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Comparative study on transverse compression testing of hybrid glass/kevlar composite pipe with PVC pipe

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Comparative study on transverse compression testing of hybrid glass/kevlar composite pipe with PVC pipe

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Abstract. The study is to intend to improve the transverse compressive strength of the novel kevlar composite pipe and compare its property with polyvinyl chloride pipe. The feasibility of the kevlar based composites pipe has been studied. The kevlar composite pipes are made up of 2% volume fraction of nanoclay as filler and it is taken as the experimental group in this group the testing samples are (N=20) and the plain composite pipes of kevlar composites are taken as control group. This group is also having (N=20) samples for testing. All these composite pipes are fabricated manually and the specimens have been prepared as per the ASTM standard. The kevlar composites pipes which is fabricated with 2% volume fraction of nanoclay have improved their compressive strength in transverse direction in the comparison of plain kevlar composite pipe and PVC pipe. The significance value p is <0.05. The filler used kevlar Novel composite pipes improved its transverse compression strength of 28% higher than the plain kevlar composite pipes and nanoclay fillers exhibited a significant improvement.

1. Introduction

Due to advancements in technology Composite materials have been supplanting traditional materials in the whole of the designing fields. The novel kevlar composites are high in compression strength and also it is very suitable to transfer the high-pressurized fluids, carrying chemicals [1]. This work analyses the strength of transverse compression on the tensile strength of hybrid glass/Kevlar composite pipe. Based on the experiments [2] performance of filament wound fibre reinforced polymer (FRP) composite pipes and their properties. The important properties such as buckling, durability and corrosion were studied. It was concluded that 55^0 wind angle will be the optimum angle for withstand maximum burst pressure. [3] was subjected a fatigue cycle of a specimen is used to analyze the performance[4]. The present study focuses on the compression behavior of various fibers and their suitability to develop composite pipes. The paramount properties of the composite pipe was studied in this paper. The transverse compression testing is carried out on the pipe which is made of hybrid glass/Kevlar Composite pipe. The test results are compared with the conventional PVC pipe. The composite pipes replaced the conventional PVC pipes where the high pressurized fluid is to be transferred. The composite pipes also used deep sea water pipe lining.

The most relevant papers for this work in google scholar is 173 and in the Sciencedirect database is 83.The related researches and compatibilities of this work are [5] The longitudinal and transverse strength of the composite pipe were studied. The composite pipes are made of kevlar fibre, basalt fibre of different compositions are studied. The suitability of high performance flexible woven kevlar fabrics for the different applications are studied. The high-velocity impact test and low-velocity impact tests were conducted for different compositions of high performance flexible woven Kevlar fabrics. [6]The feasibility of composite pipe for under water application is studied. In this study, the various failure mechanisms of composite pipes are studied. The High velocity Impact test, medium velocity impact (LVI) are conducted and the residual compression performance of the impacted composite pipes has been analysed. Various types of fibres, including kevlar, basalt fiber, carbon fiber, and glass fibre, were used to develop the pipes. The performance of the pipes is studied [7]. He studied the compressive test performance of composite pipes. The results show that the strength decreases when damage increases. Finally, an engineer model has been proposed in order to take into account this reduction.

The nanoclay in the kevlar fibre Novel composite pipe physical properties have been represented in its scope. In the past, some research has been done on composite pipes. The kevlar Novel composite pipe has been improved in its physical properties [8] analysed the influence of silica nano particles on the structural properties. To develop the interfacial grip between the kevlar fibre and to improve the compression strength, the grid material nanoclay was used as an extra fixing. The nano filler composite pipes are fabricated with nanoclay as the filler material, the filler material is used in different ranges that is plain kevlar composite pipe and the filler used kevlar composite pipe has 2% of nanoclay. The ability of this study is knowledge of development of several types of composite material by using the different fibres. This study aims to enhance the transverse compressive strength of the kevlar composite pipe which was made in addition of filler in 2% volume fraction of nanoclay compared with plain kevlar fibre Novel composite pipe.

2. Materials and Methods

The fabrication of composites and compression testing related to this research work was conducted at Saveetha Engineering Industries, SIMATS School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai. This study has two groups. The first group is the control group. In this group all composites are in plain and the other one is the experimental group. In this group composites are having nanoclay in the volume fraction of 2% as fillers. The total sample size is calculated by the sample calculator. The total number of sample is 46, and for each group, the number of sample is 23. This work is not applicable for ethical approval working on human samples. The pretest power for the study group is calculated using G-power is found to be 80% In the present work kevlar fibre is taken as a reinforcement element, nanoclay as filler , clear crystal epoxy resin(LY556), and hardener (HY951) as matrix is used to make the Kevlar Novel composite pipes hard[9]. from this research the separation of groups and samples for testing can be understood clearly. As no human samples were employed in this study the ethical approval not required for this study.

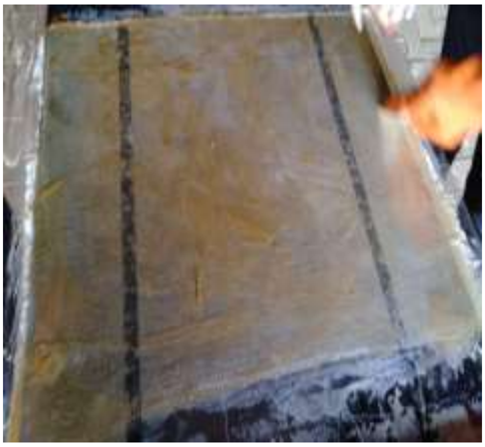

Figure 1. Arrangement of kevlar fiber layers.

Figure 2. Moulding of kevlar fibre.

Figure 3. Kevlar fibre composite pipes in Mould.

Figure 4. Fabricated kevlar fibre composite pipes.

In this work the functionalized nanoclay is used as filler in this fabrication process and it is mixed with the clear crystal epoxy resin in 2% of volume fraction and hardener is added to the epoxy resin in the 100:10 ratio and these polymer matrix is stirred until get homogeneous mixture, then the kevlar fibre were cut 100cm in length and 30cm in breadth. The plain PVC pipe is used as the mold for the fabrication, as shown in figure 1 and the mold is placing it over two layers of arranged kevlar fibre sheets and applying the epoxy resin mixture over the kevlar fibre sheets and rolling the mold across the kevlar sheets until its length, as shown in figure 2, Then the sheet entirely covers the mold, and the fabrication gets into the structure of the pipe and is allowed to laminate for 12 hours until it is completely. Then at last the PVC pipes which are used as modules are removed from the laminated fabricated kevlar composite pipes, as shown in figure 3 Apart from that the irregularities on the pipe which happens during the fabrication are removed by the surface grinding machine, as shown in figure 4. The kevlar fibre tubular composite pipes are accomplished, as shown in figure 5. The properties of the material used in the work are given in table 1.

Figure 5. Grinding the edges of the fabricated kevlar composite pipe to remove irregularities.

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Table 1. Materials used for fabrication.

Sl.no	Materials used	Properties
1.	Kevlar fibre	High strength, high modulus, toughness and thermal stability.
2.	Nanoclay	Biocompatibility, high hydrophobicity, synthetic Stability and resistance to pH changes
3.	Epoxy resin (Ly556)	Medium viscosity, it is based upon bisphenol-A resistance to chemicals and low tendency to crystalize
4.	Hardener(Hy951)	Viscosity at 25°C, 10-20 mPa*s / Specific gravity at 25°C:0.98g/c Appearance/flash point:110°C.Mix ratio 100:10

Table 2. Specifications of universal testing machine.

Specifications	Range
Capacity	40 TON
Least count	1
Load ranges	0-40 tonnes ×80kgf 0-20 tonnes ×40kgf 0-10 tonnes ×20kgf 0-4 tonnes ×10 kgf
Margin of error	1%

Figure 6. Specimen before compression test in transverse direction.

Figure 7. Tested specimen after compression test in transverse direction.

As per the ASTM-D695 standard measurements, the specimens are sectioned in the length of 62 mm and breadth of 28mm.The specimen is placed in between the clamps of the UTM machine, and fix the clamps as much as suitable, as shown in figure 6, this makes the specimen stable while the compression test is going on, and the required load is exerted until the specimen gets fracture. Then the specimen gets fracture at some point, as shown in figure 7, and readings are to be noted. This is the suitable size of the specimen to conduct the longitudinal compression test in (UTM) Universal Testing Machine as shown in figure 8, and the specifications of universal testing machine which was used to find the compressive strength is given in table 2.

Figure 8. Universal testing machine which was used to find the compressive strength in transverse direction.

The SPSS software is used to find the significance for all 20 samples of the (modified) experimental group and (base) control group, compressive strength is the dependent variable and independent variables are kevlar fibre with the addition of epoxy resin, hardener and nanoclay. The analysis was done with transverse compressive strength versus trial number graphs for two groups of work pieces will be interpreted, and all compressive values are tabulated in table 3.

Table 3. Transverse compression values for all 40 samples.

Sl.No	Transverse compression without filler(MPa)	Transverse compression with filler(MPa)
1	10.3	12.9
2	10.5	13.4
3	10.8	13.8
4	10.7	13.4
5	10.6	14.1
6	10.9	14.4
7	11.5	14.8
8	11.4	14.6
9	11.1	13.8
10	11.3	13.5
11	10.8	14.9
12	11.7	12.9
13	11.5	13.7
14	10.8	14.6
15	10.7	14.3
16	10.6	13.7
17	11.5	13.5
18	11.7	13.8
19	11.7	12.9
20	10.8	14.6

To get the significance value of both experimental group and control group, the SPSS software version 21 is used. The independent variable is kevlar fibre with the addition of epoxy resin, hardener, and nanoclay and the analysis were done with longitudinal compressive strength versus trail number graph for two groups of work pieces will be interpreted. The dependent variable is longitudinal compression strength (10).

3. Results

This research resulted in the transverse compressive strength of the kevlar composite pipe by mixing 2% volume fraction of nanoclay given good compressive strength in transverse direction than plain kevlar composite based pipe as shown in figure 9. For all 20 samples of filler added kevlar composite pipes and non-filler kevlar composite pipes. The SPSS software version 21 is used to study significance value, as shown in table 4 , mean and standard deviation for composites with and without filer, as shown in table 5, with confidence level of 95% X-axis: plain kevlar composites vs nanoclay added kevlar composites Y-axis mean transverse compressive strength (MPa) ±1SD.The addition of nanoclay as filler material to the composite pipe was helped to avoid the cracks which causes due to high pressurized fluid The significant value of the kevlar composite pipe with addition of nanoclay is 0.072.

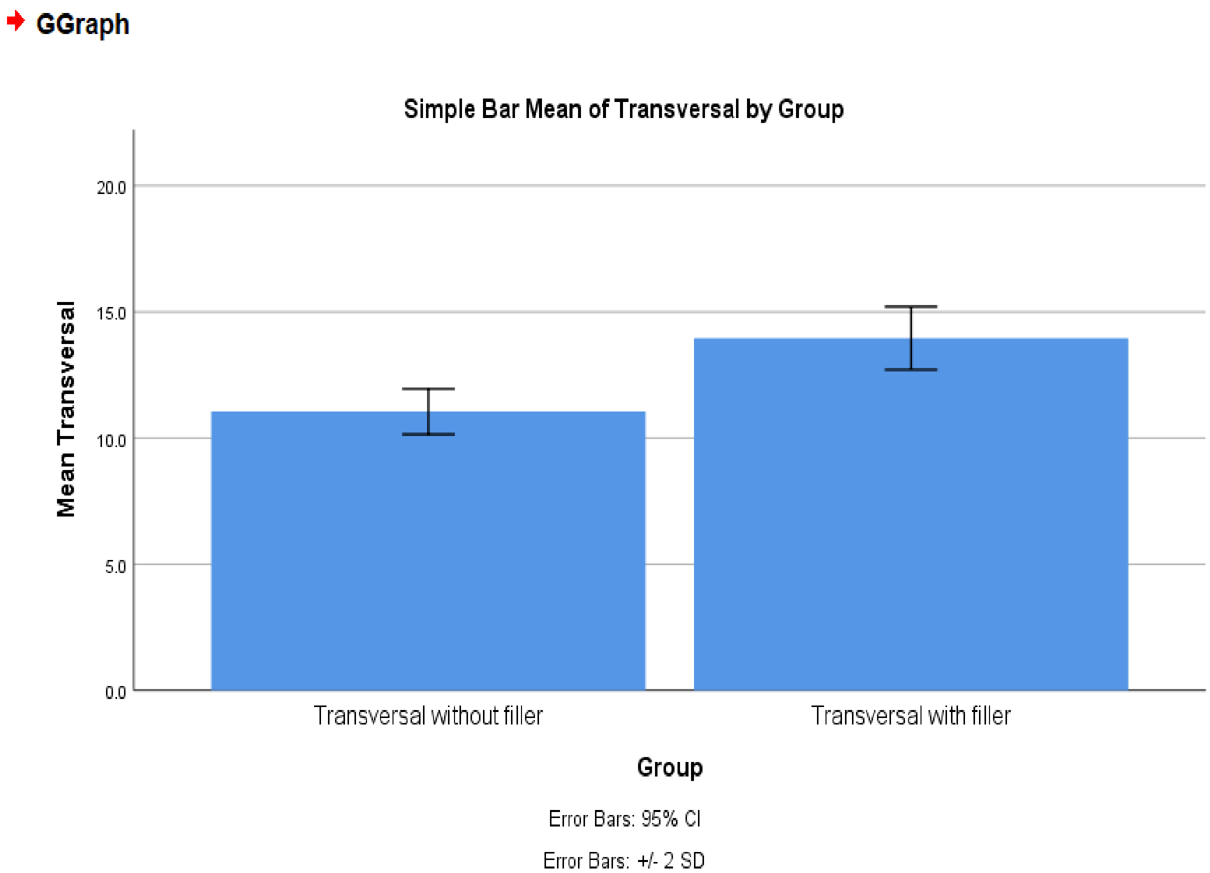

Figure 9. G graph for both control group and experimental group.

Table 4. Descriptive table representing mean and standard deviation of compression strength of kevlar fiber composite pipes without filler and with 2% nanoclay.

Group		N	Mean	Std. Deviation	Std. Error Mean
Compression	without filler	20	11.045	0.4501	0.1006
	With 2% filler	20	13.955	0.6236	0.1394

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Table 5. Descriptive table representing levene's test for equality and t-test for equality of means independent samples.

	Levene's test for equality of variances		t	df	sig .(2-tailed)
	F	Sig			
Compression Equal variances assumed	3.427	0.072	-16.921	38	0.000
Compression Equal variances not assumed			-16.921	34.570	0.000

For the both the groups, the group statistics was observed Group statistics observed, by using the SPSS software, and according to the result, the improvement was observed in the filler added kevlar Novel composite pipes.

4. Discussion

It is observed that the filler added novel kevlar Novel composite pipes longitudinal compressive strength had improved by 2.91% , by the addition of 2% volume fraction of nanoclay as the filler material, [11]composite pipes are mostly used in gas and oil industries , because it gives good corrosion resistance , high specific stiffness, thermal insulation ,composite tubes are better replacements for conventional carbon steel pipes, and also this study researched on laminated pipes and investigated its internal pressure and heat or temperature gradient.[12] This paper shows a procedure to test the stresses and strains of a composite pipe subjected to thermomechanical loading. This method is developed on the classical laminated-plate theory. The 3D analysis was used to consider the sandwich pipe. [13] In this investigation, a pressure examination is created for diverse composite thick or slight chambers. [14]developed composite material with different fibres and tested its performance. The results proved that highest ultimate tensile strength in carbon fibers reinforced tube which was 136% and 26% higher than kevlar fibers reinforced tube (KFR) and glass fibers reinforced tube (GFR), respectively. [15]In this investigation, the weariness trial of ±55° fiber wound GRP pipes with a semi-circular surface break were completed under open-finished inside tension[16]. The impact of indent-to-profundity proportions and loop anxiety proportions were explored on the exhaustion life. Additionally, the connection between delamination zone versus weariness cycle were explored [17]. The affecting factors of this study are manual fabrications, exact structures will not occur in manual fabrication and it takes more time to prepare the composite pipes.

The limitations of the study are inconsistency of the work pieces which is prepared by the manual hand lay-up method and the uniform distribution is not possible in manual manufacturing technique. The future scope are as follows. There is possibility to fabricate the same kind of pipes in future by using different types of fibres and filler materials, by different the volume fraction of the using fillers and the number of layers used. The strength of the composite pipe can be further improved by addition of wire mesh. Further the pipe can be reinforced by hybridization of two or more polymers.

5. Conclusion

Based on the study the transverse compressive strength of kevlar composite pipe shows a significant improvement of 2.91% by addition of 2% volume fraction of nanoclay as filler to the kevlar fibre and hence it is proved that addition of nanoclay to plain kevlar fiber composite to enhance the longitudinal compressive strength.

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