-Glass Fibre reinforced concrete", NBW & CW October 2006, (pp 174-180).

[21]. MuthuawamyK.R.andThirugnanamG.S,(2013),"Mechanicalproperties of hybrid fibre reinforced high performance concrete", Indian Concrete Journal, Vol 87, No. 4, April, pp.43-55.

[22]. Sinha,D.A,Varma,A.Kand,Prakash,K.B,(2013),"Propertiesofternary blended steel fibre reinforced concrete", The Indian Concrete Journal, Vol- 87, August,pp.26-30.

[23]. Chandramouli, K, Srinivasa Rao, P, Pannirselvam, N, SeshadriSekhar,T, and Sravana, Priyadrashini,T.P, (2010), " Strength and durability characteristic of glass fibre concrete",43 43 International Journal of Mechanics of Solids,Vol. 5, No.1, pp. 15-26.

[24]. Chawla, K. and Tekwari, B. (2012), "Glass fibre Reinforced concrete",Yahoo Group – Civil Engineering Portal,pp.1-7.

[25]. EdgarasLabans et al(2018) ,Flexural behaviour of sandwich panels with cellular wood,plywood ,Vol.21(2)784-805.

Dr.Binu Sukumar, et. al. "An Experimental Investigation on Glass Reinforced Polymer as a formwork material." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 18(3), 2021, pp. 01-12.