Finite Element analysis of a portable Sluice Gate for NVDA Malwa region, India (M.P)

Bilal Ahmed, Dr. M. L. Jain, Mr. Anil Mulewa,

Shri G. S. Institute of Technology and Science, Indore
Shri G. S. Institute of Technology and Science, Indore
Shri G. S. Institute of Technology and Science, Indore

ABSTRACT: This paper is based on the basic steps for analysing of sluice equipment utilized in hydroelectric power plants for analysis of an effective and safe sluice gate. The Sluice gates are used to regulate the flow of water in canals. To achieve the desired flow rate, gates are raised or lowered manually and then left in place for the desired duration. The hydrostatic pressure, fluid vibration, debris which is acted on the sluice gate cause the deformation and failure of the gate. The present paper described the application of ANSYS Workbench software for analysing the sluice gate deformation, stress, strength and reliability.

KEYWORDS: Sluice gate, Optimization, Stress Strain Analysis, Deformation, Fatigue life, Corrosion, Model.

I.   INTRODUCTION

[5].The Sluice gate is used in the systems like Dam, Water canals, Irrigation system, Pump-House to control the flow of the water. In Pump-House and Irrigation system it is mainly used to water supply from river to village area. The operation of many types of gates is successful. However, few of these may be suitable or economical for a Dam, spillway, Pump-House, Irrigation.

[9].The main objective is to select a suitable design for the type and size of gate, which will meet the hydraulic, operational, site condition and dam Requirement. The conditions like water head which could be low, medium or high, the locations like spillway, barrage, intake, navigation channels etc.

[11].Generally, the main aim of sluice gates is to allow easy flow control of water or wastewater. That includes resisting water hydrostatic pressure, dynamic pressure and limiting deformation to an amount that prevents leakage. More studies about sluice gate analysis can be found in the literature, that is, how the mechanical properties of sluice gates are affected by hydrostatic pressure. That's understood because of the simplicity of the gate analysis compared to water flow. Also, each manufacturer has their own specification that makes it difficult to generalize the behaviour of all slide gates.

We will be able to improve the shape of sluice gates by using the results of this paper to study the fluid force impacts on them. The reason of failure of sluice gate due to impact loading of Hydrostatic force of water pressure. We analysed the stress and deformation of sluice gates under operational loading using their strength specifications and the finite element method. The materials which are used in the sluice gate are (IS-2062 Structural steel). In this paper; we are study on fixed wheel vertical lifting sluice gate.

II.   CLASSIFICATION OF GATES

[1].The gates may be classified on the basis of water head above sill level as follows:

- **High head gate** — Gates operating at a height of 30m and above.
- **Medium head gate** — Gates operating at a head of 15 meters and above, but not exceeding 30 meters.
- [3].**Low head gate** — Gate which operates with a height less than 15 m.

[9].**Typical types of gates utilized in Dam and Barrage structures in India**
i.   Vertical Lifting Gates
ii.   Vertical Lifting fixed wheel gate
iii. Vertical Lift Slide gate
iv.   Radial Gates
  i.   **Vertical Lift Gate**

[9].The vertical lifting sluice gates are rectangular in shape and supported by guide C-type channel in which sluice gate operate vertically in their own plane. In the sluice gates, the skin plate is attached to a framework. The skin plate is rectangular in shape normally which placed on the back side of vertical stiffeners and girders.

Figure 1. Design model of Vertical lifting gate

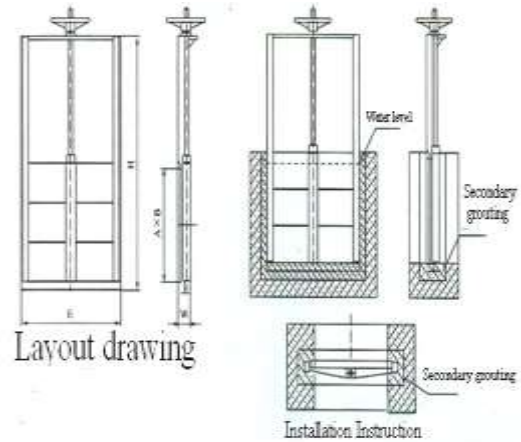**Figure 2. Design frame model of vertical lifting gate**

Figure 3. 2D drawing of vertical lift slide gates (courtesy- Alibaba.com)
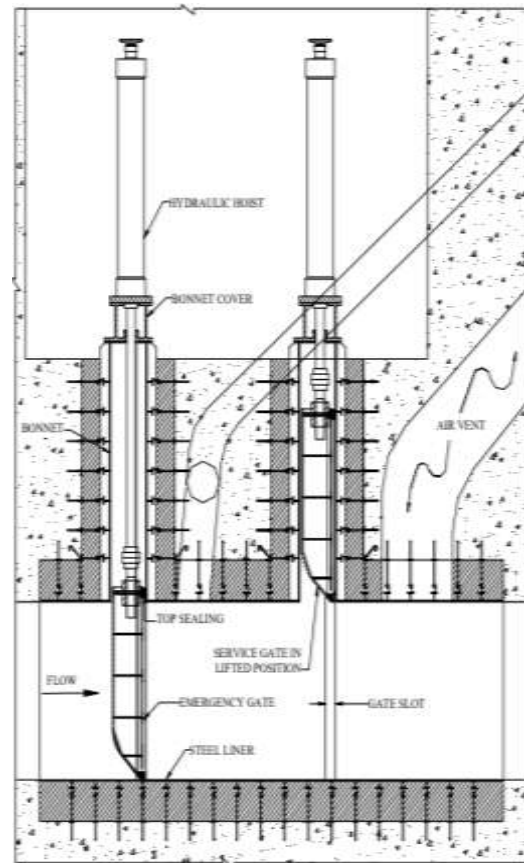

Figure 4. 2D drawing of vertical lift slide gates in tandem (courtesy- Training Program on Design of Hydro-mechanical Equipment (Gates & Hoists) for officials of Government of Bihar, India)

ii. **Fixed Wheel Vertical Lift Sluice**

[9].These sluice gates are rectangular flat 2M X 2M and are operated in vertical direction. The Gear Box Hoist system & Wire-rope drum Hoist

system which is used to operate the gate. A skin plate is supported by a system of horizontal girders and vertical stiffeners, which are connected by end girders and roller wheels. These roller wheels rolling in embedded frame and lock itself the rubber seal with the help of eccentric pin. These embedded track frames are fixed in concrete with anchors.

Components of Gate: -

[9].Gate Leaf: In order to control the fluid, it is that portion of the sluice gate that moves across it. The sluice gates have
- Skin plate
- Vertical stiffeners
- Horizontal girder,
- End vertical girder
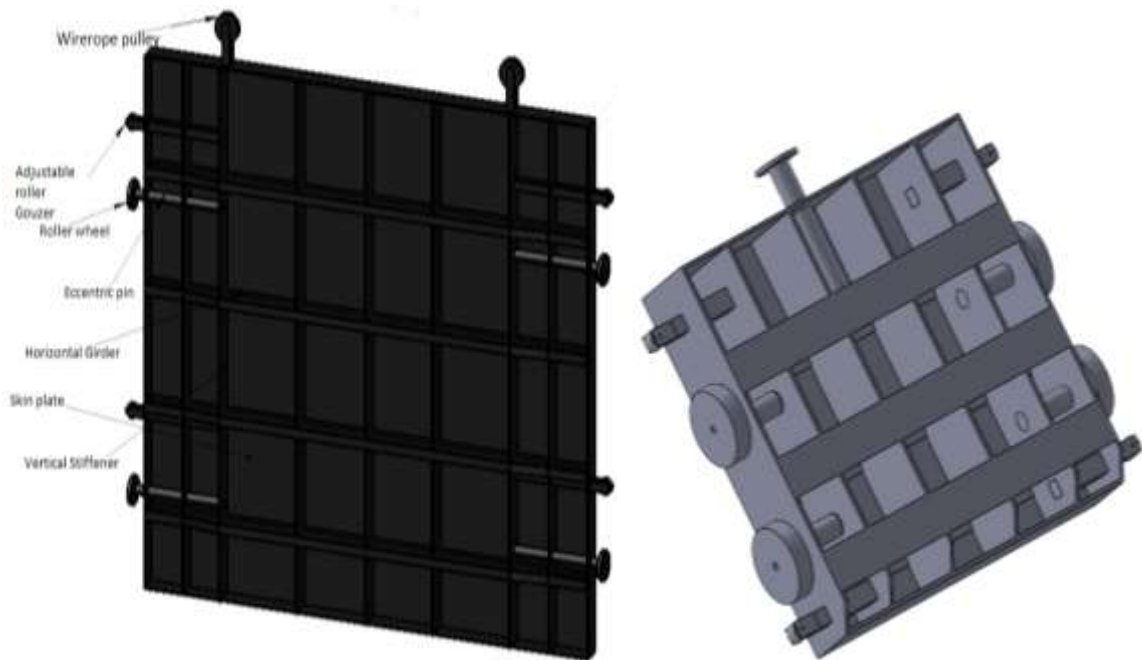- Guide roller
- wheel
- Seal assembly

Figure 5. Design model of vertical fixed wheel sluice gate

III. DESIGN AND MODELING
[6].Cad Model
There is fluid force acting on this sluice component. There is a unique way in which this fluid force distributes its forces. Fluid force distribution along the length of a rectangular sluice gate is given by-

$$F = \delta \times g \times \frac{\square}{2} \times A = \delta \times g \times \frac{\square^2}{2} \times b$$

Where
δ = density of fluid
A = area of sluice plate (b × h)
b = breadth of the plate
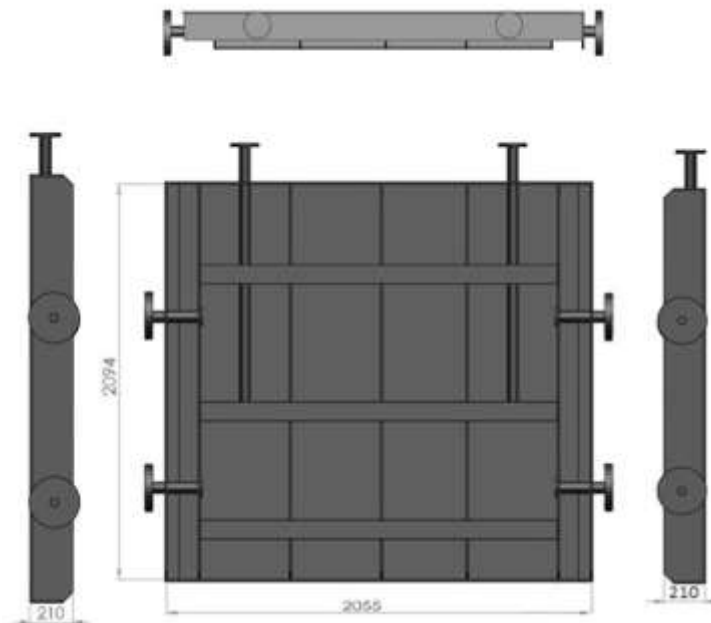h = height of the fluid providing force

FIGURE 6. TYPICAL REPRESENTATIVE OF DESIGNED SLUICE GATE - BASIC DIMENSIONS

Materials properties
All parts of the assembly model were assigned structural steel as a material

Property	unit	value
Density	(kg/m³)	7800
Poisson's ratio, v		0.3
Co-efficient of Thermal expansion		$2.1e^{-5}$
Elastic modulus, E	(GPa)	210
Yield strength	(MPa)	250
Ultimate strength	(MPa)	460

Table 1. Material properties of structural steel Sluice gates.

[2].**Design data**
The data which is mentioned below is taken from Design data book of junction structure at RD 9775 M of RBC Omkareshwar Canal (Narmada Valley Development Authority), India.

i.	Type of gate	Vertical Lift, Fixed Wheel Gate
ii.	Sluice gate size	2094 mm × 2055 mm
iii.	Full supply depth	5.2 meter
iv.	Platform Level	189.324 meter
v.	c/c of side seals	2100 mm
vi.	Sill to top seal centre	2050 mm
vii.	c/c of wheel tracks	2400 mm
viii.	Design head	5.5 meter
ix.	Operation	Regulating type

x.	Materials	IS-2062 Structural Steel

[2].**Design calculations for sluice gate are given below**

- H   5.5   M
- L   2.05 M
- B   2.1   M

Total Load on the gate -

$L \times B \ (H - \frac{L}{2}) \times 9.81$

-          188.988 KN

IV.   FINITE ELEMENT ANALYSIS

[6].Finite Element Analysis, The most effective method for analysing a problem with a virtual approach is the Finite Element Analysis. It meets all the prerequisites for an industry-ready product with the nearest optimal solution in terms of optimization.

V.   STATIC STRUCTURAL ANALYSIS

[6].Whenever it is possible to solve every problem using finite element analysis, in the first step, it would be subjected to a static structural analysis. Additionally, the work will be subjected to a variety of other analyses.

VI.   MESHING

[6].The meshing process begins with generic auto mesh and a refinement of model will be constructed with a smaller range of element sizes. An element type of Tetrahedron with second order and element size of 20mm was considered. By using ANSYS Workbench, it can be inferred that meshes with uniformity exist.
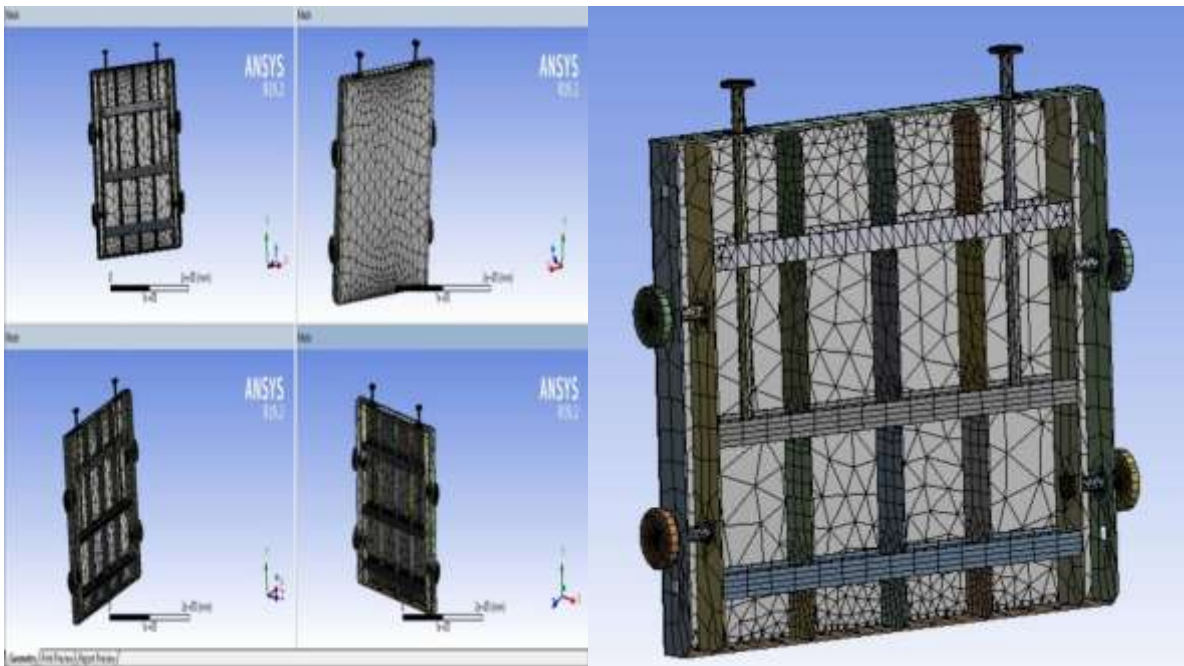

FIGURE 7. MESHING OF SLUICE GATE MODEL IN ANSYS

VII.   LOADING CONDITION

[6].The sluice gate is subjected for the direct load, the four wheels and gate side edges are fixed. The girders are equally spaced therefore loading on each girder are equal

and that's it 62996.1 N total load on gate is 188988.4 N. After converting hydrostatic pressure to force-based loading, we applied 188988.4 N to the area on either side of the sluice gate.
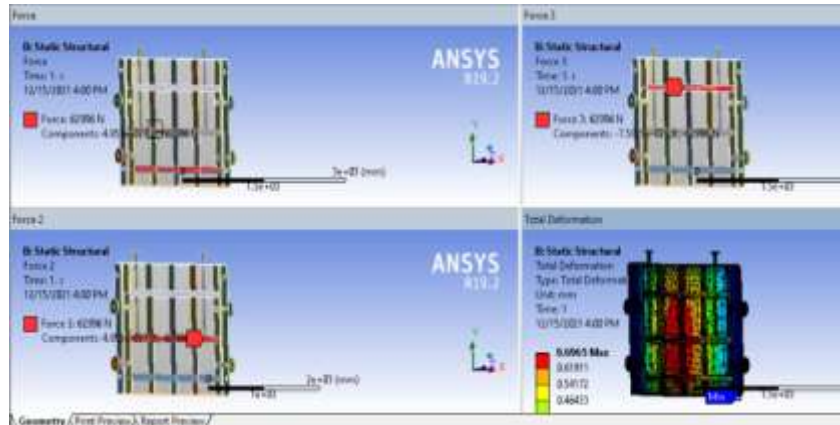
Figure 8. LOADING CONDITIONS & DEFORMATION

VIII. RESULT AND DISCUSION

The hydrostatic loading is applied on the designed sluice gate with appropriate boundary condition. The following sections explained the three different critical loading conditions and corresponding deformation and maximum principal stress behaviour of sluice gate model, these are all explained with different figures and comparative figures.

The following total Applied Load and Deformation: -

Case 1
Water pressure load: - 188.9884 KN
Total weight of water act on gat: - 19.2 Ton
Total deformation: - 0.78789 mm

Permissible Deflection = L/800
= 0.3 cm
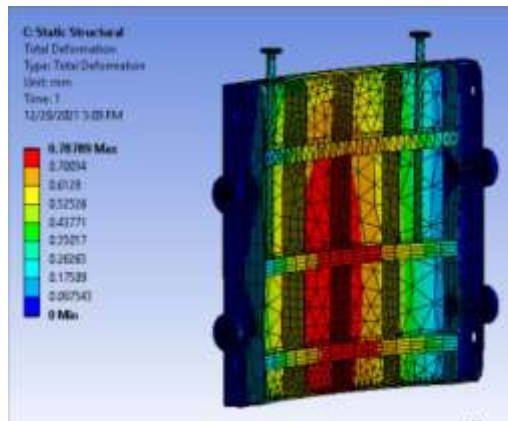= 3 mm > 0.78789 mm & hence safe

Figure 9. Deformation in the Sluice Gate

Case 2
Water pressure load: - 600 KN
Total weight of water act on gate: - 61.1 Ton
Total deformation: - 2.5 mm

Permissible Deflection = L/800
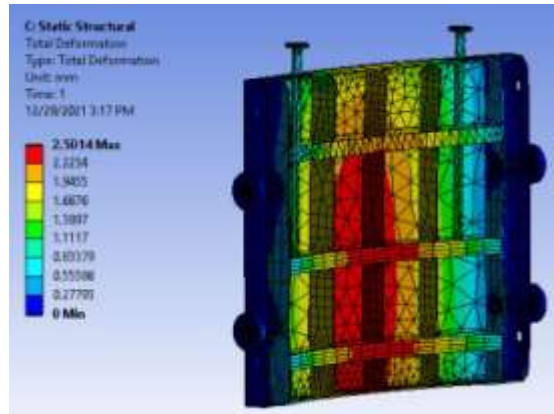= 0.3 cm
= 3 mm > 2.5014 mm & hence safe

Figure 10. Deformation in the Sluice Gate

Case 3
Water pressure load: - 700 KN
Total weight of water act on gate: - 71.3 Ton
Total deformation: - 2.5 mm

Permissible Deflection = L/800
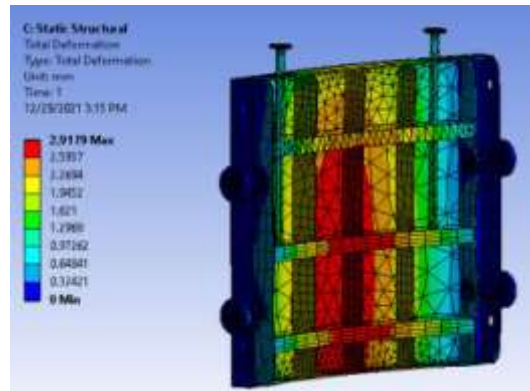   = 0.3 cm
         = 3 mm > 2.9179 mm & hence safe

Figure 11. Deformation in the Sluice Gate

After safe modeling of the sluice gate for NVDA project it Omkareshwar (M.P), we did the simulation of the design gate in Finite Element Analysis software namely Ansys 19.2.

For safe operation of the gate of the gate the model stated with different hydrostatic loading condition keeping the maximum deformation of the gate within 3mm limit. The comparison behaviours of the sluice gate during variable loading condition are shown on in figure 9, 10 and 11. On study and observation it is found that the sluice gate Design/Model with specification showing the maximum deformation of 2.9179 mm it hydrostatic pressure of 700 KN i.e. 71.1 ton Kg weight therefore, this design model performed well and able to prevent any accident during operation of the dam

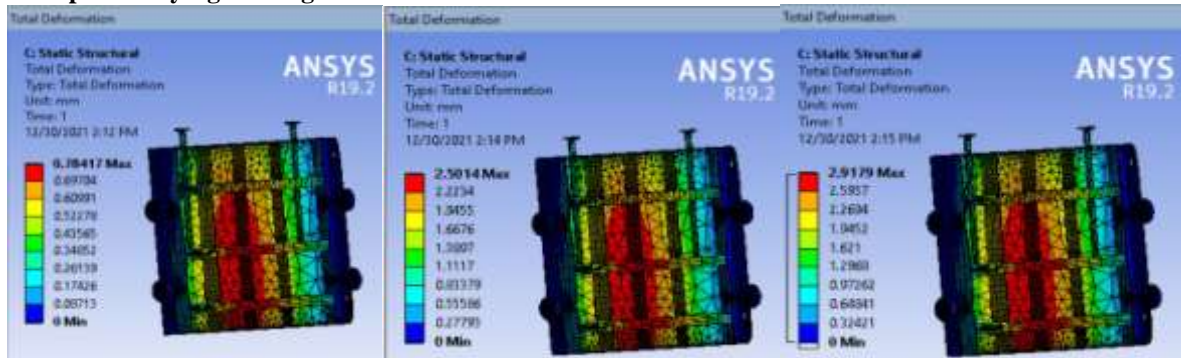**3 Comparatively figure diagram of different deformation condition.**

Figure 12. COMPARATIVELY DEFORMATION IN THE SLUICE GATE

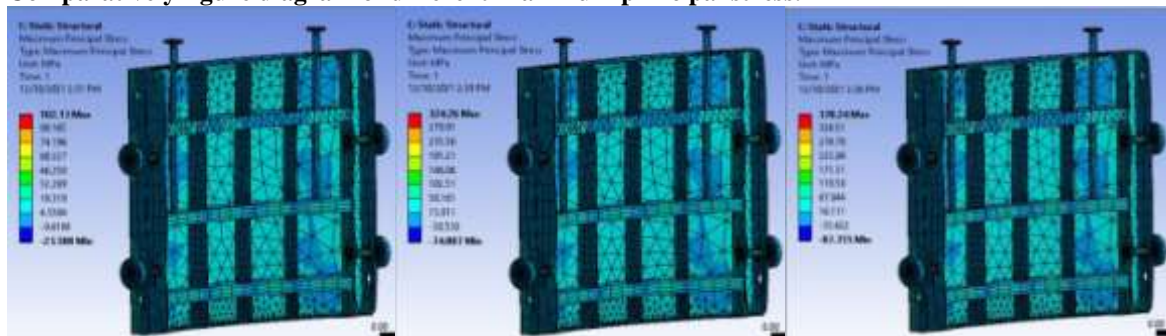**3 Comparatively figure diagram of different Maximum principal stress.**

Figure 13. COMPARATIVELY MAXIMUM PRINCIPAL STRESS IN THE SLUICE GATE

IX.   CONCLUSION

A study of the sluice component has shown that improvements are still possible on the gate. According to the results obtained, these improvements may increase the safety of factor of sluice gate as per the results obtained. As a result of our analysis, we have found that: - Deformation of sluice gate, Factor of safety, stress analysis, flow simulation, Static structural, The sluice gate has been analysed and modelled and has been found to be safe for all of the analyses done on it.

REFERENCES

[1].   Bureau of Indian standards, IS-4622:2003 recommendations for structural design of fixed-wheel gates.

[2].   Design data book of junction structure at RD 9775 M of RBC Omkareshwar Canal (Narmada Valley Development Authority), India.

[3].   Dae-Geun Kim, 2007 numerical analysis of free flow past a sluice gate, - member, lecturer, major in civil engrg., division of construction engrg., mokpo national univ, muan-gun, chonnam 534-729, korea. No.2 pp. 127~132

[4].   El zbieta Kubrak, 2020 Flow measurements using a sluice gate; analysis of applicability, - water center of Warsaw University of life sciences-sggw, ciszewskiego 6, 02-776 warsaw, poland. No. 12(3), 819

[5].   Frantisek TREBUNA (SK), 2009 Methods for Verification of Safety of the Sluice Gates in Water Power Plants, – Technical University of Košice,

[6].   HANDRAL Poornakanta, 2018 Optimization of sluice gate under fatigue life subjected for forced vibration by fluid flow. B V Bhoomaraddi College of engineering, Karnataka, India. No. 3, 129 - 142

[7].   Hydraulic Structures for Flow Diversion and Storage, Book - Gates and Valves for Flow Control, Version 2 CE IIT, Kharagpur, India.

[8].   Jozef Bocko, 2013 Analysis of Sluice Gates of Hydroelectric Power Stations, Department of Applied Mechanics and Mechatronics, Technical University of Košice, Faculty of Mechanical Engineering, Košice, Slovakia No. 7, 324-328

[9].   MD Abdul Wahab, 2005 Stress Analysis on Fixed Wheel Vertical Lift Gate, department of water resources development &

management Indian institute of technology roorkee-247 667 India.

[10]. Miroslav Pástor, 2020 Experimental and Numerical Analysis of 60-Year-Old Sluice Gate Affected by Long-Term Operation, - Technical University of Košice, 04200 Košice, Slovakia, No. 13, 5201

[11]. Sufian Natsheh, 2018 design of stainless-steel and aluminum slide gates based on a combined analytical and finite element approach, - The Graduate Faculty of The University of Akron.