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FEASIBILITY ASSESSMENT OF SUBSTITUTING STAINLESS STEEL WITH ALUMINUM ALLOY FOR HYDRAULIC GATE

Kuo-Ho Chen[1] and Tien-Kuen Huang[2]

Key words: aluminum alloy 5083, hydraulic gate, stainless steel SUS 304L.

ABSTRACT

In this paper, the feasibility of using aluminum alloy 5083 as a replacement for currently used stainless steel SUS 304L on hydraulic gate is evaluated. Relevant properties of these two materials are compared for use in hydraulic gates. Forty common types of hydraulic gates were analyzed through the finite element program PLAXIS 3D Foundation. It shows the weight for most types of hydraulic gates with aluminum alloy 5083 is in the range of 37.6-45.9% of that of stainless steel SUS 304L. At the same time, the cost of gate manufacturing is reduced 39.6-50.5% and cost of maintanence/operation can be reduced at least 18%. These advantages could make aluminum alloy 5083 a better material than the commonly used stainless steel SUS 304L for hydraulic gates.

I. INTRODUCTION

In recent decades, global warming induced climate change has shown to cause extreme flood events and associated human casualties and economy losses in a rapid upward trend. According to statistics compiled by the Intergovernmental Panel on Climate Change (IPCC), yearly global economic losses from extreme events increased from US$3.9 billion/year in the 1950s to US$40 billion/year in the 1990s (McCarthy, 2001). Flood prevention in urban area depends on suitable drainage system, and avoidance of water shortage during dry seasons relies on water stored in reservoirs. Flows of water from drainage system and reservoir are controlled by hydraulic gates. Therefore, a reliable hydraulic gate is necessary for safety of hydraulic structures.

Hydraulic gates are utilized in hydro-projects for water resources operation. On the other hand, waterproof gates are installed at the entrance of building to prevent flooding. However, design concepts for both are different. In general design head is high and duration to block water lasts long for hydraulic gates. Thus current design practice for building entranced gate cannot be applied to hydraulic gate.

The design of the hydraulic structures shall be conducted to achieve the objectives of constructability, safety, and serviceability, with due regard to inspectability and economy (U.S. Army Corps of Engineers, 2014). Therefore, in this paper, discussions on hydraulic gate will include material selection, analyses of stress and deformation, and costs for manufacturing and maintanence/operation.

In Taiwan, Tamsui River have the largest number of hydraulic gates to protect Taipei area against floods. According to existing data in Tamsui River, there are 97 gates made of cast iron & iron, 236 made of stainless steel (Tenth River Management Office, 2012). In short, stainless steel is the most commonly used material for hydraulic gates in Taiwan. One major problem encountered by stainless steel hydraulic gate is that its weight has caused difficulty in operation, maintenance and emergency handling.

On the other hand, aluminum alloys can be applied as components of engineering structures because of its light weight and corrosion resistance (Polmear, 1995). The elastic modulus of aluminum alloys is typically about one-third of that of steel. Therefore, for a given load, the size of load carrying member of a gate needs to be increased to yield equal amount of deformation as that of stainless steel gate.

In the design of hydraulic gate, the stress and deformation of its members can be carried out by two methods. One is simplified static analysis such as that applied by Japan Electric Power Civil Engineering Association (2015) and U.S Bureau of Reclamation (1956). Another one is finite element numerical method similar to that used by Chou and Lou (2000) to calculate stress and strain of high pressure sliding gate. In general, simplified static analysis will yield a conservative result.

This study evaluates the feasibility of replacing stainless steel with aluminum alloy for hydraulic gate. Stress and deformation were calculated by the finite element program PLAXIS 3D Foundation and proper structural members were sized. The

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Table 1. Mechanical properties of forged aluminum alloy.

Alloy Series	Density (g/cm^3)	Brinell Hardness (Hb)	Tensile Yield Strength (MPa)	Modulus of Elasticity (GPa)	Elongation Rate (%)	Remark (ASMInternational, 1990; Hobart Brothers Company, 2013)
1000	2.71	30	20	69.0	25	Low strength, not suitable for structural material.
2000	2.78	120	345	72.4	18	1. Susceptible to stress corrosion cracking 2. Replaced by 7000 series already, not commonly used in industry.
3000	2.73	47	35	68.9	25	Low strength, not suitable for structural material.
5000	2.66	85	228	71.0	16	1. Moderate strength and elongation rate. 2. Good in welding and resistance to marine corrosion.
6000	2.70	120	276	68.9	8	Reheating process required after welding to restore strength.
7000	2.81	135	435	71.7	13	1. High strength and density, weak corrosion resistance. 2. High cost.

Table 2. Mechanical properties of aluminum alloy 5052, 5083 and 5086.

Alloy Series	Tensile Yield Strength (MPa)	Modulus of Elasticity (GPa)	Elongation Rate at Break (%)	Density (g/cm^3)	Brinell Hardness (Hb)
5052	193	70.3	12	2.68	60
5083	228	71.0	16	2.66	85
5086	207	71.0	12	2.66	78

cost comparison of manufacturing and maintanence/operation were also conducted.

II. MATERIAL SELECTION OF HYDRAULIC GATE

In selection of material for hydraulic gate, the most important factor is safety. Other influencing factors such as corrosion, workability and economy etc. are also of concerned. The necessary factors in the selection of material for hydraulic gates are summarized as follows:

(1) Strength:

A material with higher strength can resist much larger water pressure.

(2) Hardness:

It exhibits resistance to impact deformation and abrasion.

(3) Stiffness:

This is an important factor of deformation resistance under long term loading.

(4) Ductility:

It will affect the allowable magnitude of permanent deformation and proper ductility can keep a structure stretch evenly without breaking.

(5) Density:

Higher density will have heavier weight and larger cost of operation and maintenance.

(6) Corrosion resistance:

Corrosion is an important factor of life span of hydraulic gate.

(7) Workability:

Good workability is needed in the forming of hydraulic gate, especially in welded structural application.

(8) Economy:

Cost effective is the major consideration of material selection.

1. The Aluminum Alloys

The manufacturing methods of aluminum alloys can be divided into two major categories as forging and casting. Because the size of hydraulic gate is relatively large in scale, the structural components are usually made by forging. Based on its chemical composition, forged aluminum alloys can be divided into eight series, from 1000 to 8000. However, this study will not discuss series 4000 and 8000, due to low melting point of series 4000, and limited products of series 8000. Table 1 presents the mechanical properties of series 1000, 2000, 3000, 5000, 6000, 7000 (ASM International, 1990; Hobart Brothers Company, 2013; The Aluminum Association, 2015; Wikipedia The Free Encyclopedia, 2016). After carefully examining relevant mechanical properties of forged aluminum alloy in Table 1, series 5000 is selected for further study due to its strength, welding and resistance to sea-water corrosion properties.

Depending upon magnesium alloy content, series 5000 can be further divided into series 5005, 5050, 5052, 5083, 5056 and 5086, and series 5052, 5083 and 5086are more commonly used. The relevent mechanical properties are summarized in Table 2 (ASM International, 1990). Among them, series 5083 seems more appropriate as structural members of hydraulic

Table 3. Mechanical properties of aluminum alloy 5083 and stainless steel SUS 304L.

Material	Tensile Yield Strength (MPa)	Brinell Hardness (Hb)	Elongation Rate at Break (%)	Density (g/cm^3)	Modulus of Elasticity (GPa)	Corrosion Potential, mV (3.5% Nacl)
Stainless Steel	210	135	58	8.0	206	-359
Aluminum Alloy	228	85	16	2.66	71	-887

gate, because of its high strength and larger elongation.

2. Comparison of Aluminum Alloy and Stainless Steel Material Properties

Stainless steel commonly used for hydraulic gate is the code name SUS 304L. In the following comparisons are made between aluminum alloy series 5083 and stainless steel SUS 304L, based on the eight factors indicated above.

The mechanical properties of aluminum alloy 5083 and stainless steel SUS 304L are presented in Table 3 (ASM International, 1990; Brian, 2009; Qi et al., 2010). From the table, it can be seen that the tensile yield strength of stainless steel SUS 304L is lower than the aluminum alloy 5083. The hardness of the aluminum alloy 5083 is 85 Hb, about 63% of stainless steel SUS 304L (135 Hb), thus the capability of the aluminum alloy 5083 in the resistance of instant dynamic energy and erosive abrasions is relatively weaker compared with stainless steel SUS 304L. However, drainage and flood control gates are usually installed in midstream and downstream populated areas where the face plate of gate is parallel to the flow direction. Therefore, the chance of a gate to be impacted by large object is very little. The hardness of aluminum alloy 5083 should be sufficient to resist impacts. As for ductility, although the elongation ratio of aluminum alloy 5083 is less than that of stainless steel SUS 304L, due to a recommended 1/800 deformation ratio (deformation/span) by U.S. Bureau of Reclamation (1956) and Electric Power Civil Engineering Association (2015), the reduction in elongation is not a constraint and there will be no concern of breakage in the use aluminum alloy 5083 as structural members of hydraulic gate. On material stiffness, although the elastic modulus of aluminum alloy 5083 is only one third of stainless steel SUS 304L, the deformation can be reduced by using large cross section members to meet design need. For corrosion resistance, although stainless steel SUS 304L has in general good corrosion resistance, it is weaker than the aluminum alloy 5083 in marine application (Brian, 2009; Wang et al., 2012). Aluminum alloy 5083 is a weldable alloy. Additional treatment is needed for stainless steel SUS 304L after welding. Such a procedure is not needed for Aluminum alloy 5083.

From the above comparisons, it is seen that aluminum alloy 5083 has superior properties in allowable design strength, density and weldability while slightly inferior on hardness, stiffness and elongation to stainless steel SUS 304L, but they can be overcome through proper design in hydraulic gate. Therefore, aluminum alloy 5083 as the structural members of hydraulic gate is feasible and could become a better alternative material to replace the currently used stainless steel SUS 304L.

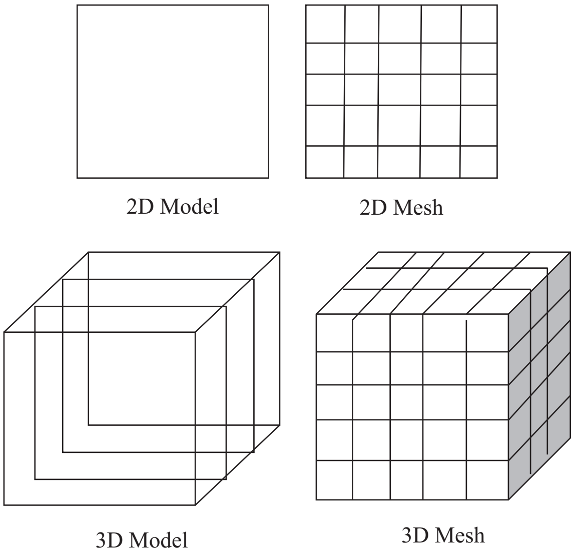


Fig. 1. Generated 3D mesh in PLAXIS 3D.

III. STRESS AND DEFORMATION ANALYSIS OF HYDRAULIC GATE

A 2D analysis is usually adopted in the design of hydraulic gate. However, such a simplified simulation can not determine torsion of the transverse beam along the vertical direction. This study will use PLAXIS 3D Foundation program to perform analysis. The program can apply load on the vertical wall in a trapezoidal distribution which is seldom seen in most structural 3D models. The program can create finite element mesh automatically and display accurately the geometry of a structure. The 3D mesh is extended from the basic 2D mesh as shown in Fig. 1.

PLAXIS 3D Foundation is composed of four basic programs including input, calculation, output and graphics. The input program establishes geometry, loading, boundary conditions, material characteristics and corresponding parameters, mesh and initial conditions etc. In the analysis of a hydraulic gate, the elements of face plate, transverse beam, vertical beam, side beam are given. Then the load applied and boundary conditions introduced. Once the input is finished, generate the finite element mesh for further calculation. Output results can be displayed by graphics.

Structural members of a hydraulic gate should sustain actions by water pressure. Assuming the allowable stress is 50% of the yield stress (Electric Power Civil Engineering Association, 2015), thus as shown in Table 3, the allowable flexural stresses of aluminum alloy 5083 and the stainless steel SUS 304L are 114

Table 4. Structural members of a 2.0 m × 2.0 m dimension hydraulic gate example.

Material	Aluminum Alloy 5083	Stainless Steel SUS 304L
γ, unit weight (kN/m^3)	26.09	78.45
Elastic modulus (GPa)	68.7	206.0
μ, Poisson's ratio	0.33	0.3
face plate thickness (mm)	10	8
transverse beam (mm)	H200 × 78 × 10/10	H146 × 50 × 10/10
vertical beam (mm)	75 × 8	75 × 8
side beam (mm)	200 × 40 × 10	146 × 40 × 10

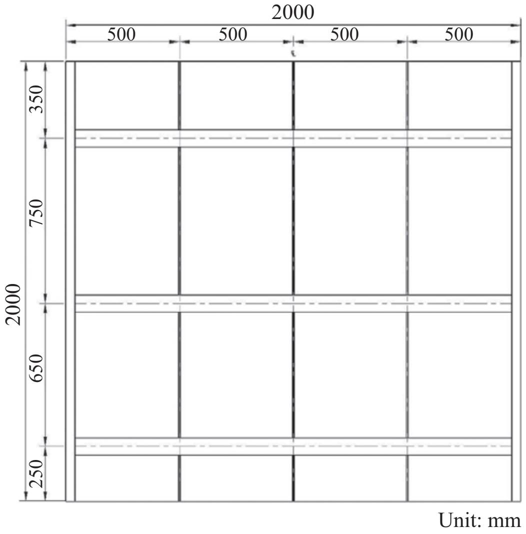


Fig. 2. Main members of hydraulic gate.

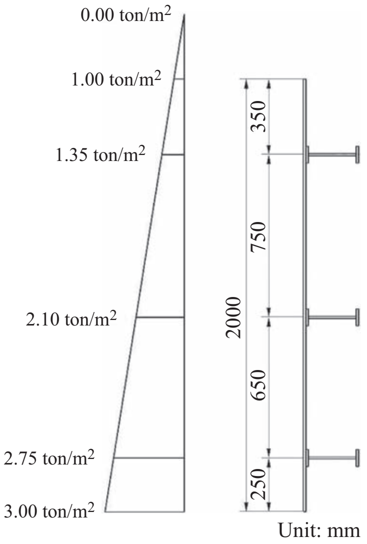


Fig. 3. Distribution of water pressure of hydraulic gate.

(228/2) MPa and 105 (210/2) MPa, respectively. In addition, to prevent seal leakage, the allowable deflection due to bending is limited to no greater than 1/800 ofthe span.

1. Detail Comparison of a Case Study

For comparison of hydraulic gates using aluminum alloy 5083 and stainless steel SUS 304L, a 2.0 m × 2.0 m (width × height) gate under 3 m water head is analyzed in more details through PLAXIS 3D FOUNDATION program. The comparisons are shown below.

1) Design with Aluminum Alloy 5083

Trial and error process are proceeded to meet the requirement of both allowable flexural stress and deformation in the structural members. It was determined that safe and economic structural members of hydraulic gate using aluminum alloy include face plate thickness of 10 mm; three transverse beams of 200 × 78 × 10 × 10 mm I-section; three vertical beams of 75 × 8 mm rectangular section and two side beams of 200 × 40 × 10 mm channel-section, as shown on Fig. 2. The three transverse beams is 0.35 m from the top and spaced at 0.75 m and 0.65 m intervals. The lower transverse beam is located at 0.25 m above the bottom. The three vertical beams are spaces at equal distance of 0.5 m. The water pressure acting on the face plate is shown in Fig. 3.

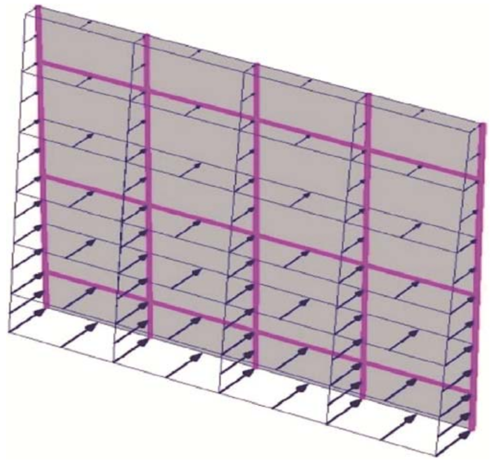
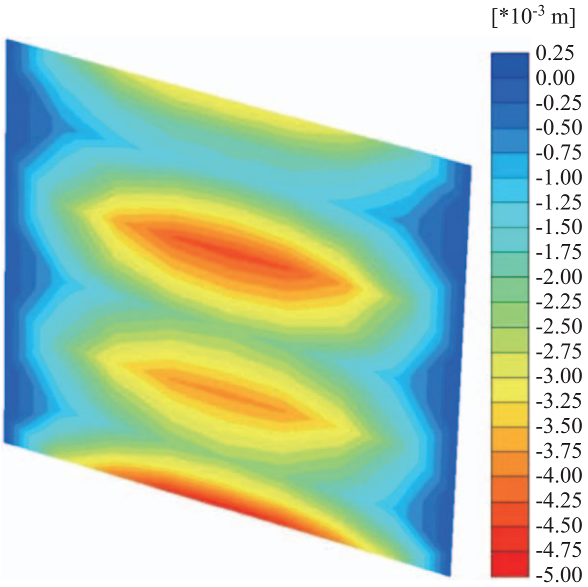


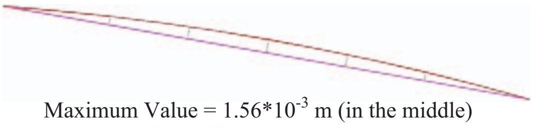
Fig. 4. Distribution of water pressure in 3D analysis.

The layout using stainless steel SUS 304L is the same as that of aluminum alloy 5083. while the dimension of structural members are modified to meet the design need by more trial and error process. After rigorous analysis, all relevant member dimensions and mechanical properties for aluminum alloy 5083 and stainless steel SUS 304L in the design example are compared in Table 4.

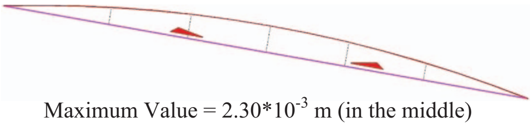


Maximum Value = 4.84*10^{-3} m (in the middle of bottom)

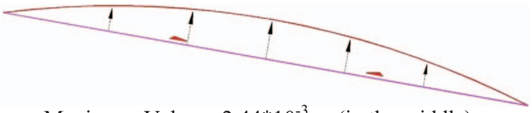
Fig. 5. Deformation diagram of face plate.



Maximum Value = 1.56*10^{-3} m (in the middle)
Upper Transverse Beam

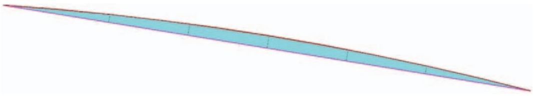


Maximum Value = 2.30*10^{-3} m (in the middle)
Medium Transverse Beam

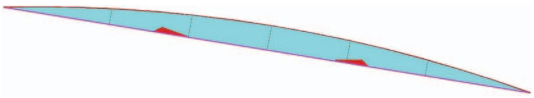


Maximum Value = 2.44*10^{-3} m (in the middle)
Lower Transverse Beam

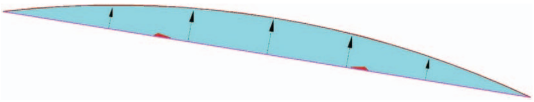
Fig. 6. Deflected curves of transverse beams.



Maximum Value = 4.94 kNm (in the middle)
Upper Transverse Beam



Maximum Value = 7.26 kNm (in the middle)
Medium Transverse Beam



Maximum Value = 7.70 kNm (in the middle)
Lower Transverse Beam

Fig. 7. Moment curves of transverse beams along major axis.

Maximum Value = 786.87*10^{-6} kNm (at both ends)
Upper Transverse Beam

Maximum Value = 701.11*10^{-6} kNm (at both ends)
Medium Transverse Beam

Maximum Value = 356.12*10^{-6} kNm (at both ends)
Lower Transverse Beam

Fig. 8. Moment curves of transverse beams along minor axis.

In the following, the structural behavior of the 2.0 m × 2.0 m hydraulic gate with aluminum alloy 5083 are described in some detail. Fig. 4 shows the distribution of water pressure in 3D analysis. Deformation diagram of face plate is shown in Fig. 5. The maximum deformation occurs at the middle of bottom with a value of 4.84 mm. The deformation in the middle between transverse beams with large interval of 0.75 m is 4.4 mm. Fig. 6 shows the deflected curves of the upper, medium and lower transverse beams, respectively. The maximum deformation all occurs at mid-section of the transverse beams with 1.56 mm, 2.30 mm and 2.44 mm from the upper to lower transverse beams. The corresponding maximum moments shown in Fig. 7 along the major axis of transverse beams are 4.94 kN-m, 7.26 kN-m and 7.70 kN-m. The moment along minor axis of transverse beams are shown in Fig. 8. It is noted that very small amount of moment is induced at the ends with values of 7.87 × 10^{-4} kN-m, 7.01 × 10^{-4} kN-m and 3.56 × 10^{-4} kN-m from the upper to lower transverse beams. This assures that the design of transverse beams is appropriate, and water pressure acting on the transverse beams evenly. The moment diagram of face plate along vertical direction (rotational axis is horizontal) and along horizontal direction (rotational axis is vertical) are shown in Figs. 9 and 10 and maximum values are 0.723 × 10^{-3} kN-m/m and 0.311 × 10^{-3} kN-m/m, respectively. Comparing with the defor-

Table 5. Summary of hydraulic gate example with aluminum alloy 5083 (transverse beams).

Transverse Beam	Max. Deformation (mm)	Span L (mm)	Deflection Ratio	Max. Moments (kN-m)	Section Modulus Z (m^3)	Flexural Stress (MPa)
Upper	1.56	2000	1/1282	4.94	1.8952×10^{-4}	26.07
Medium	2.30	2000	1/870	7.26	1.8952×10^{-4}	38.31
Lower	2.44	2000	1/820	7.70	1.8952×10^{-4}	40.63

Note: 1. Required deflection ratio 1/800; 2. Allowable flexural stress 114 MPa

Table 6. Summary of hydraulic gate example with aluminum alloy 5083 (face plate).

Max. Horizontal Moment (kN-m/m)	Max. Vertical Moment (kN-m/m)	Section Modulus Z (m^3/m)	Horizontal Flexural Stress (MPa)	Vertical Flexural Stress (MPa)
0.724×10^{-3}	0.311×10^{-3}	1.6667×10^{-5}	43.44	18.66

Note: Allowable flexural stress 114 MPa

Table 7. Summary of hydraulic gate example with stainless steel SUS 304L (transverse beams).

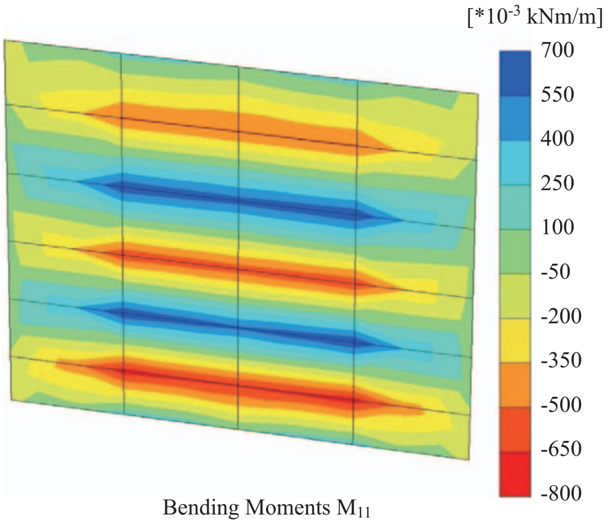
Transverse Beam	Max. Deformation (mm)	Span L (mm)	Deflection Ratio	Max. Moments (kN-m)	Section Modulus Z (m^3)	Flexural Stress (MPa)
Upper	1.72	2000	1/1163	5.21	8.6292×10^{-4}	60.38
Medium	2.40	2000	1/833	7.23	8.6292×10^{-4}	83.79
Lower	2.46	2000	1/813	7.41	8.6292×10^{-4}	85.87

Note: 1. Required deflection ratio 1/800; 2. Allowable flexural stress 105 MPa

Table 8. Summary of hydraulic gate example with stainless steel SUS 304L (face plate).

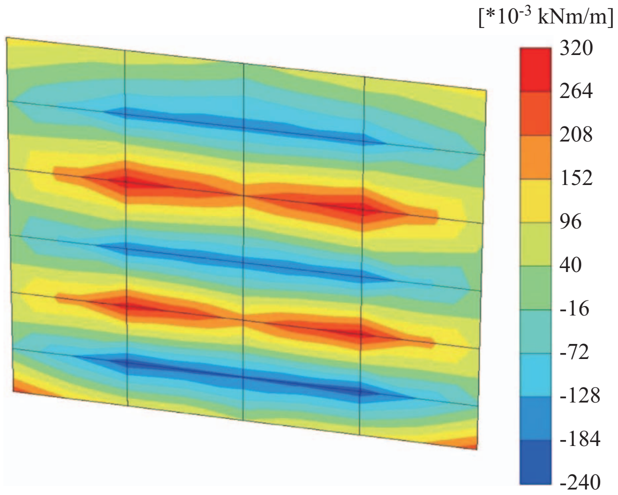
Max. Horizontal Moment (kN-m/m)	Max. Vertical Moment (kN-m/m)	Section Modulus Z (m^3/m)	Horizontal Flexural Stress (MPa)	Vertical Flexural Stress (MPa)
0.666×10^{-3}	0.266×10^{-3}	1.0667×10^{-5}	62.44	24.94

Note: Allowableflexuralstress 105 MPa



Bending Moments M_{11}
Maximum Value = 723.48*10^{-3} kNm/m
(at the quarter span of lower transverse beam)

Fig. 9. Moment diagram of face plate along vertical direction.



Bending Moments M_{11}
Maximum Value = 310.58*10^{-3} kNm/m
(at the quarter span between upper and medium transverse beams)

Fig. 10. Moment diagram of face plate along horizontal direction.

Table 9. Quantities required for a 2.0 m × 2.0 m hydraulic gate.

Member	Aluminum Alloy 5083 (m^3, kN)	Stainless Steel SUS 304L (m^3, kN)
face plate Thickness (m) × area (m^2)	0.01 × 4 = 0.04	0.008 × 4 = 0.032
transverse beam section area (m^2) × length (m)	0.00336 × 1.98 × 3 (pieces) = 0.01996	0.00226 × 1.98 × 3 (pieces) = 0.01343
vertical beam section area (m^2) × length (m)	0.0006 × 1.97 × 3 (pieces) = 0.00355	0.0006 × 1.97 × 3 (pieces) = 0.00355
Side beam section area (m^2) × length (m)	0.0026 × 2 × 2 (pieces) = 0.0104	0.00206 × 2 × 2 (pieces) = 0.00824
Sum of volume, m^3	0.07391	0.05722
Sum of weight, kN	1.9243	4.4890

mation diagram in Fig. 5, the higher moment occurs at the portion with large relative deformation. The analyzed results are summarized in Tables 5 and 6.

2) Design with Stainless Steel SUS 304L

Analyses are made using stainless steel SUS 304L as structural members with dimensions in Table 4. The results are summarized in Tables 7 and 8.

3) Design Comparison

In the above analyses, proper and economic members of aluminum alloy 5083 and stainless steel SUS 304L are selected. They can both meet the required deformation ratio and allowable flexural stress. The controlled condition is the deformation ratio. The larger cross section is used for aluminum alloy 5083 with lower stiffness to meet the required deformation ratio. The induced flexural stress is relatively lower, especially for aluminum alloy 5083. The quantities of structural members for these two types of material are summarized in Table 9, The total volume of aluminum alloy 5083 is 1.29 (0.07391/0.05722) times that of stainless steel SUS 304L yet the total weight is only 43% (1.9243/4.4890). Furthermore, since aluminum alloy is lighter, it is easier to fabricate and maintain for hydraulic gates. In addition, when used as flap gate, it will require less water level difference and be more responsive to flood operation.

2. Additional Examples

For a comprehensive comparison of hydraulic gates manufactured by aluminum alloy 5083 and stainless steel SUS 304L, more design examples are selected for further study. They includes 2.0 m × 2.0 m, 2.5 m × 2.0 m, 2.5 m × 2.5 m, 3.0 m × 2.5 m and 3.0 m × 3.0 m (width × height) of five commonly used hydraulic gates, each under water heads of 3 m, 4 m, 5 m, 6 m, 7 m, 8 m, 9 m and 10 m. The total design examples are forty. All the design examples are analyzed using PLAXIS 3D Foundation program to meet the required deformation ratio and allowable flexural stress. Trial and error process are proceeded in order to decide the proper and economic components.

3. Overall Technical Evaluation

From the analyzed results, it can be concluded that the controlled condition of all design examples using aluminum alloy 5083 is the deformation ratio while allowable flexural stress and deformation ratio control the design under high and low water head, respectively using stainless steel SUS 304L. All the design examples using aluminum alloy 5083 controlled by deformation ratio is due to its relatively lower stiffness. As for the stainless steel SUS 304L, strength will control the design underhigh water head is attributed that the flexural stress takes the lead over the deformation limit. The allowable strength is very similar for these two materials. Fig. 11 depicts material volume ratio of aluminum alloy 5083 to stainless steel SUS 304L for all forty design examples. It is shown that the volume ratio is in the range of 113-138%. Thus the weight ratio is about becomes 37.6-45.9% (0.3325 × (1.13-1.38)).

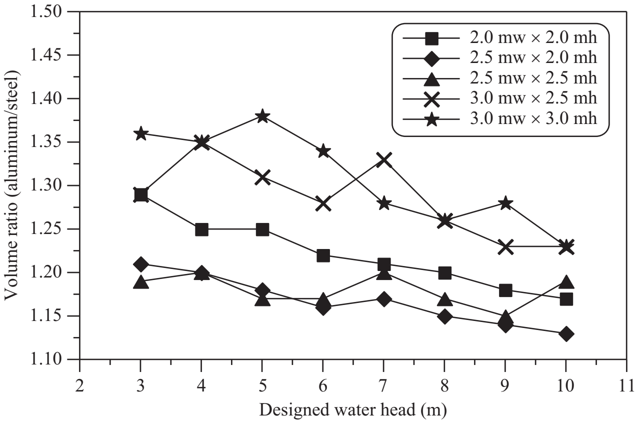


Fig. 11. Volume ratio of aluminum alloy 5083 and stainless steel SUS 304L.

IV. ECONOMIC EVALUATION BETWEEN ALUMINUM ALLOY AND STAINLESS STEEL

Assuming an identical life span of 30 years for both materials, the economy of hydraulic gate shall be evaluated on manufacturing cost and maintenance/operation expenses in the following.

1. Manufacturing Cost

For simplicity, it is assumed that cost of manufacturing a hydraulic gate is proportional to cost of material. According to the relevant publication of price index and futures market (Global international futures market, 2016; Wholesale procurement 1688, 2016),the prices of stainless steel SUS 304L and aluminum alloy 5083 are 3,595 USD/Ton and 4,745 USD/Ton respectively. Thus the price ratio of stainless steel to aluminum alloy is 1:1.32

(3595:4745). This implies that the material cost of aluminum alloy 5083 is in the range of 49.5-60.4% (1.32 × (0.376-0.459)) with respect to that of the stainless steel.

2. Maintenance and Operation Expenses

The weight of hydraulic gate is the main factor to determine power required to operate the gate. From the forty design examples studied above, the maximum weight ratio acquired for hydraulic gate with stainless steel to aluminum is 1:0.459 and the power required to operate will be 1:0.82 (3:2.459) under the lifting velocity and mechanical efficiency. Therefore, the maintanence/operation cost will be reduced at least by 18% (1-0.82 = 0.18) with aluminum alloy.

V. CONCLUSIONS

In this paper, the feasibility of replacing stainless steel SUS 304L with aluminum alloy 5083 for hydraulic gate is evaluated. Forty commonly used hydraulic gates were analyzed through the finite element program PLAXIS 3D Foundation. In addition, costs for manufacturing and maintanence/operation were evaluated. The main conclusions are summarized below:

(1) In comparison with stainless steel SUS 304L, aluminum alloy 5083 is superior in allowable design strength, density and weldability and inferior in hardness, stiffness and elongation. However, these inferior properties do not prevent the use of aluminum alloy 5083 to design hydraulic gates to meet code requirements.
(2) To meet design code, the required weight for most types of hydraulic gates with aluminum alloy 5083 is in the range of 37.6-45.9 % that of stainless steel SUS 304L.
(3) The manufacturing cost of hydraulic gates with aluminum alloy 5083 is about 49.5-60.4 % that of stainless steel SUS 304L and the maintanence/operation cost can be reduced at least by 18%.
(4) Aluminum alloy is lighter than stainless steel and will be effective in resolving problems currently encountered by stainless steel gate on operation, maintenance and emergency condition due to its weight.
(5) Aluminum alloy 5083 can also improve sensitivity of flap gate made by stainless steel. Thus will enhance regional drainage efficiently and reduce chance of flooding.
(6) The aluminum alloy 5083 is suitable as the structural members of hydraulic and may become the better alternative material to substitute the commonly used stainless steel SUS 304L.

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