UPGRADATION OF STEEL TP COMPOSITES IN HYDROMECHANICAL COMPONENTS

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ABSTRACT

Hydro flow control gates and its embedded parts play a major role in dams, main regulators, and canals to regulate water for its esteemed usage. Hydro-Mechanical gates in steel are serving more than a century but its maintenance and replacement in steel results in higher life cycle cost. Corrosion of steel takes place in an unpredictable manner. There are also many factors that catalyst the rate of corrosion. Hence surface protective treatments are to be done periodically. To make use of the advancement in materials, Fibre Reinforced Polymers (FRP) that satisfies the requirements in terms of physical, mechanical, corrosion resistant, and maintenance free products in hydro-gates. The durability of FRP is utilized for sluice tanks, canal gates, embedded parts, operating platform, and hoist enclosures. Life cycle cost of products made of fibre reinforced polymers is far less compared to conventional materials. This study provides technical comparison of steel and composites and also various tests carried on the FRP products.

1. INTRODUCTION

Hydro-mechanical components serve a vital role in water supply, irrigation and river navigation systems. Most gates are operated either vertical or radial to regulate the flow of water at desired level through various hoisting mechanisms – manually, electrically, hydraulically operated. Proper selection of design, materials, fabrication of gates and their hoisting arrangements is essential to control the flow for longer life.

2. CORROSION VS. ECONOMY

Corrosion is a natural occurring process for most materials. Materials with iron content tend corroded easily.Products that are immersed or exposed to water condition suffer vigorously in corrosion. There are many factors that induce the rate of corrosion. Hydro-gates not only affected by corrosion by also by erosion. Hence to utilize the properties of steel, protective coatings are provided to increase its lifetime. The most commonly used method includes metallic coatings, duplex, polymers and organic coatings. These coatings systems has to be maintained periodically to safeguard the life of steel product and it does to the level best if quality procedure are followed during application. These are coatings that could with stand both resistance and erosion. Research for eco-friendly effective coating systems has been developed in recent times. When the gates are periodically maintained with these high performance coatings, the cost of maintenance will be higher than the initial cost. Any damage or defect found after installation, it may lead to internal corrosion and premature failure occurs. Operational of gates due to corrosion failure costs a huge loss to the country.

3. ADVANCEMENT IN MATERIAL

(a) Selection of materials based on load bearing criteria, environmental condition, design & fabrication ease are to be considered.

(b) Composite material can satisfy for the above condition except fabrication like metallic composites difficult to fabricate. Hence polymeric composite – Glass fibre reinforced polymers are used in the place of steel material. Polymeric composites are classified into glass, aramid and carbon based on percentage of SiO_2. The cost effective type of polymeric composite is glass fibre reinforced polymer (GFRP) in terms of physical, mechanical, chemical, cost, availability.

3.1 Comparison of Properties GFRP vs. Conventional materials

The physical and mechanical properties of GFRP material is tested as per standards at National test house, Chennai. The comparative properties of different materials involved in Hydro-Mechanical equipments are as below,

Table 1 shows the physical and mechanical properties comparison of various materials. The GFRP being a composite material, its combined density value is 2.14g/cm³ which is 3.6 times lesser than steel and its tensile properties varies from 220 Mpa (transverse direction of material) to 240 Mpa (longitudinal direction).

Table 1

SL. No.	Material	Density (g/cm³)	Tensile Strength (Mpa)	Compressive Strength (Mpa)	Flexural Strength (Mpa)
1	Cast Iron	7.5	100-150	350-400	100-150
2	Steel	7.85	410-440	410-440	410-440
3	Glass Fibre Reinforced Polymers (GFRP)	2.14	220-240	320	278
4	Wood	0.75	100	40	10

3.2 Advantages over steel

The advantages of composites fibre composites over steel material is as follows:

1. Resists a broad range of chemical and is unaffected by moisture or immersion in water, also resists UV rays and insect damage.
2. Greater mechanical property in longitudinal direction.
3. Weighs 75% less than steel, hence easy to handle.
4. Easy to fabricate with simple tools hence safer.
5. Good insulator to heat & electricity.
6. Will not permanently deform under impact, reinforcement distributes impact load to prevent surface damage.
7. Less installation cost & less or no maintenance, hence lower life cycle cost.

3.3 Applications

1. Polymer composites have wide range of applications in Aerospace, marine, construction, defence, transportation, tanks, pipelines.
2. Owing to its mechanical and chemical properties it is widely used in Hydro-mechanical equipment.
3. Restoration of old civil and mechanical construction.

4. COMPOSITE PRODUCTS

The existing damaged steel products can be replaced by fibre reinforced polymer products for the following.

Canal gates, paddle gate, sluice plugs, head set, top channel / top beam, chequered plate, groove angle / channel, hoist enclosures / canopy, ladders.

4.1 Composite canal gates:

Shutters are arranged to close openings on the vertical walls of canals, by sliding vertically along lateral guides built in masonry work. The composite gates comprises of main skin with end flanges of required thickness. According to the site condition, the stiffeners are incorporated. The stiffeners used are L angles & C - channels or sandwich type made of polymers. The shutters are designed in such a way to with stand different load situations during long life span.

A shell liner FEA model was built for the gates including the stiffeners. NEi Nastran solver is used to analyse stress states & deformation.Hydrostatic pressure testing is done for a height of 3 m this will be considered as a load safety factor.

Table 2

	Depth (m)	Pressure (Mpa)
Top of shutter	1.8	0.0177
Centre of gravity	2.4	0.0235
Centre of pressure	2.6	0.0255
Bottom of shutter	3	0.0294

Modelling is done in FEA as the pressure changes with depth. Maximum lifting force is considered applied on to the Rod – shutter Interface.

From Figure 1, Finite Element Analysis is carried out, the maximum deformation is 4.2mm, the safety factor of the laminate is 5.6, bearing stress – 5, shear is 4.5 & compression is>10 times the normal load. Load testing of a sample shutter of size 450x600x8mm inch with stiffeners is done. The ultimate compressive load is 195.1 KN and at deformation of 5mm the load is 93.4 KN.

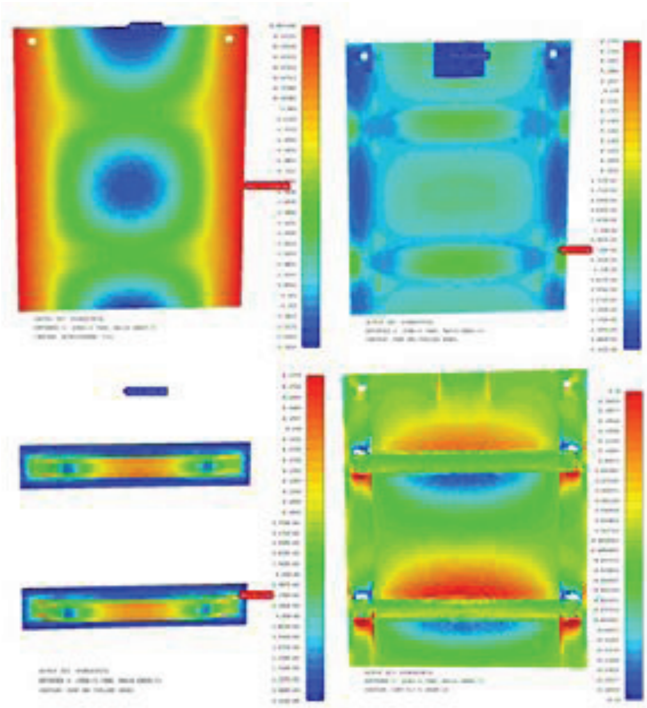

Figure 1 : FEA result of composite shutter 890x1200mm

4.2. Composite plugs:

The main role of plug is to control the flow of water in tanks. The flow of water is obstructed or released through a conical shape product known as "Plug".The composite plugs are highly rigid at top & bottom to with stand compression & tension forces. It is made of sandwich construction. The advantage of this type of construction is higher specific strength and load bearing capacity.

Sluice plug of size top OD 220mm, bottom OD 95mm and with skin 6mm is tested with UTM 1000KN capacity, the ultimate compression load is 283.8 KN and the ultimate tensile load is 45.14KN.

4.3. Composite head set:

Light duty composite head set assembly acts as a casing for operation of screw gearing shutter and sluice plugs. The assembly consists of two parts – top & bottom part. Bottom part acts as load bearing component & top part acts as casing and for locking assembly. A cast nylon ring is impregnated inside the bottom part to accommodate steels balls. This reduces the friction of the cast iron nut for operation

From Figure 2, the ultimate compressive load for bottom part headset is 152.40 KN.The tensile test is carried out to find the shear forces during operation. Load is applied ondiagonal sides of the product.The tensile strength of the productis 65.6 KN

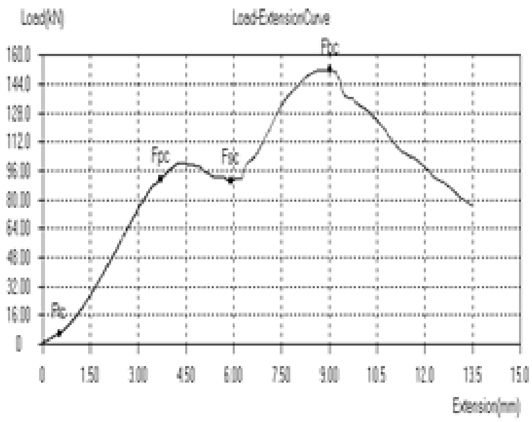

Figure 2 : Compression test result of headset bottom part.

4.4. Top channel:

Composite top channel acts as a supporting structural member for the headset to operate the plugs. To increase the load bearing capacity of the product, composite stiffeners are provided at loading points. The either ends of the product are fixed to the masonry.

The product is tested for load – deformation test at a span length of 750mm.The compression loads are applied at the mid span. The ultimate breaking load is 6531 kg.

4.5 Top beam

Composite top beam also acts as a supportive structural member for regulating of shutters. The composite material with "I" section are locked together by channels at both ends. The mid portion takes up the load while operating the cast iron nut placed in the head set assembly.

From Figure 3, the ultimate breaking load is 9621 kg at a span length of 1000mm with ends fixed.

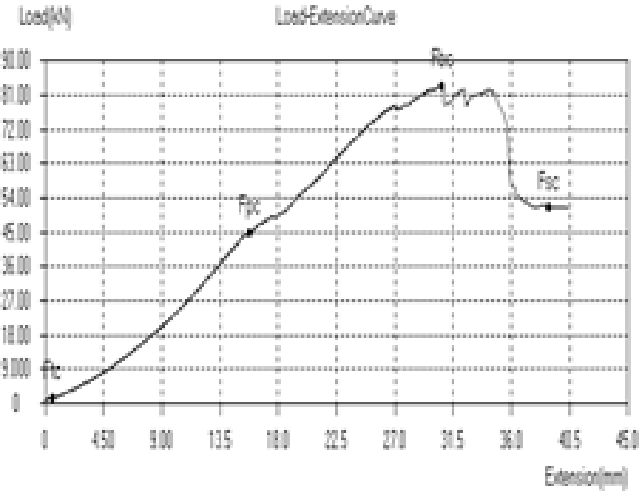

Figure 3 : Compression test resultof 150x90mm compositeTop beam

4.6. Chequered plate:

The operating platforms in the deck bridge are laid up with composite chequered plate. It is stiffened either by steel or composite structurals at the bottom. This takes care of the bending moment. The component has good rigidity, antiskid and corrosion resistance properties. Ease in fixation of fasteners to the supporting structurals.

From figure 4, The UDL (Uniformly Distributed Load) test on 8mm thick composite chequered plate is carried out;the ultimate breaking load is 8520kg. The panel size is 400mmx400mm. Point load of 20mm diameter is applied on the composite chequered plate of same size and the breaking load is 1262 Kg.

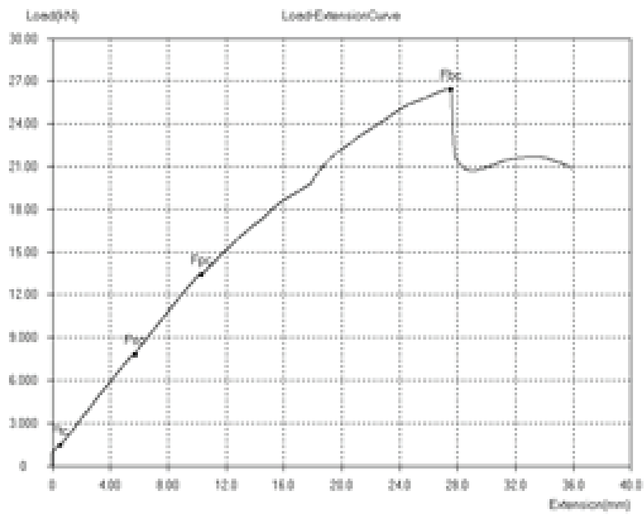

Figure 4 : UDL test on Composite Chequered plate.

4.7 Groove angle / channel:

Groove Angle / Channel acts as an embedded parts in concrete structure. It plays a major role in raising and lowering of shutter in a defined path. To reduce friction while lifting along the groove, UHMWPE (Ultra High Molecular Weight Polyethylene) liner is incorporated in the flanges of the Angles / channels.

Composite Angle 65x65x6 sample has been tested for load deformation test at a span of 500mm and edges fixed the compressive load is applied and deflections at mid span at specified loads & ultimate breaking load 794 kg.

Composite groove channel 75x75x8mm and Figure 5- Composite groove channel 100x100x8mm sample has been tested for load – deformation test at a span of 750mm and edges fixed. The compressive load is applied at mid span; the ultimate breaking load is 1944 Kg for channel 75x75x8 and for composite groove channel 100x100x8, the ultimate breaking load is 2694 Kg. The impact strength of the material is 324 KJ/m^2 in longitudinal 186 KJ/m^2 in transverse direction of reinforcement.

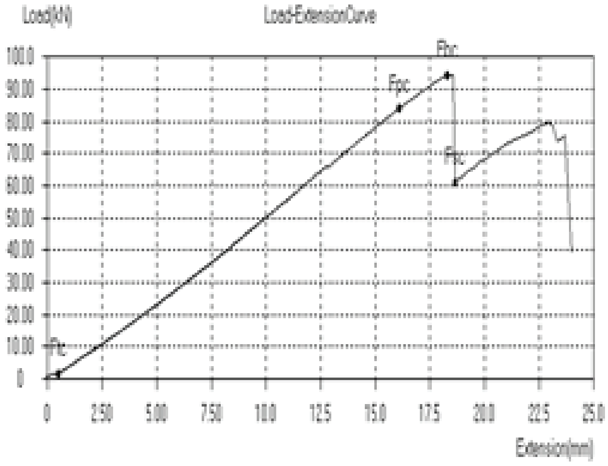

Figure 5 : Load – deformation test on 100x100mm groove channel.

4.8 Other products

The applications of glass fibre reinforced polymer material are now used in almost all products in place of conventional materials. Products such as motor cover, starter box, dial gauge and hoist assembly enclosures in composite material have the advantages of excellent durability, strength, electric insulator, and ease in handling and corrosion resistance property.

5. CONCLUSION

The consumption of carbon steel materials are still increasing in India. The choice of material is selected based on the major factors – its load bearing capacity and life cycle cost. The life cycle cost of steel in immersed or water exposure environment is higher than its initial cost. Then the resale value of steel is high and so it is pilferage to theft irrespective of its valued intension of usage. To counter the unavoidable expenditure, composite – FRP materials are substituted in place of steel. For its unique physical, mechanical and chemical properties and also that could be tailored based on the application; the composites can be stated as wonder material. The composite gates and its embedded parts are tested to find its load bearing capacity. From the results it can be concluded that Glass fibre reinforced polymer composites can replace steel gates and its embedded parts up to 2 meters height. The research and testing is on midst way for composite products more than 2 meters. The up-gradation to composite materials will definitely lower the life cycle cost.

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