ANALYSIS OF FIBER REINFORCED PLASTIC NEEDLE GATE FOR K.T. WEIRS

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Abstract—Steel needle gates which are being used in Kolhapur Type Weirs (K.T. weirs) need to be replaced to overcome their disadvantages like heavy weight, corrosive nature, maintenance cost etc. Fiber Reinforced Plastic (F.R.P.) having advantages like light weight, low maintenance cost, corrosion resistance, longer service life etc. can be thought of as a replacement to steel in K.T. Weirs. In the present investigation an attempt is made to analyze the FRP Needle gates using finite element method. A generalized software tool is developed using FORTRAN which gives structural responses (deflections, stresses) as a result by input of material properties.

Keywords— Kolhapur Type Weir; Needle Gates; F.R.P.; F.E.M.; FORTRAN;

I. INTRODUCTION

For K.T. weirs needle gates are used to facilitate as a barrier for water. The gates are 2.15 m long and 0.5 m in height and are made of steel. The Steel needle gates are effectively used in K.T. weirs but are having some major disadvantages as: Heavy weight, high maintenance cost, highly corrosive, short life, difficult to repair on site, chances of stealing the gates. To replace the steel, an attempt of using Fiber Reinforced Plastic/Polymer can be made for making needle gates for K.T. Weirs. Fiber Reinforced Plastic/Polymer is a composite material made by combining two or more materials to give a new combination of properties. FRP needle gates are having advantages like: light in weight, low maintenance cost, on site repairing, anticorrosive, long life. Hence it necessitates to the proper attempt of design and development of Fiber Reinforced Plastic Needle Gates

II. OBJECTIVE AND SCOPE

The basic aim of the investigation is to understand the behaviour of the gates under the application of the reservoir load. The present investigation provides efficient finite element analysis software which takes up combinations of the parameters defining data to derive the nature of structural response of the structure. To demonstrate the usefulness of the software and to draw qualitative conclusions the following data has been taken.

a) Thickness of the arch ring = 5 mm
b) The elasticity coefficient E = 2.5 x 10^7 KN/m^2
c) Poisson's ratio (μ) = 0.15
d) Density of the material (γ) = 25 KN/m^3

Instead of conventional planer system the plank in the form of arch ring is considered as a gate which will be dominated by in plane stresses also leading to insignificant development of flexural moments. Thus the thickness of the gate can be optimized resulting into economic benefits. The proposed arched ring constitute the three dimensional spatial structural system whose analysis could be undertaken only through finite element solution technique.

III. FINITE ELEMENT IDEALIZATION OF THE SYSTEM

The system to be investigated is represented through a key diagram as shown in fig.1.

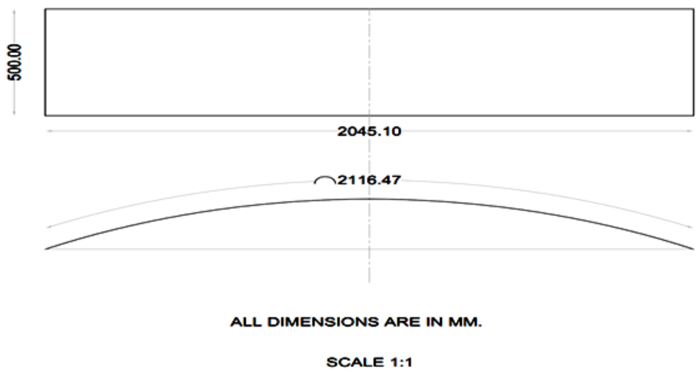


Fig. 1 Schematic presentation of the proposed systems

With a view to undertake a parametric investigation the data is converted into ten independent problems. For all of them the radius of the circle is 2341 mm (2.341m) and the heights are as shown in table no. 1.

Problem nos. with respective heights

Prob. No.	1	2	3	4	5	6	7	8	9	10
Height (m)– H	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0

Table no. 1

It may be noted from fig. 2 that the system is having an axis of symmetry therefore it is considered sufficient to deal with only half the region beyond the central line. In the present case the right hand side half region is considered for the purpose. This is shown in fig.2.

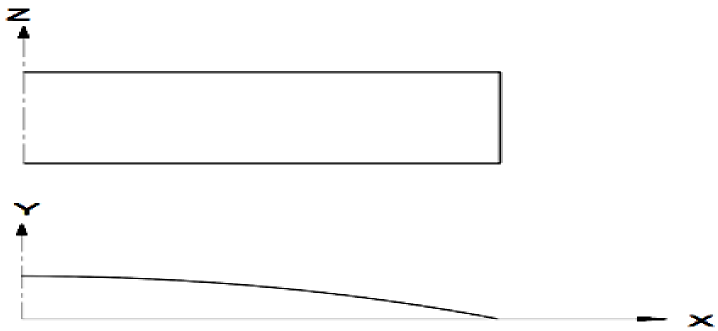
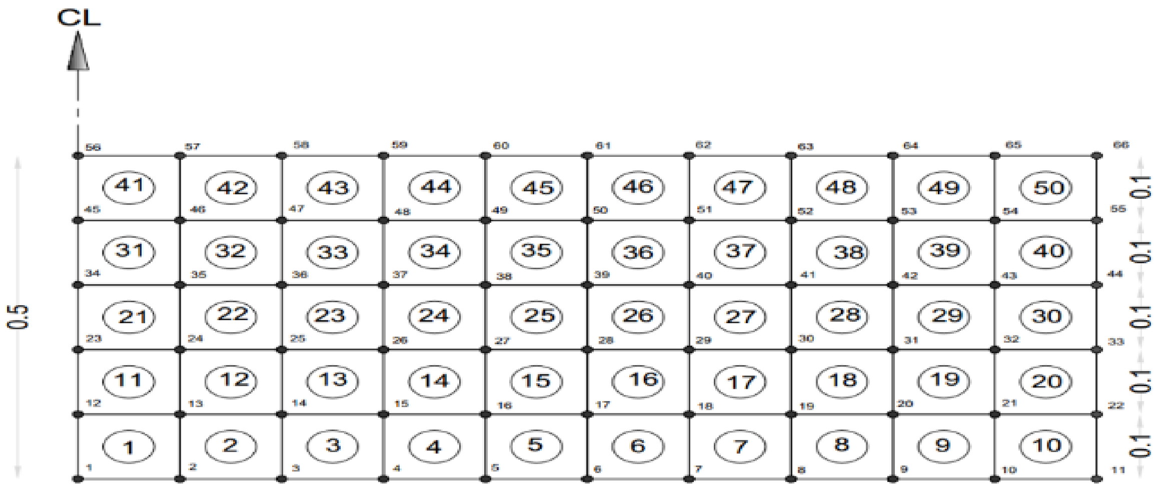


Fig.2. Details of the sections being analysed along with details of reference system (x, y, z) adopted.

The finite element idealization is developed by adopting four node elements. With a view to illustrate the nature of idealized system the problem no. 1 is considered with the details as shown in fig. 3.



All dimensions are in M.

Fig.3. Elevation - Idealization details for problem no. 1.

In the same manner the idealization details for problem nos. 1 to 10 are prepared by incrementing 0.5 m segment above the basic details shown in fig.3. With this the idealization for all the problems has features as shown in table no. 2.

Main Features of the Idealized systems adopted for prob. no. 1 to 10.

Prob. No.	1	2	3	4	5	6	7	8	9	10
No. of Nodes	66	121	176	231	286	341	396	451	506	561
No. of Elements	50	100	150	200	250	300	350	400	450	500

Table No.2

IV. FORMULATION OF EQUATIONS OF EQUILIBRIUM OF THE IDEALIZED SYSTEM AND THE SOLUTIONS

For the formulation of equations of equilibrium of the idealized system the versatile frontal solution technique is employed. The important details of this solution technique concerns consideration to the elements sequentially in the case of all the problems considered. This has led to a frontal width of 78. Thus giving rise to the equations in a very compact manner. Having formulated the equations of equilibrium the solutions are derived by employing the following boundary conditions: Base nodes 1 to 11 are restrained in Y and Z directions. The same are kept free in X direction because the lateral support on the right hand side of the idealized system has uncertain character, therefore the nodes on the boundary are also kept free from any restrain. The self-weight of the system is considered. For this the nodal loads are computed by means of an inherently provided algorithm in the software. The load arising from the reservoir water has a basic character of acting in the direction normal to the exposed surface. For this also the algorithm provided in the analysis program computes the equivalent nodal loads. With all this the systems happen to be cantilever with simple supports at the base.

V. RESULTS AND DISCUSSIONS

Nodal Displacements:

In general the displacement has six components namely translations in (X, Y, Z directions) such as (U, V, W) and the rotations around X, Y, Z axes such as($\theta_X, \theta_Y, \theta_Z$). Of these the translational components U, V, W are practically important for describing the behaviour of the systems. On observing details of all the problems it follows that:

- The translations in X- direction (U) are negligible in case of all the problems considered.
- The translations in Y – direction (V) are corresponding to the behavior of a cantilever subjected to normal load over its axis. The load being due to reservoir water pressure.
- The translation component in Z – direction is influenced by the weight of the structure and is of insignificant order and in any case they represent only minor permanent changes in the vertical geometry of the systems.

These are relatively of significant order and their variation over the height of the segments is graphically shown over fig.4.

(Note: For problem no. 1, Series 1 represent extreme left vertical node line i.e. node nos. 1, 12, 23, 34, 45, 56. Series 2 represents next vertical node line i.e. node nos. 2, 13, 24, 35, 46, 57. The representation is same for next series and next problems also.)

Problem No. 1

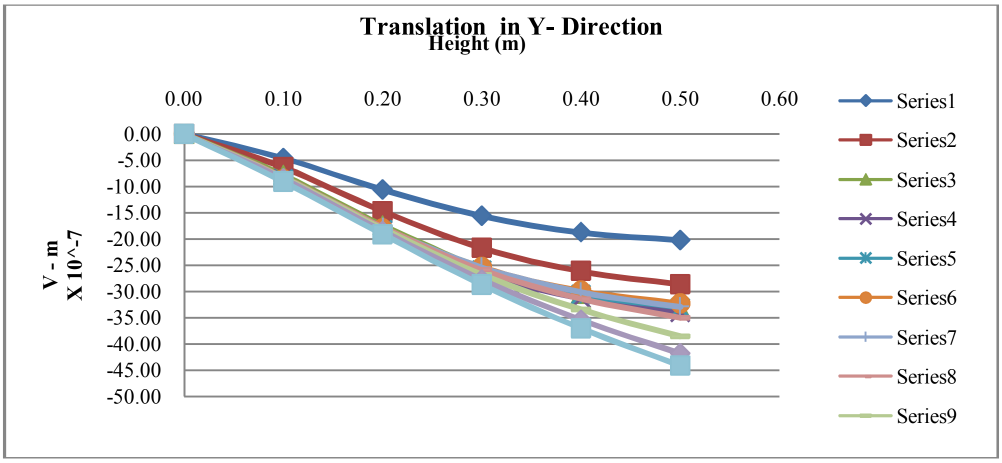


Fig 4. (Detailed response of the translations in Y – direction)

The structural response of elements is referred to local in plane (x, y - axes). The structural response thereby has membrane stresses $(\sigma_x, \sigma_y, \tau_{xy})$ and flexural details (M_x, M_y, M_{xy}). It is noted that flexural component (M_x, M_y, M_{xy}) are of insignificant order and therefore the components $(\sigma_x, \sigma_y, \tau_{xy})$ are important from the view point of ascertaining the structural safety. The manner in which the variation of deflection 'V' is shown over the height of the structure is now adopted to show the variation of $\sigma_x, \sigma_y, \tau_{xy}$. Complete details are presented in fig. no. 5, 6 & 7.

Problem No. 1

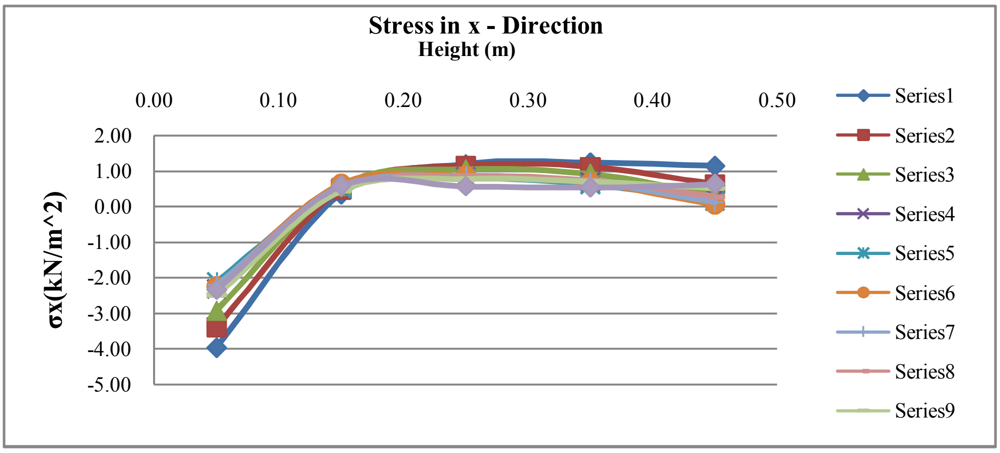


Fig.No. 5 (Variation of σ_x.)

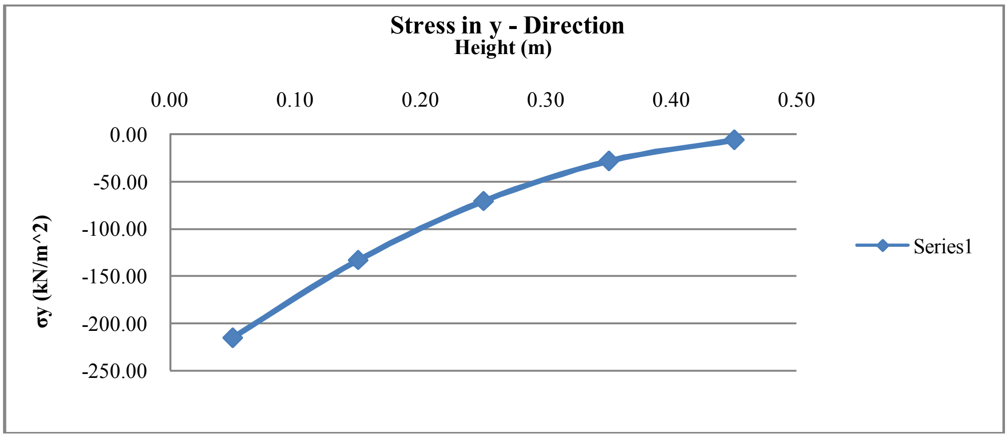


Fig. No. 6 (Variation of σ_y.)

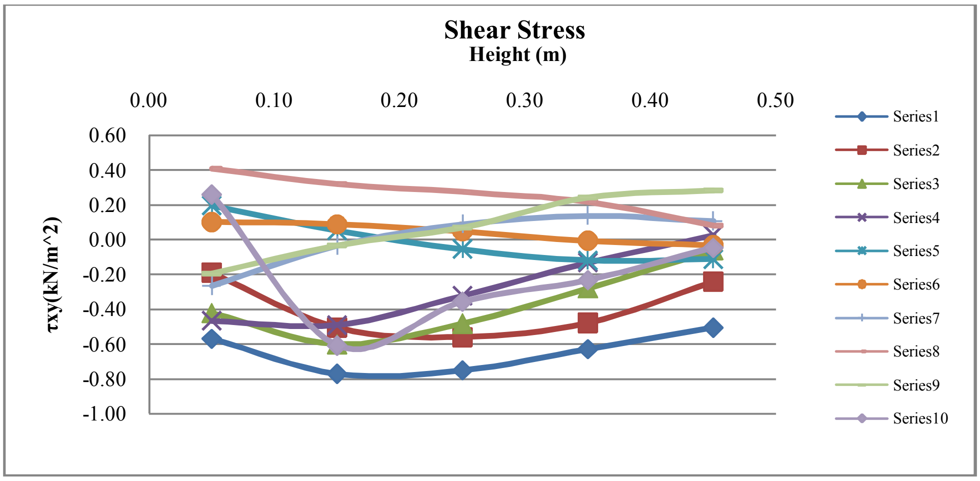


Fig. No. 7 (Variation of τ_{xy}.)

VI. CONCLUSION

On the basis of the details derived for the structural response of the ten problems considered following broad conclusion could be drawn.

- The software used is quite efficient for the purpose of realistic investigations.
- On the view point of serviceability aspect all these structures are found to be over safe.
- The normal stress σ_x which is to start with compressive at the base of the structure changes its sign to tensile stresses after the height of 0.1 m to o.2 m.
- σ_y- Compressive stresses in Y – direction at the base of the structure has the same values for the entire profile of the problem.
- Shear stresses show random characteristics.

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