

Gates of the Primary Closure System
for a surge barrier

Torsion or Sector?

(Evaluation of Structural types)

T e r a M a t s u

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1 . Introduction

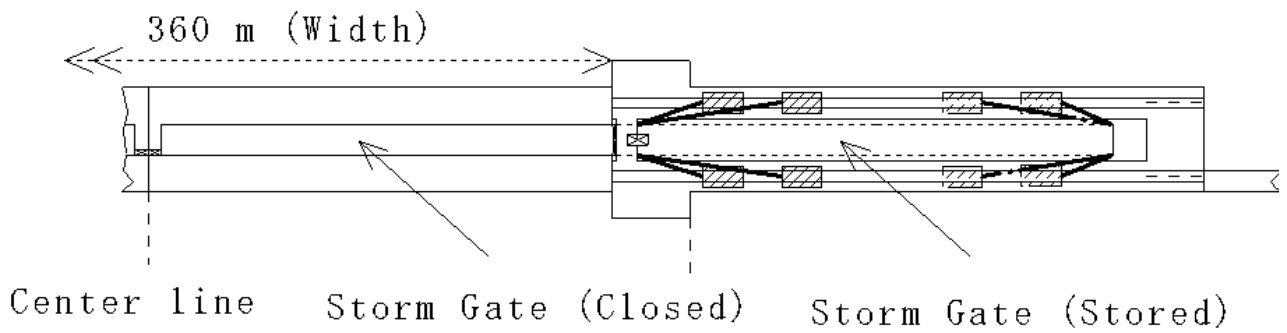
This report intends to evaluate relative merits of a torsion type rolling gate and a sector type gate when they are used as the primary closure system for a surge barrier. The evaluation includes cost, reliability, operability, maintainability, durability and constructability, and method of construction on the torsion type rolling gate is further explained.

The sector type gate to be compared is Maesland type whose image is given on Fig.-1 and corresponding torsion type rolling gate is shown on Fig.-2. Both gate have same principal particulars such as height, width and hydraulic loads. Main features of both gates are shown on Table-1

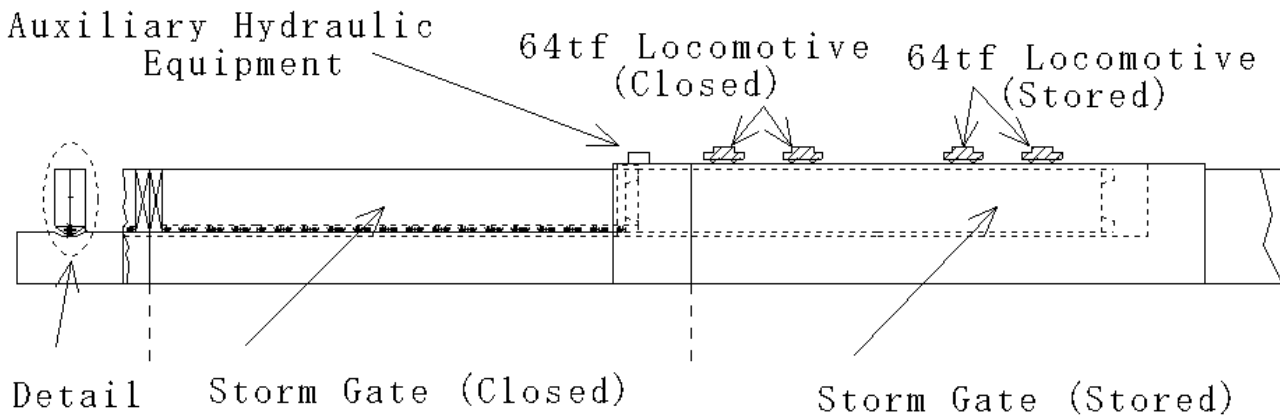
| Table-1 Main feature of gates to be compared | | |
|-----------------------------------------------------|-----------------------------------------------------------|-------------------------------------|
| Gate type | Horizontal sector gate | Torsion type rolling gate |
| Gate width | 360 m | |
| Gate height | 24.6 m | |
| Tide-level difference | 7.7 m | |
| Gate image | Fig-1 | Fig-2 |
| Gate composition | A pair of two leaves | A pair of two leaves or single leaf |
| Gate structure type | Axial (arms) & bending (leaves) | Torsion |
| Driving mechanism | Racks, Pinions, Wire-drums, locomotives, locomobiles etc. | |
| Gate movement | Rotation around a vertical axis | In horizontal direction |
| Hydraulic load support | Spherical pedestals at arm end | A rail under gate bottom |
| Foundation structure | Gate bottom | Concrete structures |
| | Pedestal | Concrete honeycomb structures |
| Gate storage | Gate leaf | Docks |
| | Arm | Storage plazas |



Fig.-1 Image of Horizontal Sector Gate



PLAN



ELEVATION

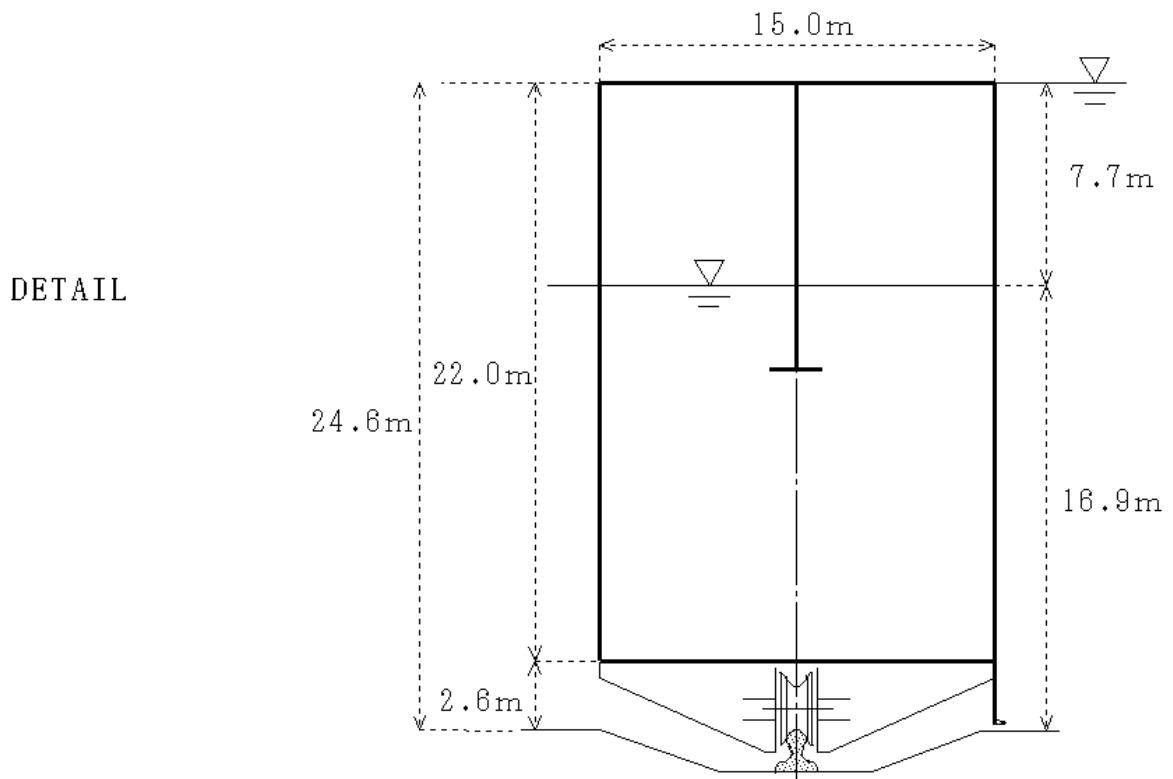


Fig.-2 Torsion Type Rolling Gate

2 . Relative merits

2 . 1 Summery of evaluation

Table-2 shows a summery of evaluation on relative merits of the two gate types with respect to cost, reliability, operability, maintainability, durability and constructability. The results are shown by marks which are defined on Legend symbol of the table. Details of each result will be explained in the next section 2 . 2 .

| Table-2 Summery of relative merits between the two gate types | | | | | | |
|----------------------------------------------------------------------|------|------------------------------|-------------|-----------------|------------|------------------|
| Gate type | Cost | Reliability | Operability | Maintainability | Durability | Constructability |
| Horizontal sector gate | × | ○ | ○ | ○ | ○ | ○ |
| Torsion type rolling gate | ◎ | ○ | ○ | ○ | ○ | ○ |
| Legend symbol | | | | | | |
| | × | Not acceptable | | | | |
| | △ | Limited but still acceptable | | | | |
| | ○ | Acceptable | | | | |
| | ◎ | Better | | | | |
| | ◎ | Excellent | | | | |

2 . 2 Detail of evaluation

2 . 2 . 1 Cost

| Table-3 Estimated approximate weight | | |
|---------------------------------------------|---------------------------|------------------------|
| Gate type | Torsion type rolling gate | Horizontal sector gate |
| Approximate weight (tf) | 20,000 | 46,000 |

Table-3 shows estimated approximate weight of the two gate types. The weights include a gate leaf, embedded parts and operating machinery. They correspond to Sample Gate (Example 1) of Appendix "Comparison of steel weight" which explains their estimation procedure. The longer the gate width becomes, the more the difference in weight expands. As construction cost of a gate almost directly corresponds to its steel weight, it can be concluded that initial cost of the torsion type rolling gate is less than half of the horizontal sector gate. Result of evaluation on the two gate types is given as Table-4 accordingly where mark definition of Table-2 is applicable.

| Table-4 Relative merits of Initial Cost | | |
|-----------------------------------------|----------------|------|
| Gate type | Evaluation | Mark |
| Horizontal sector gate | Not acceptable | ✕ |
| Torsion type rolling gate | Excellent | ◎ |

2 . 2 . 2 Reliability

2 . 2 . 2 . 1 Evaluation method

Although there may be a several ways of understanding reliability, let us evaluate it, here, by relative level of loss possibility in gate functions. The gate function includes items as following.

(1) Gate bearing force function

Against a ship collision

Against a reverse tide level difference between both sides of the gate

Against an uneven settlement of foundation structures

Others

(2) Gate opening and closing function

With a normal tide level difference between both sides of the gate

With a reverse tide level difference between both sides of the gate

With an uneven settlement of foundation structures

With sediments of the sea bottom gate set zone

Others

(3) Water tightness

Durability of gate sealing system

Others

- (4) Foundation structure function
 - Foundation structure
 - Ground curing
 - Others
- (5) Others

2 . 2 . 2 . 2 Additional information

Following two informations will fill in the gap of Table-1 and are helpful in evaluating reliability.

(1) Foundation structure

Fig.-3 gives an image of concrete honeycomb structure which will work as a foundation for pedestals of the horizontal sector gate.

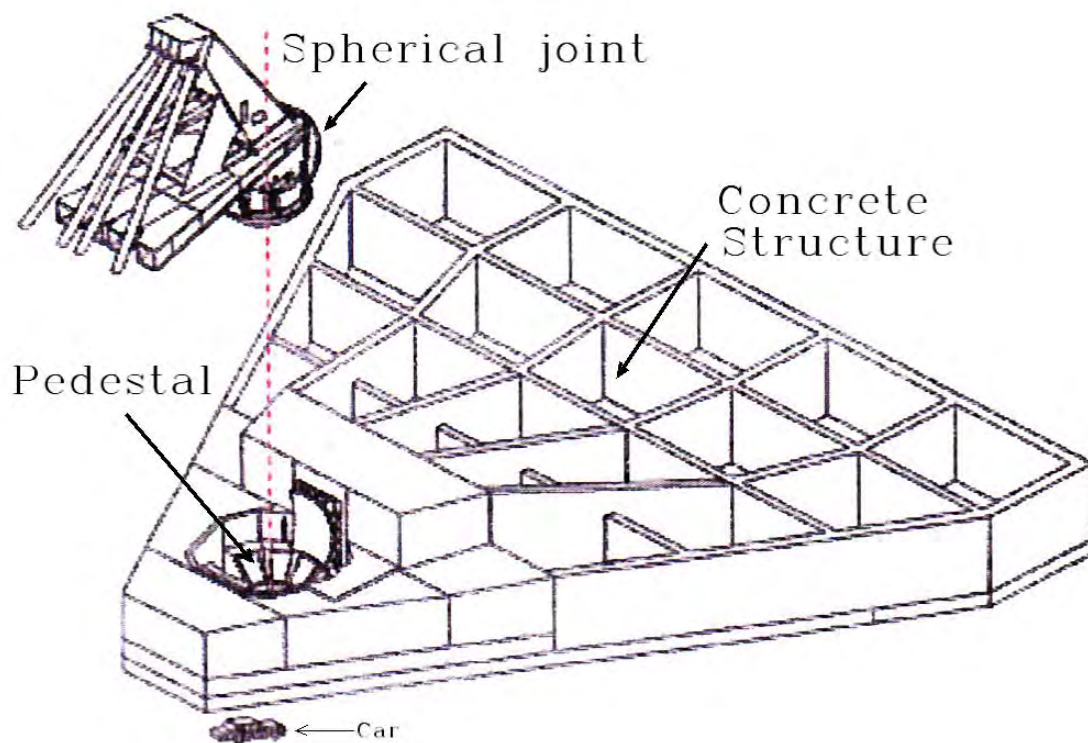


Fig.-3 Image of concrete honeycomb structure

Fig.-4 gives an image of submerged tunnel type concrete structure which will work as a foundation under gate leaf bottoms. The figure shows for the torsion type rolling gate as an example.

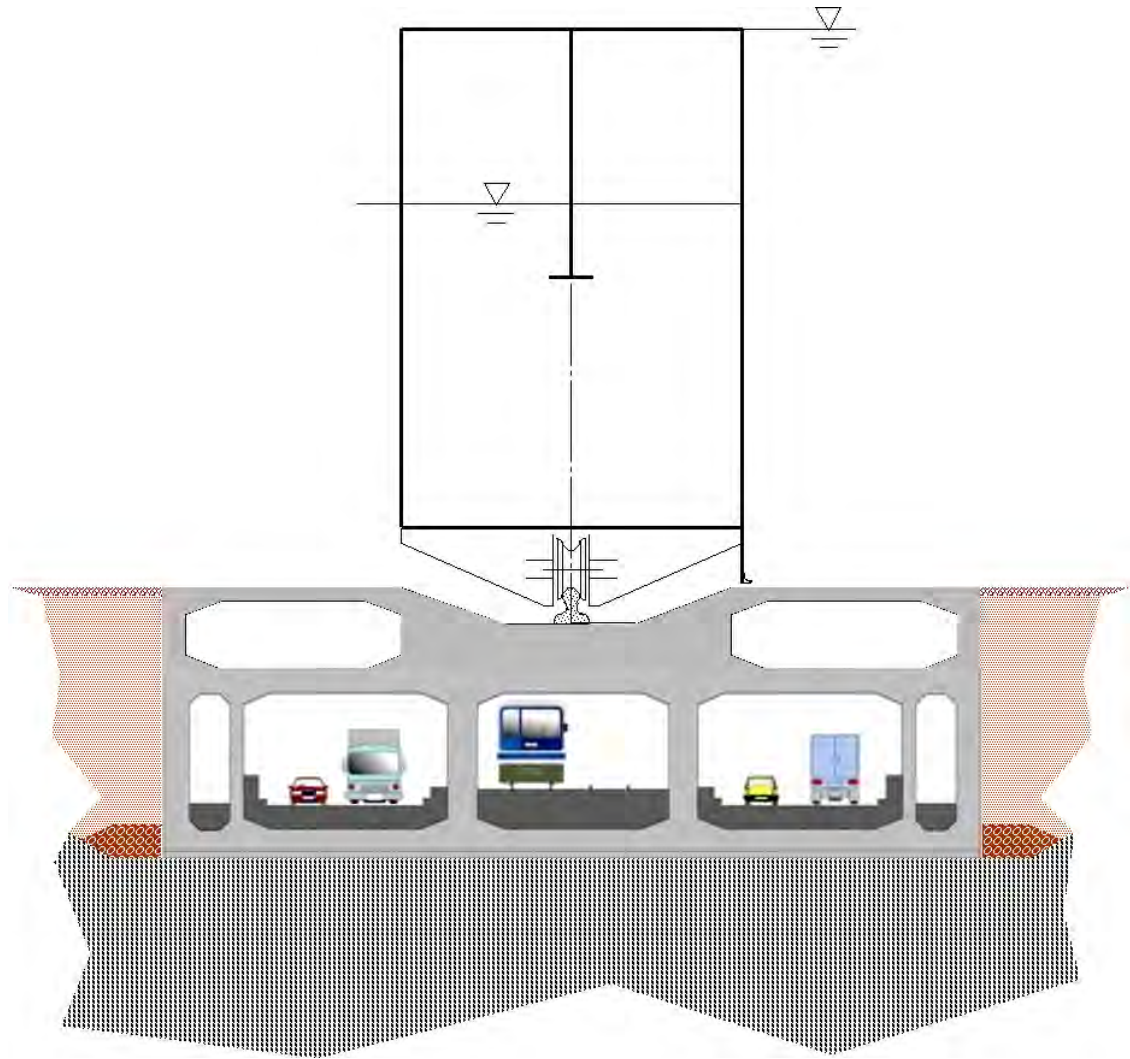


Fig.-4 Image of submerged tunnel type concrete foundation structure.

(2) Support end of the torsion type rolling gate

Table-1 explains that hydraulic load on the torsion type rolling gate is supported by a rail under the gate bottom. Thus the hydraulic load and the rail reaction force are in condition of balance, but their point of action is different and torsion moment will still remain in the gate body. The torsion moment will be transported to a supported gate end by gate body's sectional torsion rigidity. Fig.-5 presents an image of the gate end support. A totally closed gate body will be supported by couples of wedges which become functional with aid of the wedging apparatus. A gate during its movement can be supported by, for instance, couples of rollers mounted on the support brackets, couples of rollers mounted on side walls of the dock, couple of reaction forces on gate rails and locomotive rails etc.

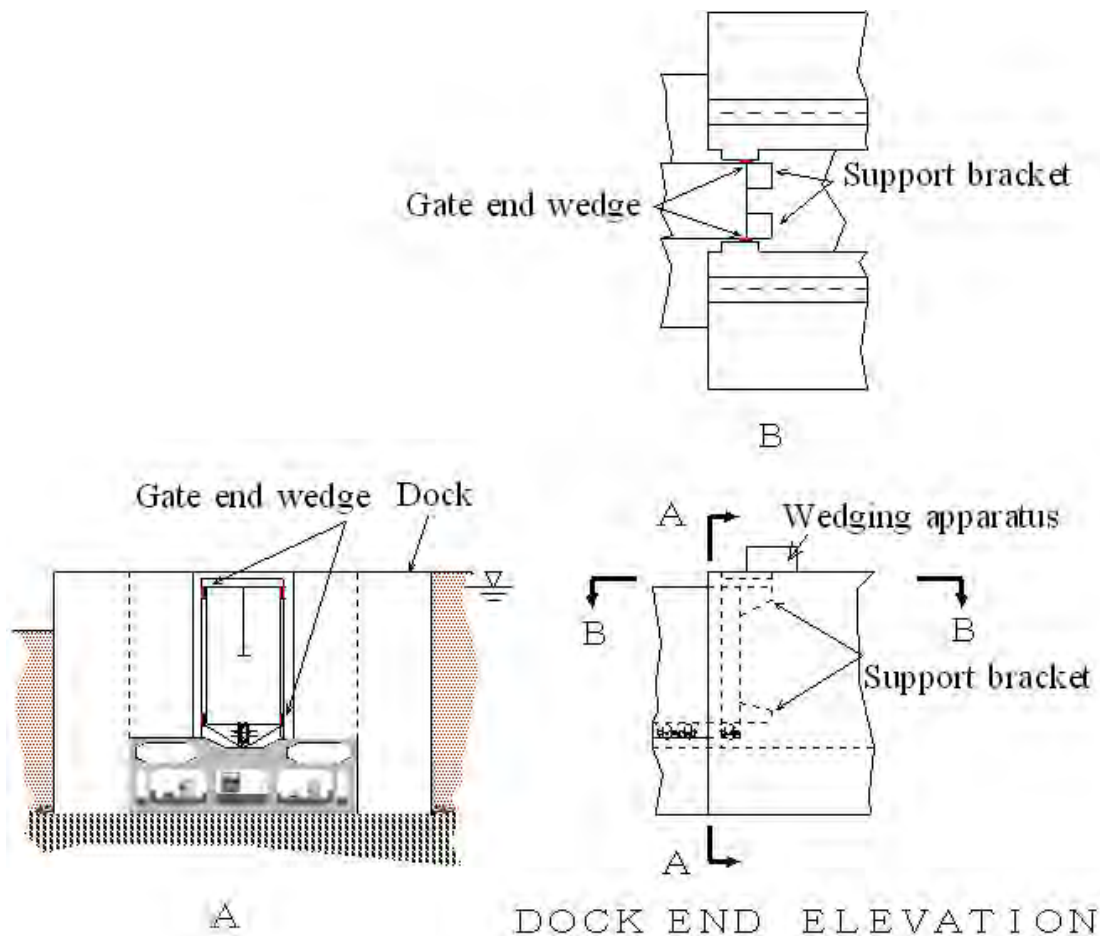


Fig.-5 Image of gate end support

2 . 2 . 2 . 3 Results of Evaluation

| Table-5 Merit and Demerit Analyses (Reliability) | | | |
|--------------------------------------------------|--------------------------------------------------------------------------------|---------------------------|-------------------------------------------------------------------------|
| Horizontal sector gate | | Torsion type rolling gate | |
| Merit/Demerit | Description | Merit/Demerit | Description |
| Demerit (1)① | There may occur a minor damage of gate due to a ship collision. | | |
| Merit (2)③ | Uneven settlements of foundation structures may not require any countermeasure | Demerit (2)③ | Uneven settlements of foundation structures may require countermeasures |
| Merit (2)④ | Natural underflow can be used to eliminate sea bottom sediments. | Demerit (2)④ | Equipment to eliminate sea bottom sediments is required |

Table-5 shows results of merit and demerit analyses of the reliability on all the gate functions. Three demerits and two merits have been extracted from three of the gate functions on remainders of which

the two gate types have no demerits. Accordingly marks of merit or demerit on all the gate functions are given as shown on Table-6 and marks of relative merits on the reliability between two gate types is given as shown on Table-7 where mark definition of Table-2 is applicable.

| Table-6 Merit or Demerit (Detail of Reliability) | | | |
|---------------------------------------------------------|----------------------------------------------|------------------|--------------|
| Gate function | | Merit or Demerit | |
| | | Sector type | Torsion type |
| (1) Bearing force | ① Ship collision | △ | △ |
| | ② Reverse tide level difference | ○ | ○ |
| | ③ Uneven settlement of foundation Structures | ○ | ○ |
| | ④ Others | ○ | ○ |
| (2) Opening and closing function | ① Normal tide level difference | ○ | ○ |
| | ② Reverse tide level difference | ○ | ○ |
| | ③ Uneven settlement of foundation structures | ○ | △ |
| | ④ Sediments of the sea bottom | ○ | △ |
| | ⑤ Others | ○ | ○ |
| (3) Water tightness | ① Durability of gate sealing system | ○ | ○ |
| | ② Others | ○ | ○ |
| (4) Foundation structure | ① Foundation structure | ○ | ○ |
| | ② Ground curing | ○ | ○ |
| | ③ Others | ○ | ○ |
| (5) Others | | ○ | ○ |

| Table-7 Relative Merits of Reliability | | |
|-----------------------------------------------|------------|------|
| Gate type | Evaluation | Mark |
| Horizontal sector gate | Acceptable | ○ |
| Torsion type rolling gate | Acceptable | ○ |

2 . 2 . 3 Operability

2 . 2 . 3 . 1 Evaluation method

Operability of the two gate types is evaluated according to following items.

- (1) Amount of operation time for gate opening or closure.
- (2) Magnitude of gate operation load
- (3) Possibility of channel navigation
 - During gate construction
 - During maintenance work
 - During gate renewal work
- (4) Others

2 . 2 . 3 . 2 Additional information

No additional information is required.

2 . 2 . 3 . 3 Results of Evaluation

| Horizontal sector gate | | Torsion type rolling gate | |
|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Merit/Demerit | Description | Merit/Demerit | Description |
| Demerit (1) | Operation time is longer because closing operation consists of travel step, sinking step and debris flushing step. | Merit (1) | Operation time is short because operation consists of only travel step. Debris flushing step is included in the travel step. |
| Merit (2) | Operation load is small because trunnion friction force which is majority of the load is supposed to be much smaller than wheel friction force of the torsion type rolling gate. | Demerit (2) | Operation load is bigger because wheel friction force which is majority of the load is supposed to be much bigger than trunnion friction force of the horizontal sector gate. |
| Merit (3)① | Single navigation channel is always available during gate construction. | | |
| Merit (3)② | There will be almost no restriction of channel navigation during maintenance work. | | |
| Merit (3)③ | Only short time navigation channel block may happen during gate renewal work. | | |

Table-8 shows results of merit and demerit analyses of the operability on all the evaluation items. Two demerits and five merits have been extracted from five of the items on a remainder of which the two gate types have no demerits. Accordingly marks of merit or demerit on all the items are given as shown on Table-9 and marks of relative merits on the reliability between two gate types is given as shown on Table-10 where mark definition of Table-2 is applicable.

| Item of Operability | | Merit or Demerit | |
|-----------------------------------------------------------|----------------------------|------------------|--------------|
| | | Sector type | Torsion type |
| (1) Amount of operation time for gate opening or closure. | | △ | ○ |
| (2) Magnitude of gate operation load | | ○ | △ |
| (3) Possibility of channel navigation | ① During gate construction | ○ | ○ |
| | ② During maintenance work | ○ | ○ |
| | ③ During gate renewal work | ○ | ○ |
| (4) Others | | ○ | ○ |

| Gate type | Evaluation | Mark |
|---------------------------|------------|------|
| Horizontal sector gate | Acceptable | ○ |
| Torsion type rolling gate | Acceptable | ○ |

2 . 2 . 4 Maintainability

2 . 2 . 4 . 1 Evaluation method

Maintainability of the two gate types is evaluated according to following items.

- (1) Conditions of maintenance circumstance
- (2) Frequency of maintenance works
- (3) Difficulty of maintenance works
- (4) Others

2 . 2 . 4 . 2 Additional information

No additional information is required.

2 . 2 . 4 . 3 Results of Evaluation

| Horizontal sector gate | | Torsion type rolling gate | |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-------------|
| Merit/Demerit | Description | Merit/Demerit | Description |
| Merit (1) | It is possible that outage of gate function is selected according to meteorological forecasting. | | |
| Demerit (2) | In a general way, required maintenance frequencies of a year are one or less of underwater work and six or less of ordinary work.. | | |
| Merit (3) | There is no need of handling heavy parts during underwater maintenance work. | | |

| Item of Maintainability | Merit or Demerit | |
|--------------------------------------------|------------------|--------------|
| | Sector type | Torsion type |
| (1) Conditions of maintenance circumstance | ○ | ○ |
| (2) Frequency of maintenance works | △ | △ |
| (3) Difficulty of maintenance works | ○ | ○ |
| (4) Others | ○ | ○ |

Table-11 shows results of merit and demerit analyses of the maintainability on all the evaluation items. One demerit and two merits have been extracted from three of the items on a remainder of which the two gate types have no demerits. Accordingly marks of merit or demerit on all the items are given as shown on Table-12 and marks of relative merits on the maintainability between two gate types is given as shown on Table-13 where mark definition of Table-2 is applicable.

| Table-13 Relative Merits of Maintainability | | |
|----------------------------------------------------|------------|------|
| Gate type | Evaluation | Mark |
| Horizontal sector gate | Acceptable | ○ |
| Torsion type rolling gate | Acceptable | ○ |

2 . 2 . 5 Durability

2 . 2 . 5 . 1 Evaluation method

Durability of the two gate types is evaluated according to following items.

- (1) Actual work record of large scale gates
- (2) Durability of gate structures
- (3) Durability of gate driving systems
- (4) Durability of gate sealing systems
- (5) Others

2 . 2 . 5 . 2 Additional information

No additional information is required.

2 . 2 . 5 . 3 Results of Evaluation

Table-14, shows results of merit and demerit analyses of the durability on all the evaluation items. Fig.-6 and Fig.-7 are supporting data of Table-14. Four merits have been extracted from four of the items on a remainder of which the two gate types have no demerits. Accordingly marks of merit or demerit on all the items are given as shown on Table-15 and marks of relative merits on the durability between two gate types is given as shown on Table-16 where mark definition of Table-2 is applicable.

Table-14 Merit and Demerit Analyses (Durability)

| Horizontal sector gate | | | Torsion type rolling gate | | | | |
|------------------------|--------------------------------------------------------------------------------------------------------------------------------------|------------|---------------------------|----------------|-----------------|-------------|------------|
| Merit/Demerit | Description | | Merit/Demerit | Description | | | |
| Merit (1) | Actual work record of large scale gates | | | | | | |
| | Gate type | Purpose | Year of completion | Gate width (m) | Gate height (m) | Country | Photograph |
| | Sector type | Storm gate | 1997 | 360 | 22 | Netherlands | |
| | | Storm gate | 2011 | 200 | 22 | Russia | |
| | Torsion type flap | Dock gate | 1973 | 100 | 14.5 | Japan | Fig-6 |
| Dock gate | | 1976 | 80 | 12 | Singapore | Fig-7 | |
| Merit (2) | Durability of gate structures of the two gate types has been supported by above shown Actual work records. | | | | | | |
| Merit (3) | Durability of gate driving systems has been supported by work records of various projects including above shown Actual work records. | | | | | | |
| Merit (4) | It is expected that wear-out rate of gate sealing parts due to gate operation is not so big. | | | | | | |



Fig.-6 Torsion type large scale flap gate of Nagasaki, Japan since 1973.



Fig.-7 Torsion type large scale flap gate of Singapore since 1976

Table-15 Merit or Demerit (Detail of Durability)

| Item of Durability | Merit or Demerit | |
|---------------------------------------------|------------------|--------------|
| | Sector type | Torsion type |
| (1) Actual work record of large scale gates | ○ | ○ |
| (2) Durability of gate structures | ○ | ○ |
| (3) Durability of gate driving systems | ○ | ○ |
| (4) Durability of gate sealing systems | ○ | ○ |
| (5) Others | ○ | ○ |

Table-16 Relative Merits of Durability

| Gate type | Evaluation | Mark |
|---------------------------|------------|------|
| Horizontal sector gate | Acceptable | ○ |
| Torsion type rolling gate | Acceptable | ○ |

2 . 2 . 6 Constructability

2 . 2 . 6 . 1 Evaluation method

Constructability of the two gate types is evaluated according to following items.

- (1) Constructability of gates.
- (2) Constructability of gate driving mechanisms.
- (3) Constructability of docks.
- (4) Others

2 . 2 . 6 . 2 Additional information

Information of Chapter 3 . will fill in the gap of Table-1 and is helpful in evaluating constructability.

2 . 2 . 6 . 3 Results of Evaluation

Table-17 shows results of merit and demerit analyses of the constructability on all the evaluation items. One merit and one demerit have been extracted from one of the items on remainders of which the two gate types have no demerits. Accordingly marks of merit or demerit on all the items are given as shown on Table-18 and marks of relative merits on the constructability between two gate types is given as shown on Table-19 where mark definition of Table-2 is applicable.

| Table-17 Merit and Demerit Analyses (Constructability) | | | |
|---------------------------------------------------------------|-----------------------------------------------------------------|---------------------------|------------------------------------------------------------------|
| Horizontal sector gate | | Torsion type rolling gate | |
| Merit/Demerit | Description | Merit/Demerit | Description |
| Demerit (1) | Yard fabrication element method is not applicable to gate arms. | Merit (1) | Yard fabrication element method (see Chapter 3.) is applicable. |

| Table-18 Merit or Demerit (Detail of Constructability) | | |
|---------------------------------------------------------------|------------------|--------------|
| Item of Constructability | Merit or Demerit | |
| | Sector type | Torsion type |
| (1) Constructability of gates. | △ | ○ |
| (2) Constructability of gate driving mechanisms. | ○ | ○ |
| (3) Constructability of docks. | ○ | ○ |
| (4) Others | ○ | ○ |

| Table-19 Relative Merits of Constructability | | |
|-----------------------------------------------------|------------|------|
| Gate type | Evaluation | Mark |
| Horizontal sector gate | Acceptable | ○ |
| Torsion type rolling gate | Acceptable | ○ |

3 . Construction method of a torsion type rolling gate

Although a number of options for construction method of a torsion

type rolling gate may exist, an example shown here is a yard fabrication element method where each main construction element is fabricated in a yard (such as a dry dock etc.) as much broad range of construction parts as convenient so that a volume of field work may become minimum. Table-20 shows main work items of this construction method. Table-21 and Fig.-8 define the yard fabrication elements. Concrete placement of the elements will be carried out on a timely base at a fabrication yard, a field yard or a work site. The main work items of Table-20 are so fit together that a time loss and a cost increase of the construction may be acceptable. Main technologies which seem to be helpful in completing the construction will be in the fields of offshore engineering, submerged tunneling method, shipbuilding, oceanfront hydraulic steel structure (including gates) etc.

Table-20 Main Work Items

| Main work item | | Explanation |
|----------------|-----------------------|-----------------------------------------------------------------------------------------------------------|
| 1 | Yard fabrication | Yard fabrication elements defined on Table-21 and Fig.-8 are fabricated in yards such as dry-docks. |
| 2 | Site dredging | Sea bottom trenches for the embedded elements are dredged at work site. |
| 3 | Embedded elements | The elements are towed to the site and submerged in the trenches, that is followed by back-filling work. |
| 4 | Dock elements | The elements are towed to the site and submerged on the embedded elements of docks. |
| 5 | Gate elements | The elements are towed to the site and submerged on the embedded elements of gates. |
| 6 | Gate driving elements | The elements are shipped to the site on a heavy lift vessel or other applicable vehicle and set in place. |

Table-21 Yard Fabrication Elements

| Name of elements | Numbers required | Contents |
|-----------------------|------------------|-----------------------------------|
| Embedded elements | 4 | Two for a gate and two for docks. |
| Dock elements | 2 | For left and right banks. |
| Gate elements | 2 | Left and right gate leaves. |
| Gate driving elements | 2 | For left and right gate leaves |

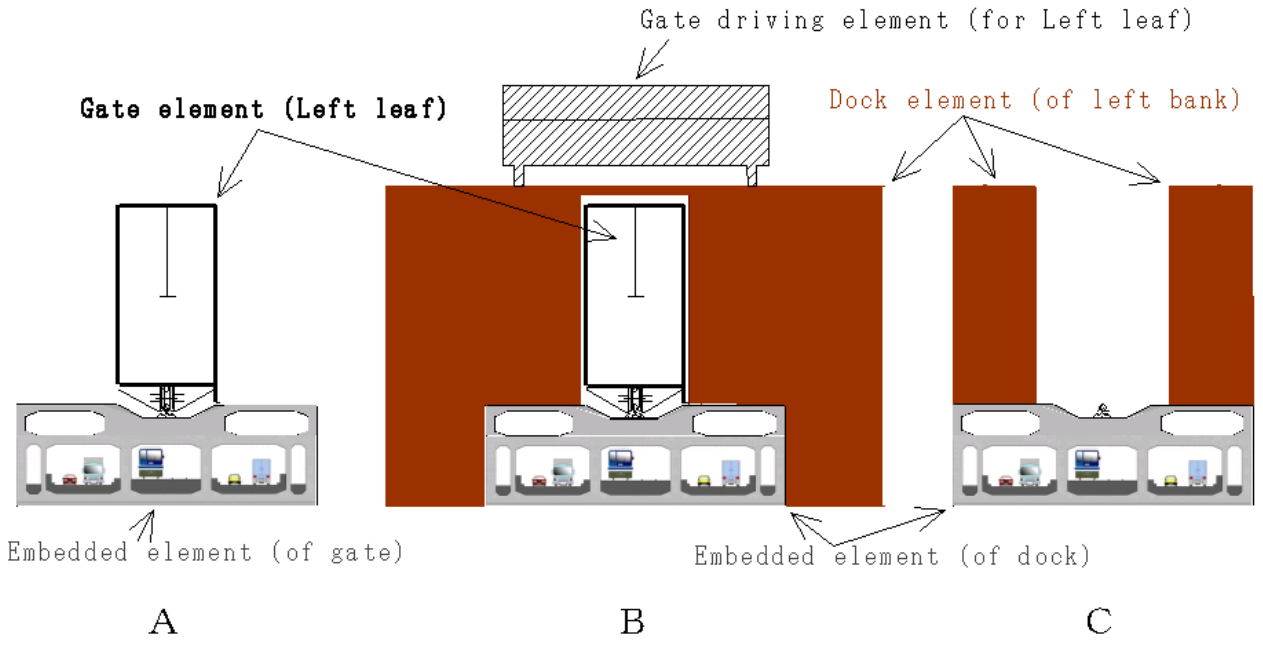
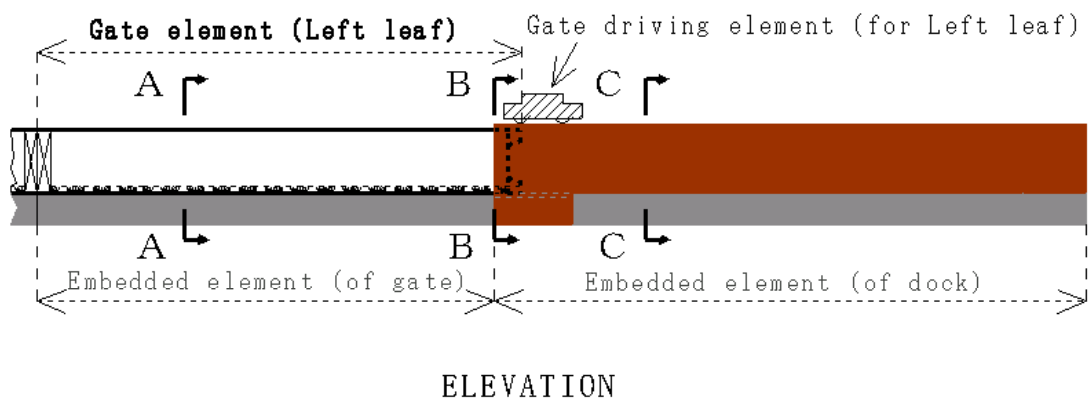
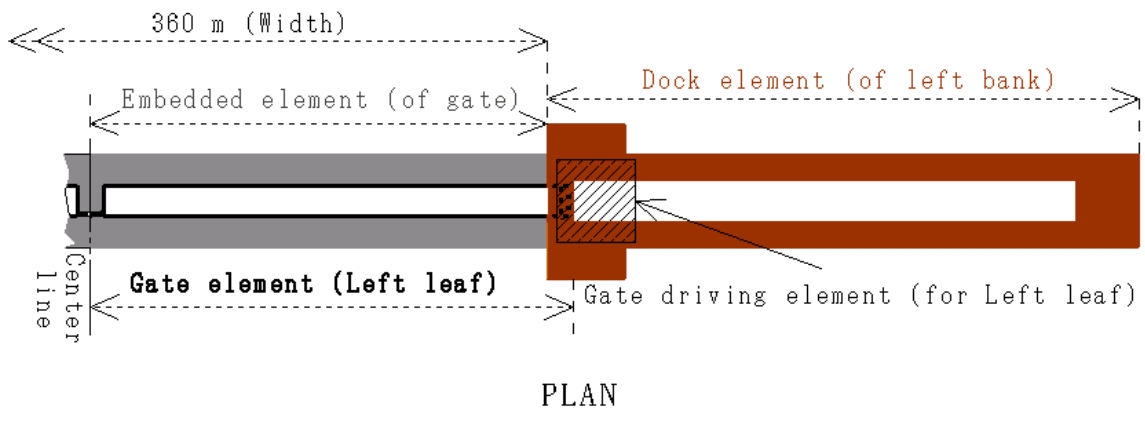


Fig.-8 Yard fabrication elements

4 . Conclusion

Evaluation of relative merits between a torsion type rolling gate and a sector type gate when they are used as the primary closure system for a surge barrier was made with respect to cost, reliability, operability, maintainability, durability and constructability and it was able to conclude that a torsion type rolling gate is overwhelmingly excellent from cost point of view. Notwithstanding the conclusion, there still remain secondary subjects to be solved before the torsion type rolling gate works out.

Appendix: Comparison of steel weight

Appendix

Torsion Type Gate

Comparison of Steel Weight

TeraMatsu

| | |
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| 3 . Torsion type vs. Sector type (Case 2) | 3 |
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| 3 . 1 . 1 Weight difference | 3 |
| 3 . 1 . 2 Estimated approximate weight | 4 |
| (1) Torsion type | 4 |
| (2) Sector type | 4 |
| 3 . 1 . 3 Target weight | 4 |
| (1) Torsion type | 4 |
| (2) Sector type | 5 |
| 3 . 2 Verrazano Narrows Gate (Example 2) | 5 |
| 3 . 3 NY-NJ Outer Harbor Gate (Example 3) | 6 |
| 4 . Conclusion | 6 |
| Fig.-1 Storm Gate of Torsion Type Structure (Rolling Gate) | 7 |
| Fig.-2 Storm Gate of Torsion Type Structure (Flap Gate) | 8 |

1 . Purpose

Steel weight of a torsion type super large storm gate is overwhelmingly less than other structural types. This engineering data intends to show the weight difference by following two comparisons.

Case 1 Torsion type vs. Other types

This shows the difference between torsion type and other structural type gates and tries to give its global image. Weight data given are results of detail or concept designs carried out in past.

Case 2 Torsion type vs. Sector type

This shows the difference between torsion type and sector type gates. Sector gates are working at storm barriers for Maeslant, St. Petersburg and New Orleans to close their water passages whose width is quite huge. This type has been also proposed in concept designs of a storm barrier to protect the New York City. The weight difference of following three examples which have something to do with the New York project is given.

【Example 1】 Sample Gate having same width as Maeslant project gate

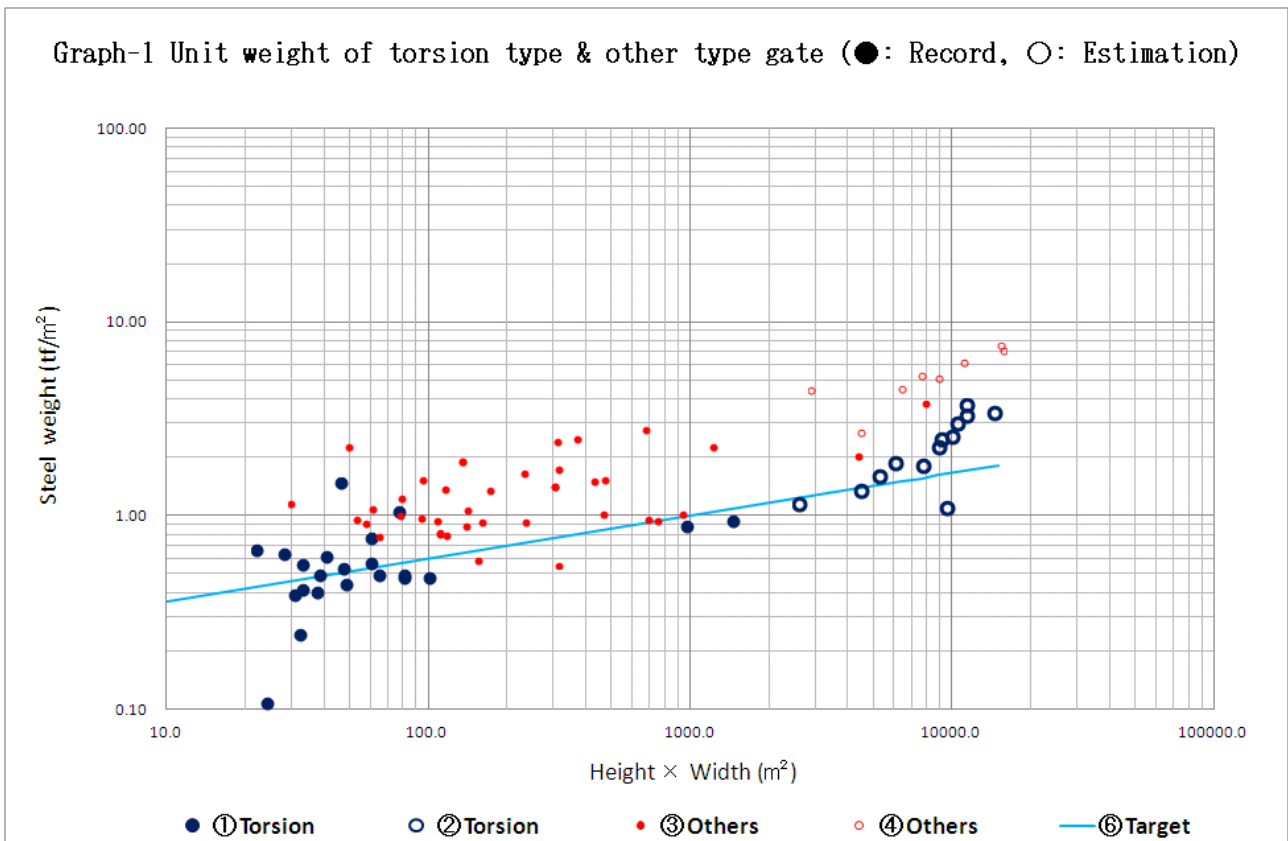
【Example 2】 Gate of an Verrazano Narrows storm surge barrier (Arcadis)

【Example 3】 Gate of an NY–NJ Outer Harbor Gateway (Halcrow)

2 .Torsion type vs. Other types (Case 1)

Graph-1 shows weight difference between torsion type and other structural type. Vertical and horizontal axes on the graph are in logarithmic scale of unit weight (tf/m^2) and gate leaf area (m^2) respectively. Solid marks (● & ○) and hollow marks (● & ○) correspond to a result of detail design and concept design respectively. Blue marks and red marks correspond to torsion type and other structural type respectively.

The graph also shows a target line of the torsion type's design optimization. The target line coincides with the power approximation curve of detail design records (●). Comparison of the target line to the red colored marks (● & ○) on the graph gives a global image of the torsion type's superiority.



3 .Torsion type vs. Sector type (Case 2)

A sector type gate is working at storm barriers for Maeslant, St. Petersburg and New Orleans to close their water passages whose width is quite huge. This type has been also proposed in concept designs of a storm barrier to protect the New York City. The weight difference in this case is shown by three examples all of which has something to do with the New York project.

3 . 1 Sample Gate (Example 1)

Sample Gate has same width as Maeslant project gate but its height and hydraulic condition were so selected that they may fit in actual site conditions such as tidal, meteorological, terrain, traffic etc. condition much better than the Maeslant gate does. Maeslant gate width was selected because more reliable sector gate weight estimation is possible based upon its weight record.

3 . 1 . 1 Weight difference

Table–1 shows weight comparison on a sample gate whose design particulars are given at the table bottom. The comparison is made between the torsion type and sector type where Estimated approximate weight and Target weight are given in the forms of unit weight (tf/m²) and total weight (tf). The weights include a gate leaf, embedded parts and operating machinery. Final steel weight will become definit after their optimum design completes against all design conditions and the estimated approximate weight and the target weight image its upper and lower limit respectively.

| Gate type | Estimated approximate weight | | Target weight | |
|-----------|------------------------------|---------------|---------------------------|------------|
| | Unit (tf/m ²) | Total (tf) | Unit (tf/m ²) | Total (tf) |
| Torsion | 2.21 | 20,000 | 1.61 | 14,000 |
| Sector | 5.16 | 46,000 | 2.74 | 24,000 |

Note: (1) Gate width & height are 360 & 24.6 m respectively.
(2) Tide level difference is 7.7 m.

3 . 1 . 2 Estimated approximate weight

(1) Torsion type

The weight on the table corresponds to the torsion type rolling gate shown on Fig.-1. Estimation step is as follows.

Selection of the closed shell thickness according to scantlings and hydraulic condition shown in the figure.

Computation of the closed shell weight.

Weight computation of each part.

1) Major member = Closed shell weight x 1.1

2) Gate leaf = Major member x 1.65

3) Embedded part = Gate leaf x 0.2 Estimated approximate weight

4) Operating machinery = Gate leaf x 0.1

It is thinkable that the result may be on the large side since big allowance is included in each estimation step in order to compensate incompleteness of the estimation procedure.

Fig.-2 shows a flap gate of same size as Fig.-1 and it is only for reference. All existing torsion type gate is flap type. The rolling type is much more in weight but its applicability is much more than the flap type.

(2) Sector type

The estimation was made based on the unit weight of the Maeslant barrier gate whose width is same size as Fig.-1. The estimation step is as follows.

Obtaining Maeslant gate weight from a public information source.

Computation of unit weight (tf/m^2).

Adjustment of the unit weight according to differences in working water head and gate width between Maeslant gate and the model gate. It is thinkable that the result may be close to the final weight since the weight estimation started at a actual record which has similar gate width. Furthermore, the Maeslant gate is one of a few existing super large storm gates and its reliability is very high.

3 . 1 . 3 Target weight

(1) Torsion type

Unit weight is obtained by approximate formula (1) which was established through statistical analysis of weight records.

$$\text{Unit weight (tf/m}^2\text{)} = 0.2173 \times (\text{Gate leaf area})^{0.2204} \dots (1)$$

It is thinkable that the final weight of torsion type rolling gate may not be less than the result since all the weight records used are of flap type.

(2) Sector type

Unit weight is obtained by approximate formula (2) which was established through statistical analysis of weight records.

$$\text{Unit weight (tf/m}^2\text{)} = 0.375 \times (\text{Gate width} \times \text{Gate width})^{0.169} \dots (2)$$

The weight records used contain various kinds of structural type except torsion type and a high pressure gate is also excluded. They are very general such as Radial, Sector, Flap, Roller (Shell type, Girder type, Double leaf), Visor, Rising sector etc. and their degree of dispersion is pretty high. The formula gives average level of the group, on the other hand, the record of Maeslant locates in an upper level portion of the group and it is thinkable that the final steel weight may not cross over the target weight and stay above it. For a reference, statistical treatment was made on an assumption that all records were bending type although a few of them are other than it.

3.2 Verrazano Narrows Gate (Example 2)

| Gate type | Estimated approximate weight | | Target weight | |
|-------------------------------------------------------------|------------------------------|---------------|---------------------------|------------|
| | Unit (tf/m ²) | Total (tf) | Unit (tf/m ²) | Total (tf) |
| Torsion | 1.87 | 14,000 | 1.56 | 12,000 |
| Sector | 5.35 | 41,000 | 2.46 | 19,000 |
| Note: (1) Gate width & height are 860 & 96 ft respectively. | | | | |
| (2) Tide level difference is 30 ft. | | | | |

Table-2 shows weight difference estimated on the gate proposed by Arcadis in their concept an Verrazano Narrows storm surge barrier. Its design particulars are given at the table bottom. All estimation steps are exactly similar to those explained at section 3.1 except that the unit weight used is of the St. Petersburg

flood protection barrier gate whose width is close to the conceptual design gate in size much more than the Maeslant gate.

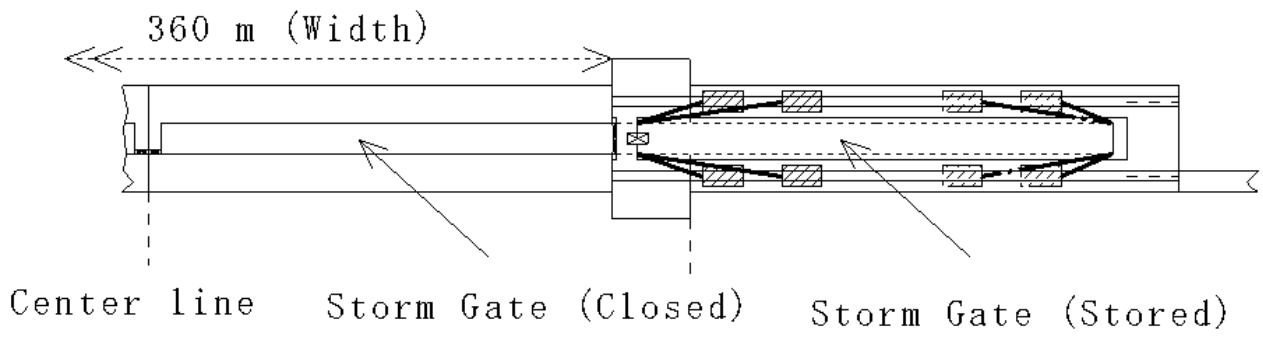
3.3 NY–NJ Outer Harbor Gate (Example 3)

| Table–3 Comparison on NY–NJ Outer Harbor Gate | | | | |
|-------------------------------------------------------------|------------------------------|---------------|---------------------------|------------|
| Gate type | Estimated approximate weight | | Target weight | |
| | Unit (tf/m ²) | Total (tf) | Unit (tf/m ²) | Total (tf) |
| Torsion | 1.36 | 6,000 | 1.38 | 6,200 |
| Sector | 2.61 | 12,000 | 2.18 | 9,700 |
| Note: (1) Gate width & height are 600 & 80 ft respectively. | | | | |
| (2) Tide level difference is 30 ft. | | | | |

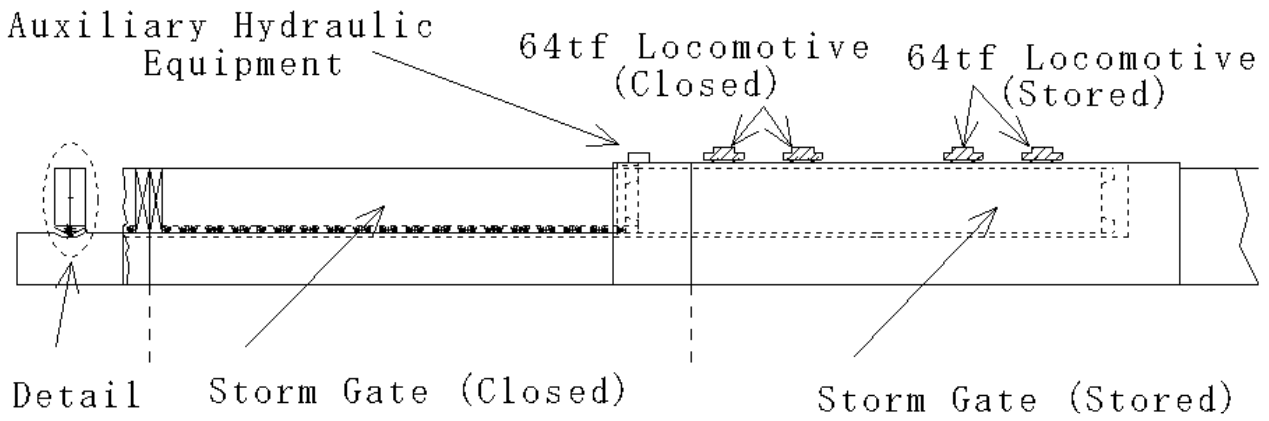
Table–3 shows weight difference estimated on the gate proposed by Halcrow in their concept an NY–NJ Outer Harbor Gateway. Its design particulars are given at the table bottom. All estimation steps are exactly similar to those explained at section 3.1 except that the unit weight used is of the St. Petersburg flood protection barrier gate whose width is close to the conceptual design gate in size much more than the Maeslant gate.

4. Conclusion

It has been verified by the engineering data that steel weight of a torsion type super large storm gate is overwhelmingly less than other structural types including sector gates. The longer the gate width becomes, the more the difference in weight expands. As construction cost of a gate almost directly corresponds to its steel weight, the statement, "The initial cost of torsion type super large storm gate is equal to or less than 1/3 ~ 1/2 of the ordinary technology" comes into existence.



PLAN



ELEVATION

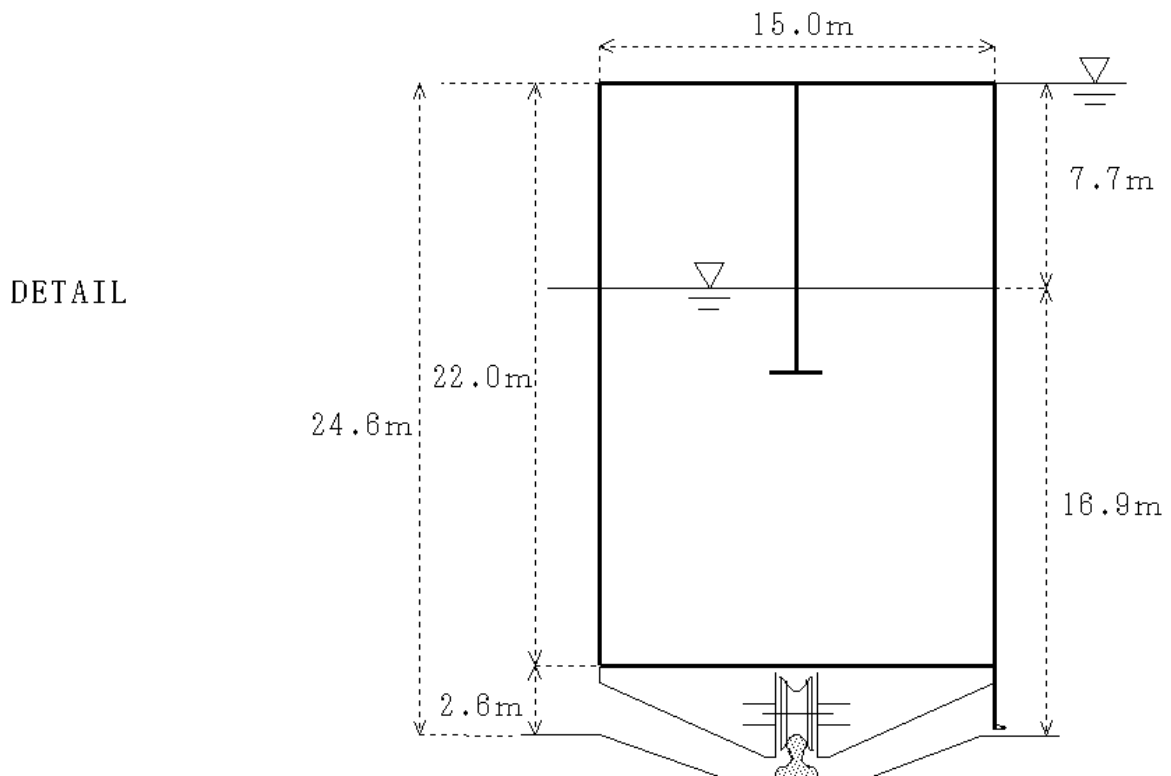
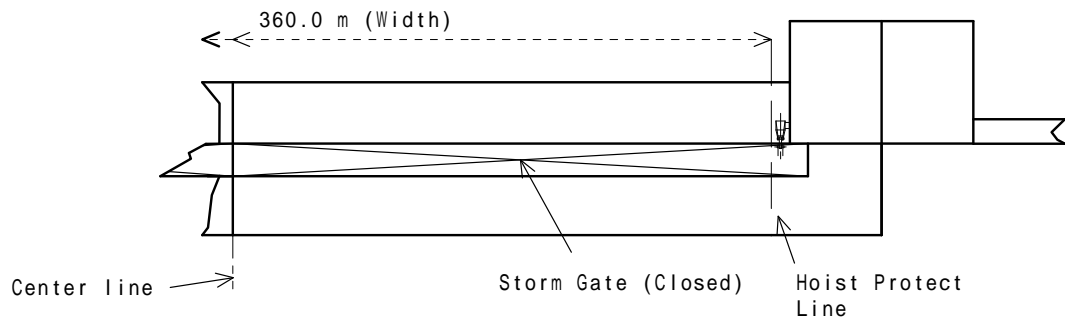
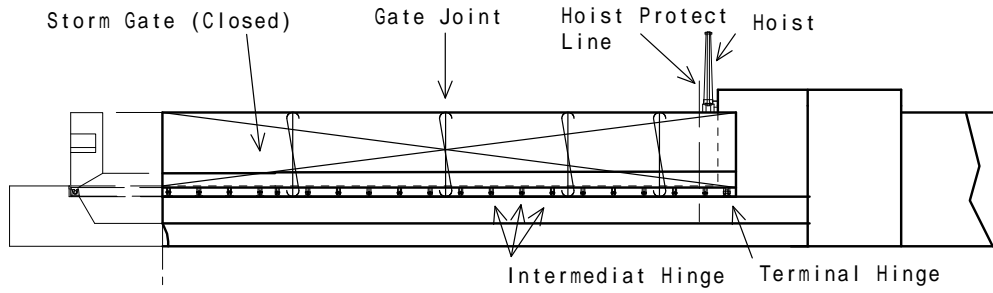


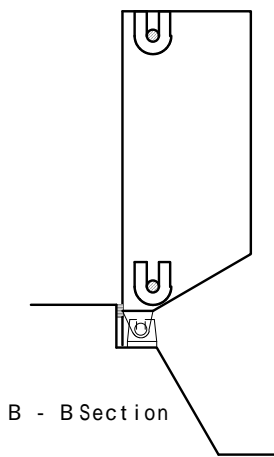
Fig.-1 Storm Gate of Torsion Type Structure (Rolling Gate)



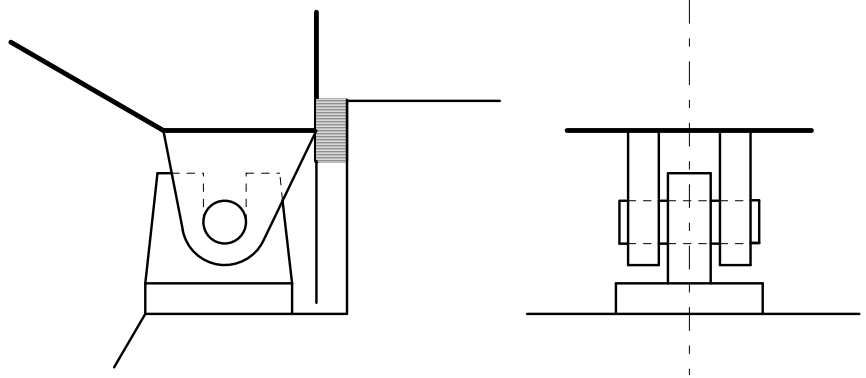
PLAN



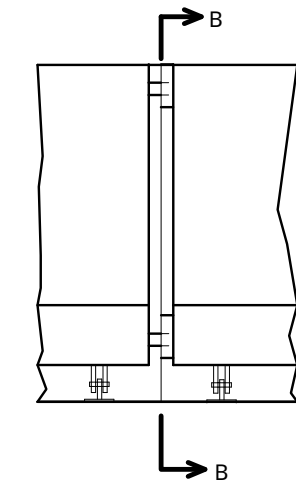
ELEVATION



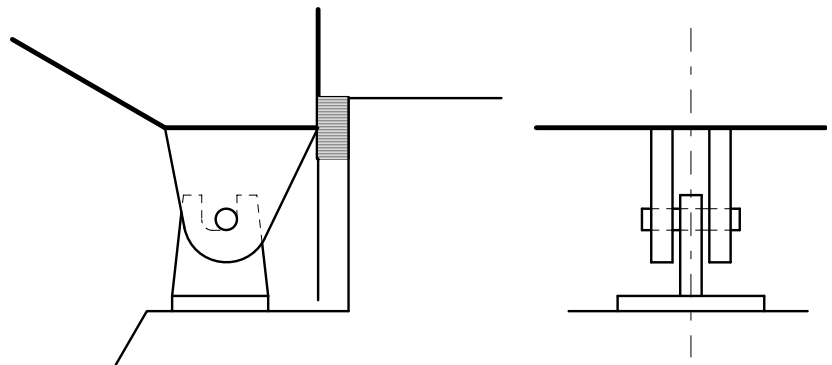
B - B Section



TERMINAL HINGE DETAIL



JOINT DWTAIL



INTERMEDIATE HINGE DETAIL

Fig.-2 Storm Gate of Torsion Type Structure (Flap Gate)