Design and Analysis of Radial Lift Gate for Reservoirs and Sub-Canals.

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Abstract : Conserving water resources for optimal utilization and for both agricultural and drinking water purposes is the need of the hour. Canals, sub-canals are the arteries for water bodies. Design, control and commanding flow rate in the sub-canal system is the prime motive of the paper for which, **RADIAL GATES** can help in solving hydrodynamic flow control.

Aluminum Composite Panel (ACP) and Carbon Fiber Reinforced Polymer (CFRP) composite materials are used in the construction of radial gates. The composite materials can be used to sustain high loads and Hydro-dynamic pressures created by water, stored in the dam reservoir and sub canals. The gates are designed in such a way to eradicate the corrosion and icing effects from desalinated water. The gates had been experimentally tested in three ways to know their shock absorbing capacity and to know the shock resistance and buckling capacities under varying loads. The tests conducted are 1)Impact Test to know the strength using IZOD impact testing setup, 2) Tension and torsion test for flexural rigidity using UTM. The optimal ply angle for gate lift is suggested as 28.5 degrees to improve the axial and shearing loads. The gates are light in weight and more economical for the use in dams and reservoir or sub canals.

***Index Terms* - Reservoir, Radial gate, Composite material, Impact testing, Aluminum.**

I. INTRODUCTION

A dam and a reservoir, both are referred to as blockades designed to reserve water in them. But main difference between them is that the dams are designed to withhold water along with regulating water channels which are used for industrial application, irrigation, and navigation use. However its main function has been the generation of Hydro-electric Power.

Whereas, A Reservoir refers to a natural or artificial place where water is collected and stored for use, especially water for supplying a community, irrigating lands etc., it is a repository or chamber for holding a liquid or fluid. In other words they are water holding structures, whose primary purpose is to regulate the inflow or outflow of water from one dam onto another or terminal usage. The reservoir gate's main function is to act as delivery heads through which the deposited water is let out of the reservoir. Rural Reservoirs are used either in diversion canals, balancing, lift irrigation schemes etc. While Urban Reservoirs are used to cater to the industrial, drinking water demands of the urban population. Radial gates are predominantly used, while vertical lift gates are used very rarely now-a-days. The design and analysis of radial lift gate for reservoirs and sub-canals is discussed in this paper.
The Radial gate is made using Aluminum Composite Panel (ACP) and Carbon Fiber Reinforced Polymer (CFRP) with ACP as Core covering the CFRP material in the shape of Radial.

figure.1. model radial gate made up of composite material sandwiching

- **Aluminium** or aluminium is a chemical element with the symbol Al and atomic number is 13. It is a silvery-white, soft, non-magnetic and ductile metal in the boron group Aluminium of 7075-T6 alloy is used as outer core for Radial Gate.
- **Poly-urethane (PUR and PU)** is a polymer composed of organic units joined by carbamite (urethane) links. While most polyurethanes are thermosetting polymers that do not melt when heated, thermoplastic polyurethanes are also available.
- **Fibre glass** is a common type of fibre reinforced plastic using glass fibre. The fibres may be randomly arranged, flattened into a sheet or woven into a fabric. The plastic matrix may be a thermoset polymer matrix – most often based on thermosetting polymers such as epoxy, polyester resin or vinyl ester or a thermoplastic. Cheaper and more flexible than carbon fibre, it is stronger than many metals by weight and can be moulded into complex shapes. Its applications include aircraft, automobiles etc.

II. HOISTING MECHANISM

Hoist is an equipment with which the gate can be lowered or lifted at the required speed of travel or held in a position at partial opening as desired .For spillway gates the hoists are installed on a hoist bridge supported by the piers. The hoist may be supported on the under deck below the road way. For an economical hoist provision, it shall be so located that the hoisting angle does not change considerable during the hoisting operation. Such a hoist is available at a location on the downstream side of the crest of the dam. This however involves larger pier sizes. An alternative of the arrangement could be upstream hoist location involving larger hoisting capacities. If the reservoir water is of corrosive nature, the hoisting cable is tied to stream side of the leaf so that it remains protected against corrosion. This arrangement makes the cable accessible for any gate position and enables inspection and repairs to the same. For this project the Hoisting of gates was done using Servo Motors.

Requirements for hoisting operation: The essential requirements of the hoist are **-**

1. Reliable in operation.
2. Smooth working.
3. Ability to sustain the vibrations of the gate, held at partial openings.

Main Components of Hoisting mechanism:- 1.Hoist frame, 2. Pulleys, 3. Wire ropes, equalizer plates, 4.Servo motors.

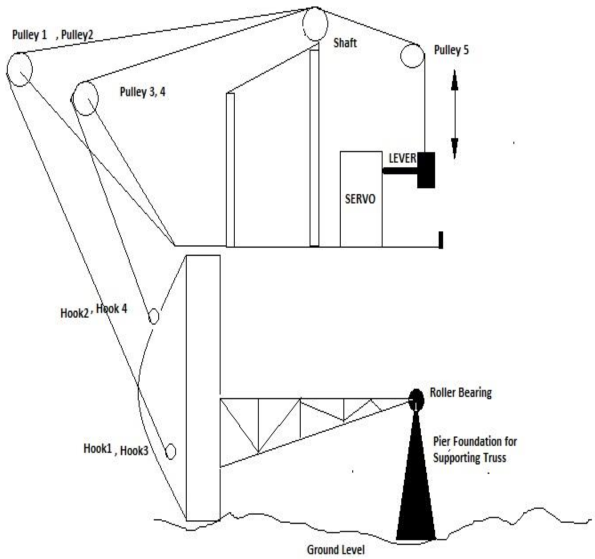


figure 2

Problem Description: Urban reservoirs are used to provide water to the industrial needs, drinking water demands of the urban population. While many rural reservoirs are used either in sub-canals or lift irrigation schemes, the water table in urban and rural regions has shown major drop especially in Visakhapatnam district of Andhra Pradesh state in India. The water levels had severely fallen from 5m to 15m on an average during the passing of past decade. Swift urbanization invasions into water bodies, non-timely rainfall for the agricultural crop cycle and prevalent depletion of natural resources are some of the causes for the fall of water levels. This current scenario poses a grim reality of depriving water needs to the residents, Agricultural demands, and industrial establishments of the district.

The Main feeder lines for supply of water resource to meet the demands of Visakhapatnam district are canals from Godavari River through Yeluru canal, Raiwada canal etc. Drinking water supply is through Meghadri Gedda, Kanithi balancing reservoir etc. unfortunately Meghadri Gedda and Kanithi balancing reservoirs have reached dead storage levels in the month of December-2018. With summer approaching, to cater to the demands of the stake holders; civic authorities are facing tough task to meet the demands. So to fulfill the high demand of water, the radial gates are proposed to use at the canals. Actually the radial gate is made of mild steel, high carbon steel, and stainless steel. More over the power requirement is high due to the heavy load of the gate. The maintenance of the gate is very high. So we have designed the radial gate by using ARP (Aluminum Reinforced Polymer) the weight of the gate is less due to the use aluminum composite material. In this construction of this radial gate the metal percentage is very less. Due to the less weight of whole radial gate the power required to uplift the radial gate is very less. The gate can be easily replaced because it is of less cost and low weight.

III. FORCES ACTING ON THE DAMS/ RESERVOIRS

Uplifting forces, hydrodynamic forces, Silt Forces, wave forces, quake forces etc. act on the dam structure. Ice Pressure is neglected as, the recorded minimum temperature for the past century is above 14^0c. For sake of simplicity the forces acting on the dam along the horizontal and vertical axis are considered.

3.1 Hydrodynamic Pressure: The pressure created by the Water head at the inlet to the dam. Uniform Varying load with atmospheric pressure at the top level of the dam/ reservoir and maximum loading at the bottom end is assumed. The center of gravity for a triangular loading is assumed to be at a height of $1/3^{rd}$ of its overall height.

$$\textbf{Pressure (P)} = \Upsilon_w \times H^2/2 \qquad (3.1) \qquad [\text{Here, } \Upsilon_w = 9.81\ kN/m^3 = 1000\ kgf/m^3]$$

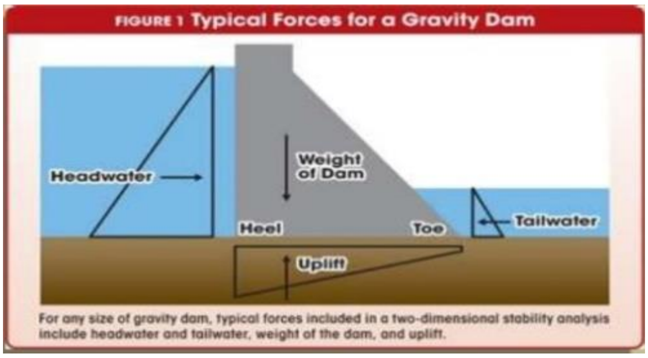


figure.3.1

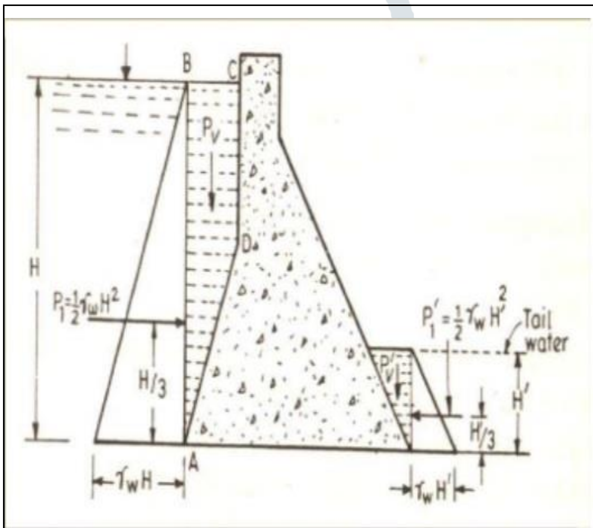
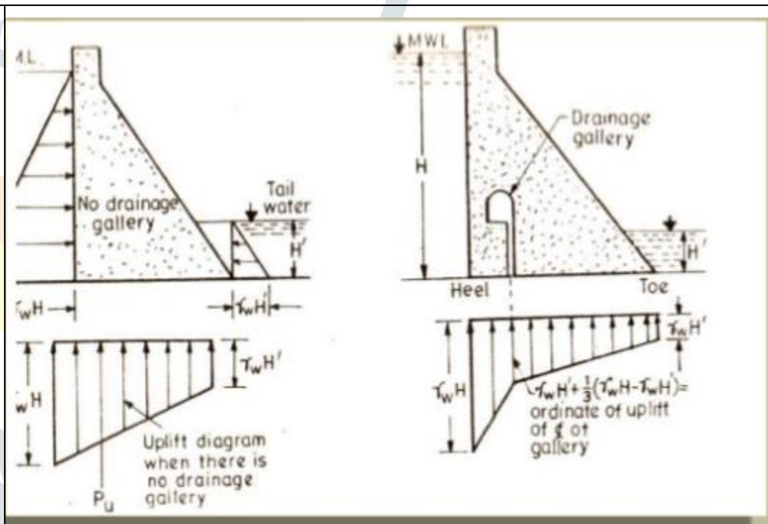
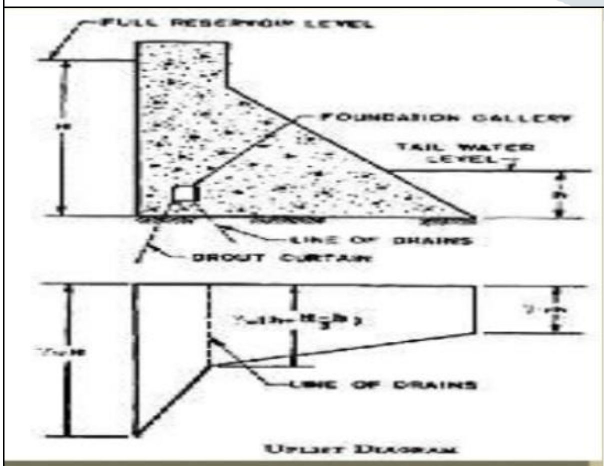
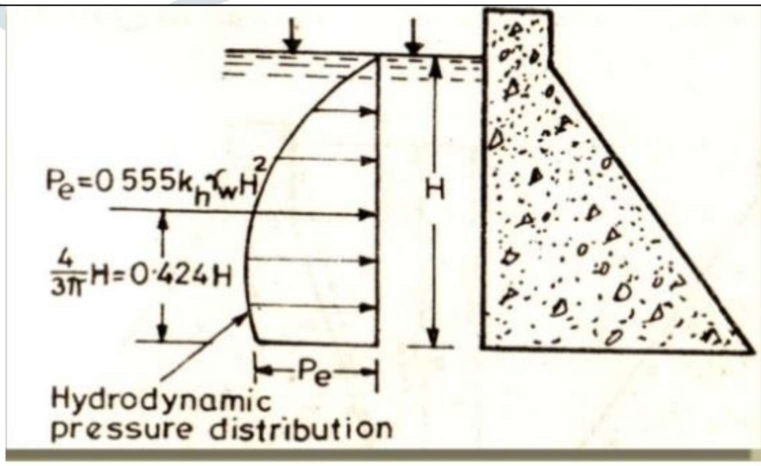
3.2. Uplifting Pressure: If water seeps through the dam/ reservoir foundation structure; the water pressure subcutaneously lifts the dam/ reservoir structure from its bed. This is one of the principal components looking while studying designing dam stability analysis. The hydro static pressure at heel and toe are calculated and finally the uplift pressure is computed from the Pressure Distribution diagram as follows;

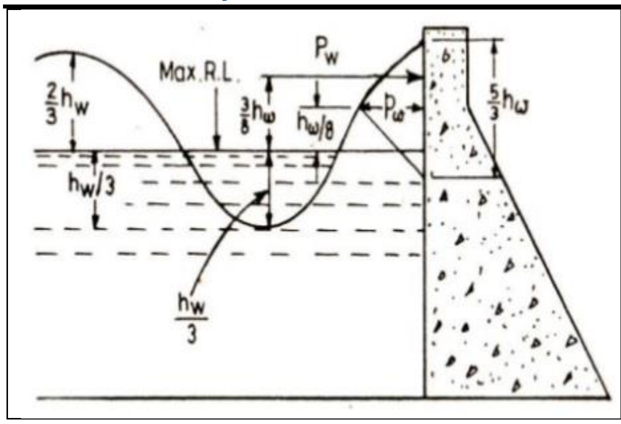
$$U = k \times \Upsilon_w \times b \times (H + H')/2 \qquad (3.2.1)$$

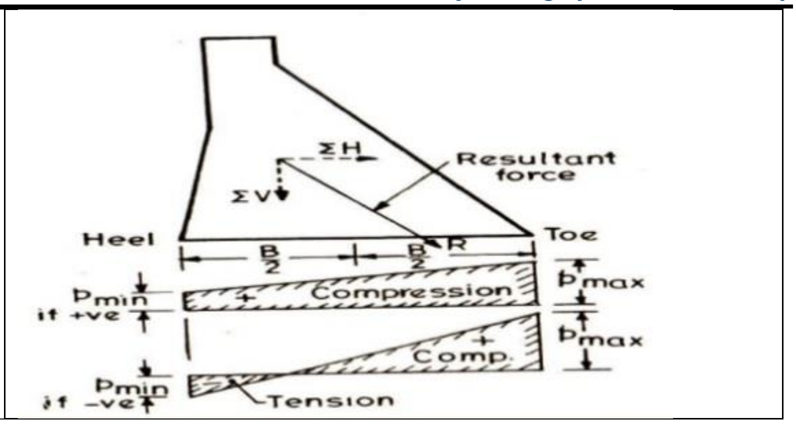
Drainage gallery generally reduces the uplift pressure; the uplift pressure with drainage gallery is given by formula;

$$U = \Upsilon_w \times H' + (\Upsilon_w \times H - \Upsilon_w \times H')/3 \qquad (3.2.2)$$

Table.3.2 Diagrammatic depiction of forces acting on Dams/Reservoirs





3.3. Wave Pressure: Though, stored water has potential energy; the water is continuously flowing into the dam/ reservoir and possesses Kinetic energy. This induces vibrations and waves. The waves are multiplied even in case of Seismic Failures i.e. Vertical Acceleration and Horizontal Acceleration. Moreover; ice formation owing to its continuous slamming on the dam/ reservoir wall causes waves. The maximum crest is 2/3rd of height and trough of 1/3rd of height.

3.4. Stabilizing forces: weight of dam is the stabilizing force for the dam. The Weight of the dam should be more than the vertical components of the forces on the dam. The weight causes compression while horizontal is responsible for tension & shearing action on the dam/ reservoir gates.

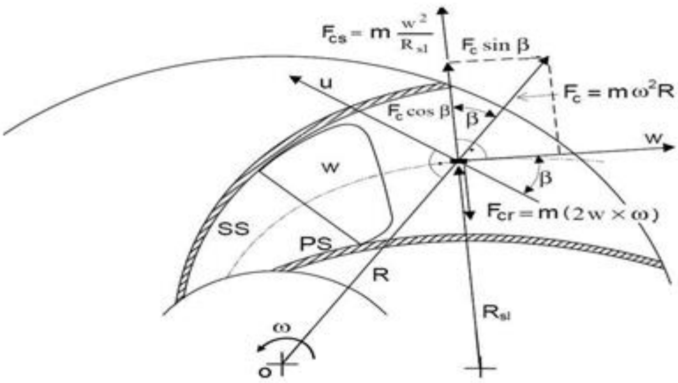


figure.3.5

3.5. Forces Acting on Radial Gate:
Applying Bernoulli Equation to points 1 and 2;

$$\frac{P_1}{r} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{r} + \frac{V_2^2}{2g} + z_2 \quad \textbf{(3.5.1)}$$

P_1, P_2 : Pressure at chosen point
V_1, V_2 : fluid flow speed
Z_1, Z_2 : elevation of the point above reference plane
g : acceleration due to gravity
ρ : Density of fluid at all points in the fluid
In still water conditions; $Z_1 = Z_2$ the above equation becomes;

$$P_2 - P_1 = \rho V_1^2 / 2g \quad \textbf{(3.5.2)}$$

Table.3.5

Gate Opening (d) m	**Height (ΔH) m**	**Velocity (V) m/s**	**Pressure Difference (P_2 - P_1) N/m^2**
0.5	6	V=√2gh	58750
1.0	5.5	V=√2gh	53950
2.0	4.5	V=√2gh	44086
4.0	2.5	V=√2gh	24250

IV. ALUMINUM REINFORCED PANELS

Aluminium is a light weight and rust resistant material. Fibre Reinforced Aluminium (FRA) is a mixture of carbon fibre and Aluminium. If used together with a phase-change material (PCM), it creates a smart environmental friendly system which is light weight, greater strength than steel structures, economical, effectively reduce carbon foot print etc. Sandwich composite is a type of composite materials that is assembled by bonding of two thin facings on a lighter core where the core used to separate the thin facings. In this type of material the flexural rigidity is increased as the two skin surfaces separates. The objective of using sandwich structured composite materials is to reduce the weight and increase strength and also better excellent thermal insulation properties. Aluminium skin surface is embedded with alternate layers of polyurethane & acrylate, owing to its shatter resistant properties. Each polyurethane & acrylate are fused together as single layer. Total six layers are hand layup with ply angle of 28.5^0 (using Bevel Protractor). Using Three- point bending test axial compression and lateral crushing loads are evaluated on sandwich composites. Finally results are compared with strength to weight ratio of Aluminium rods and Aluminium composite panel.

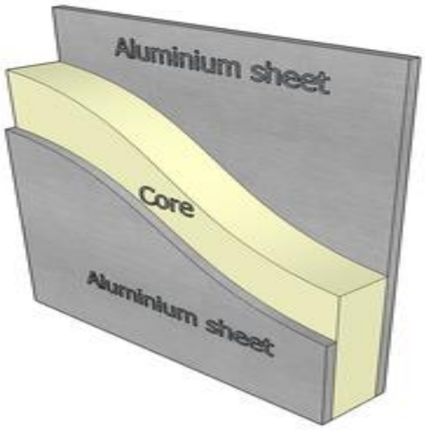


figure.4

Vertical lift crest gates and radial gates are manufactured using FRA sandwich composite. Crest gates of dimensions 67.4 x 67.4 x 67.4 m^3 and radial gates 40.44 x 40.44 x 13.48 m3 and 60.66 x 40.44 x 13.48 m^3 are made. The inclination angle from axis of dam to toe of the gate is 57^0. The inclination angle is much higher than angle of repose, indicating free flow downstream.

V. EXPERIMENTAL SETUP

A flexi-glass model of the dam/ reservoir with water storage of dimensions 50 x 48 x 16.5 cm^3 on upstream side and downstream side of length 50 x 35 x 15 cm^3 is made. FRA - Vertical lift gate of dimensions 10 x 10 x 6.5 cm^3 is made. Radial Crest Gate of dimensions 6.2 x 8 x 5 cm^3. The scale of 1cm = 8.578 m is considered in the model design. The total storage capacity of dam/ reservoir is assumed to be 25 x 10^9 litres (equivalent to cultivate 10,000 acres of land downstream) of which 50% is for agricultural purpose and the 50% for drinking purposes – of available water resources.

Let,

a. Height of the dam H : 24 cm
b. Height of Water h : 18.5 cm
c. Top of the dam a : 6.0 cm
d. Bottom of the dam b : 16.0 cm
e. Weight density of water : 9810 N/m^3
f. Force exerted by water F
g. Weight of dam per unit meter length of dam (W) = mg

$F = w*A*h = w(h*1)h/2 = 9810*0.5*(0.185)^2 = 167.874$ N

Weight of dam/ meter length of dam (W) = $w_0 * ((a + b)/2) * H * 1 = w_0 [(0.07+0.16)/2] * 0.23 * 1 = 0.026 w_0$

$AN = (a^2 + b^2 + a*b)/3*(a + b) = [(0.07^2 + 0.16^2 + 0.07*0.16)]/ 3(0.07 + 0.16) = 0.06$ m

$x^- = (F * h)/3W = 10.35/w$

eccentricity, $(e) = (d - b)/2 = [\ 0.06 + 10.35/4 – 0.16/2\ ]$
$= 10.35/w – 0.02$

$\sigma_{max.} = W/b*(1 + 6e/b) = 6.25 * W * [0.25 + 388.125/w]$

$\sigma_{min.} = W/b*(1 - 6e/b) = 6.25 * W * [1.75 - 388.125/w]$

$\rho_{acrylate} = 1.19$ gm./cc $= 1.19 \times 10^3$ kg/ m^3

Weight of Acrylate = 21.248 kg

$w_0 = \rho g = 1.19 \times 10^3 \times 9.81 = 11.674 \times 10^3$

$\sigma_{max.} = 2628.5\ N/m^2$; $\sigma_{min.} = 1006.75\ N/m^2$.

VI. SCHEMATIC ELECTRIC CIRCUIT DIAGRAM FOR HOSTING OPERATION USING SERVO MOTORS

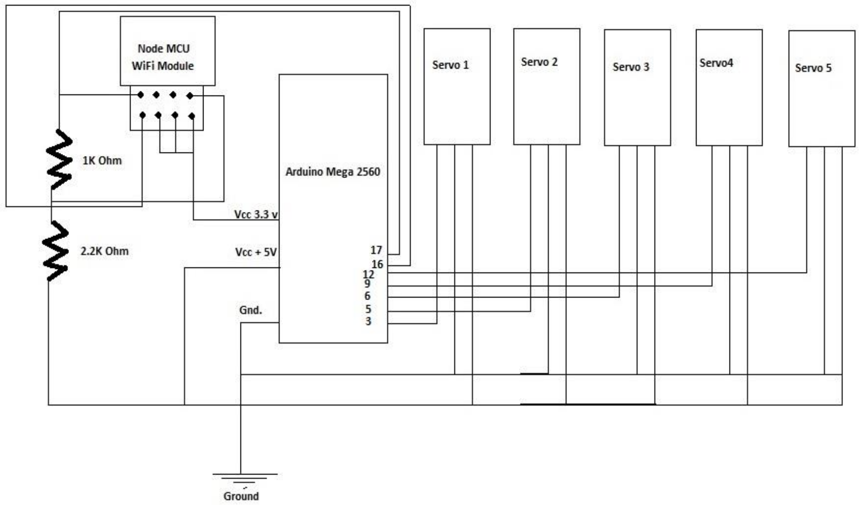


figure.6

VII. CAD MODELS OF RESERVOIR AND RADIAL GATE ASSEMBLY WITH HOIST MECHANISM

An optimal design of lifting mechanism that is efficient, effective and well-equipped with trustable mechanism and proficient control system lift the gate is vital from the technical perspective of the problem & eventually for public site. Electricity driven, connected shafting, completely bounded gear reduction, protected and elastic couplings, indented drums, and toughen stainless steel cables.

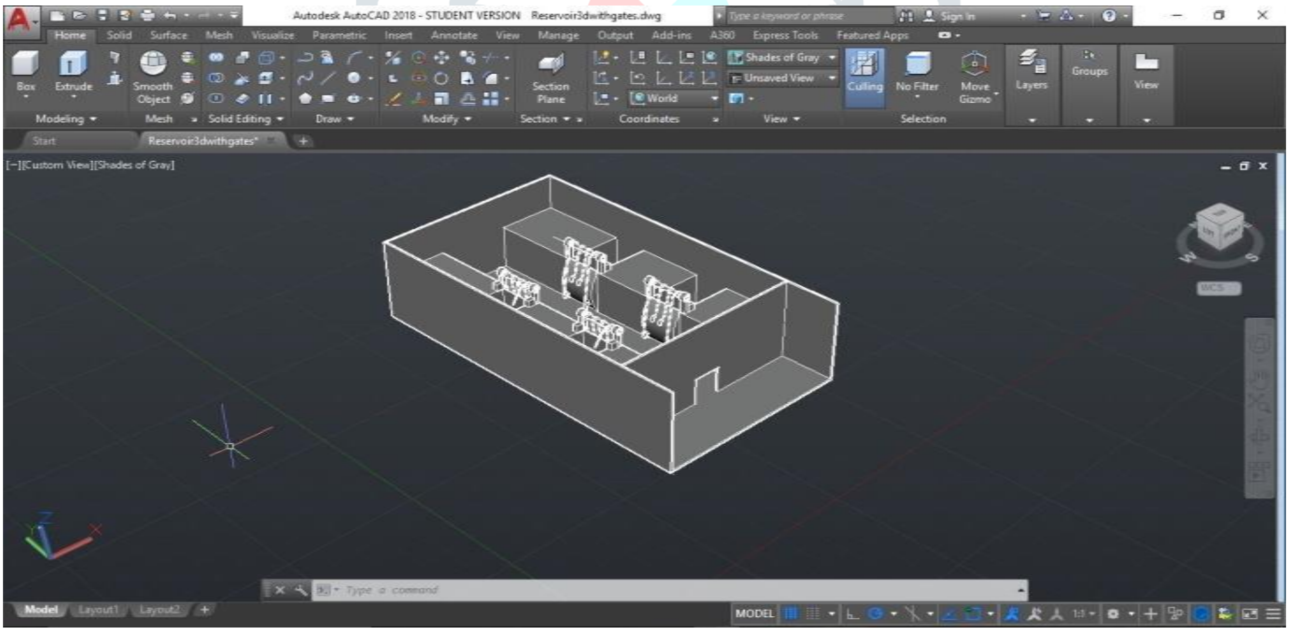


figure.7.1

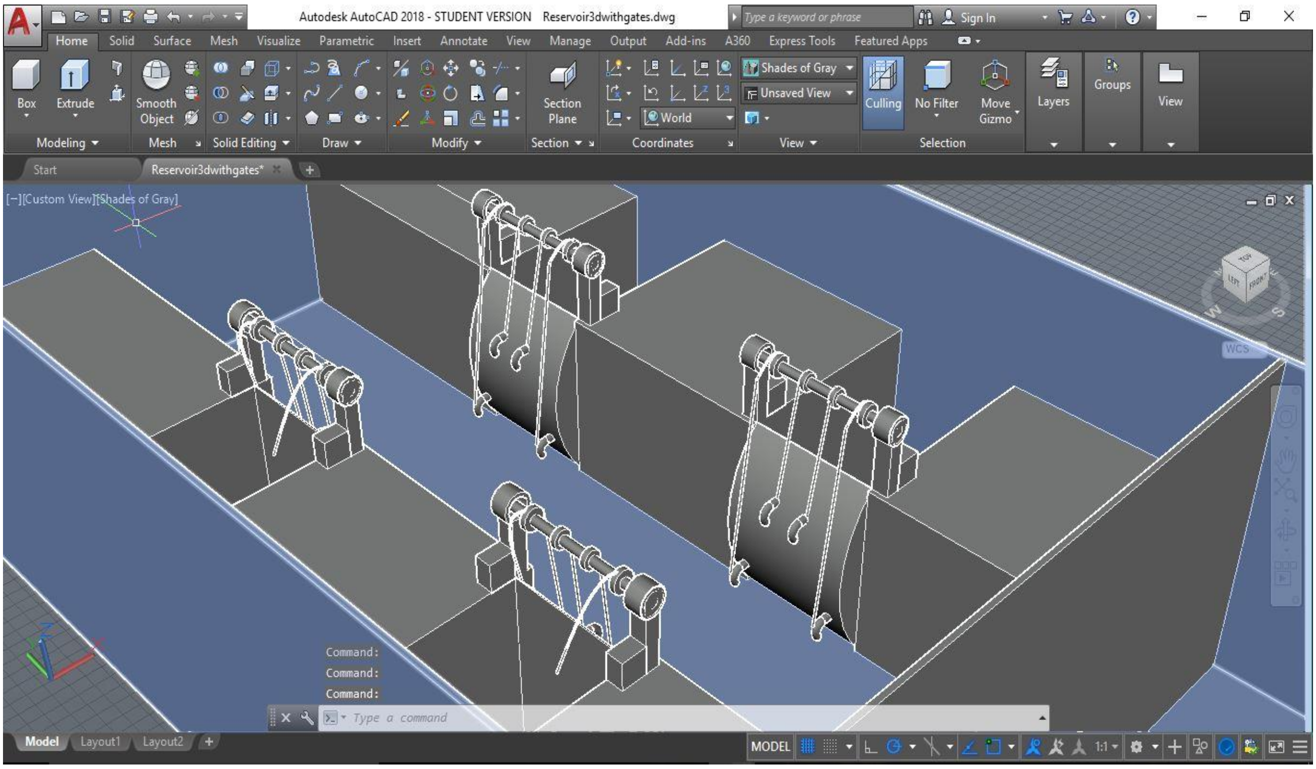


figure.7.2

VIII. RESULTS AND DISCUSSION

The Values for the IZOD impact test and UTM are obtained as **25 Joules** and **175 KN** respectively. The composite samples are tested using universal testing machines to determine the tensile, flexural and compressive properties. The strength of composite samples generated with respect to various sandwich structures to be reinforced with different core materials are analyzed. The results indicated that polyurethane based sandwich panels tend to have better tensile and compressive load bearing capacity as compared to Aluminum Honeycomb due to their structure and also Aluminum has better flexural properties because of its core line up which can undertake bending easily

IX. CONCLUSION

The various mechanical tests which were conducted on the samples are 3 Point Bending Test, Tensile Test and Compression Test. All these mentioned tests were conducted by adhering to ASTM standards for testing of composites materials. For the Bending Test it was observed that Aluminum Honeycomb has the highest Bending Load of 1.87KN and HDPU Foam has the least 0.47KN. This shows that Aluminum Honeycomb has flexural strength 4 times more than that of HDPU Foam. For the Tensile Test it was observed that as Aluminum Honeycomb can easily tear in linear loading, the value of Tensile Load is least for it 1.37KN and Rockwell which had stronger bonding among the particles, due to is chemical composition has the highest value of Tensile Load at 2.67 which is almost 2 times the value of Aluminum Honey Comb. For Compressive Test, the value of compressive load is highest for Rockwell foam based sandwich panels and HDPU Based panels have a similar behavior due to the chemical bonds of the foams which bind them together while loading along the axis. In case of Aluminum Honeycomb the value falls to 4.49KN which is lesser as it tends to crush easily when compressed. Results suggests that polyurethane based sandwich panels tend to have better tensile and compressive load bearing capacity as compared to Aluminum Honeycomb due to their structure and also Aluminum has better flexural properties because of its core line up which can undertake bending easily. The gates tend to have light weight and more economical for the use in dams and reservoir or sub canals and also the PU foam acts as a shock absorber in taking up all the hydro-dynamic pressure created by water and aluminum is observed to show resistance to corrosion.

X. ACKNOWLEDGMENT

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