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VLFS 연결을 위한 연육교 설계 연구

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A Study on the Design and Analysis of a Bridge Connecting VLFS

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ABSTRACT: *For the development of the practical design and analysis scheme of a bridge connecting to the typical VLFS, relevant design criteria and theory and techniques are studied and numerical analysis for the verification of the structural safety of the bridge are carried out.*

For the design of a typical steel bridge, characteristics of proper type bridge are reviewed and the requirements for the bridge of this kind are studied as well as the environmental loads. By using the design spiral technique, several alternatives are investigated and an efficient type of a bridge is initially designed. Structural idealization is performed to make overall structural analysis first, and the structural behaviors of the proposed bridge in the given loading condition are evaluated.

Through this study a bridge is finally proposed and it is found that this one works well for the connecting function of the bridge.

1. Introduction

For the floating airport structure that is installed in the shallow waters, the links such as bridge is necessary. When the dolphin mooring system that uses fixed pile or fixed adjacent structure is used for the mooring of the large floating structures, the bridge can be designed to connect the floating body and the dolphin mooring system and also the bridge can be designed that connects the land and the mooring system. The former one should be movable one and the latter will be fixed one. In this paper fundamental design and analysis procedure of such bridge is studied and a final bridge is proposed.

2. Basic Design Process

The basic design process of the movable and fixed bridges for VLFS studied here and specific dimensions are follows.

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1) Determination of the distance between the floating structure and the shore, and it is set to be 300 m.
2) Water depth around the structures is to be determined and it is 35 m.
3) Checking of the sea route and the possible passing ships maximum height and it is assumed that there is no sea route across the bridge.
4) Restrictions to the bridge height and the usage of the surrounding sea area and it is assumed that there is no restrictions to the bridge height, however it should be adjusted to the height of the dolphin mooring system and VLFS itself.
5) Number of people and vehicles that use the bridge can be calculated according to the needed transportation requirements.
6) Type of the transportation between the land and the floating structure and type of transportation can be truck and vehicles.

For the development of the bridge that is suitable for the VLFS, fundamental characteristics of bridge structures are studied and above constraints are reviewed in association with these characteristics in the following chapters.

3. Determination of Principal Dimensions of Bridge

3.1 General approach

To plan and design a bridge it is necessary first to imagine it. Generally the designer approaches the problem successfully in two stages. The first and most important state consists of the creation of the bridge scheme. This scheme is checked and put on the drawing. This checking is carried out regarding application to the local conditions, considering span, construction height, profile, cost and general view and harmonic matching with locality. Design calculation is done on the basis of structural mechanics. The analysis starts with the deck, stringers, and transverse beams, which determine deck weight. Final analysis includes main carrying bridge members, determination of the forces, total weight, and so on. At the preliminary design the purpose is only to explain the characteristics of the alternatives. After that the chosen scheme should undergo detailed design. The aim of the detailed design is the structure of the bridge.

3.2. Basic dimensions for the bridges for VLFS

As discussed earlier, the VLFS is going to be installed about 300m apart from the shore. The bridge between the shore and the VLFS, i.e., the dolphin mooring at first, should have 300 m length. And the transportations need the trucks and buses, thus the breadth should have at least 2 times of the width of the general truck. Water depth of the VLFS site is 35m, thus the bridge should have piers that go into 35m depth. In view point of environmental circumstances, the significant wave height at the site was given as $H_{1/3}$ = 5.61m, and thus the possible maximum wave height is to be 1.8 $H_{1/3}$, i.e., 10.1m. Once the air gap is taken 1.5 m, the distance between water plane and the bridge bottom is to be 6.6m. From the parent bridge concepts and using the design spiral techniques, and based on the analysis of the merits and demerits of various bridge type, 3 span bridge is proposed at first. The lengths of each span are taken to be 90m, 120m, 90m, and totaling 300m length. Table 1 shows the basic dimensions of the fixed bridge proposed.

Table 1 Basic dimension of a bridge

L	300m	HHW	6.6 m
B	8.8m	H	2.2 m
Spans	3 spans b1=90m, b2=120m, b3=90m	Shape	A continuous three-span system, main bridge system consists of plate girders

3.3. Conceptual Design of a Bridge for VLFS

Based on the study of a general bridge design process and the requirements for the bridge for VLFS, several alternatives can be conceptually developed. The design of the bridge usually starts with the development of a series of possible alternatives. By comparing alternatives, considering technical and environments parameters, we can find out the most expedient solution at the given local conditions.

Since the distance between the floating structure and the shore is 300m and the water depth around the structure is set to be 35m, corresponding rough profiles of the bridges are obtained as shown in Fig. 1 and Fig. 3.

3.3.1 First Alternative

To illustrate a practical application of the basic principles discussed above for the design of a steel bridge between the shore and VLFS (dolphin mooring system), First alternative is proposed. This one is obtained through the Design Spiral approach. Total length of the bridge is 300m, and total 3 spans are employed. The configuration is shown in Fig. 1. The first alternative utilizes a continuous 3-span system deck system in which main bridge system consists of plate girders. The bridge spans are 90m + 120m + 90m. The main plate girders have a constant height, which gives the simplicity and economy. In Fig. 2, a movable bridge profile is shown. Total length of 19m movable bridge can connect the points between dolphin mooring part and the VLFS. For the detail design of the movable bridge, the motion of the VLFS due to the tides and also VLFS motion itself should be analyzed. Schematic drawing of both fixed bridge and movable bridge is shown in Fig. 1.

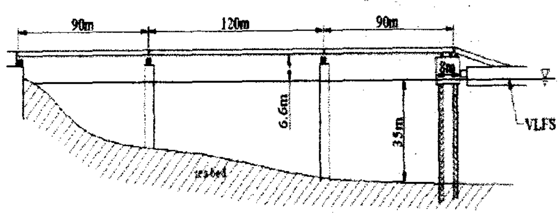

Fig. 1 Bridge Profile Case1

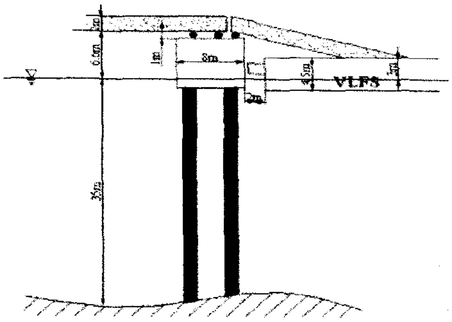

Fig. 2 Detailed Bridge profile Case

3.3.2 Second Alternative

For the better structural behaviors of the bridge, second alternative is proposed. This one is obtained through the Design Spiral approach, also total length of the bridge is also 300m, and total 4 spans are employed. The configuration is shown in Fig. 3. The second alternative utilizes a continuous 4-span system deck system in which main bridge system consists of plate girders. The bridge spans are 70m + 80m + 80m +70m. The main plate girders have a constant height, which gives the simplicity and economy.

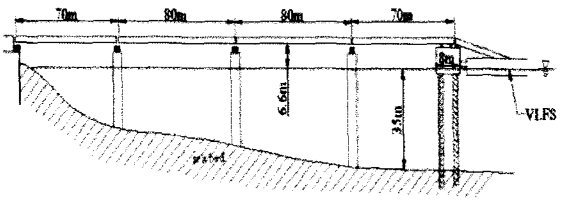

Fig. 3 Bridge Profile Case2

4. 2nd Phase Design of the Bridge

4.1 Structural configuration of the Bridge

As shown in Fig. 1 and Fig. 3, the schematic profile of the proposed bridge is determined. For the structural integrity and the safety of the bridge, fundamental dimensions of the various parts are determined based in the Design Spiral Method . The initial sectional properties of the bridge section is illustrated in Fig. 5 and the dimensions and the corresponding structural characteristics of I beam girder is documented in Table 2

For the cases of Fig. 1, and Fig. 3 structural analysis using FEMAP and m*STRESS are performed. Fig. 4 show the detailed section of the bridge girder.

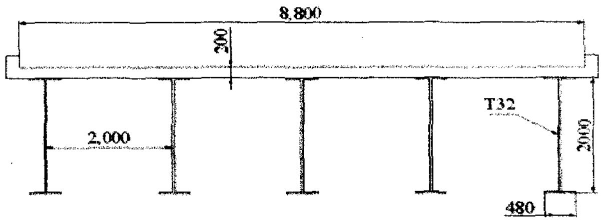

Fig.4 Detail section of bridge girder

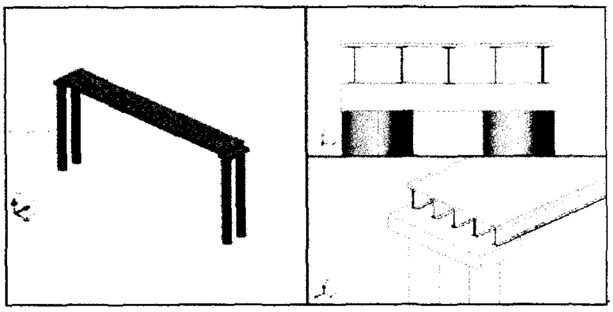

Fig. 5 The initial sectional properties of the bridge section

Table 2 Sectional Property of Girder

Area (A)	143.6602 in^2
Moment of Inertia (Izz)	1430.022 In^4
Moment of Inertia (Iyy)	117972.2 In^4
Torsional Rigidity (J)	78.42927 In^4

4.2 Finite Element Analysis of the Bridge

Finite Element Analysis is carried out for the base part, i.e., girder of 80m length span, and 120m span, respectively. Following Figure and Table show the analysis results

CASE 1

The geometric properties of the model of the bridge employed here are listed in Table 3. Fig. 6 shows the boundary conditions of the bridge. Fig. 7 shows the deformed shape of the bridge, in case of DB-24 loading condition and shows the maximum deflection at mid span.

Table 3 Characteristics of Beam Element

Geometry Property	Overall Length	3149.6 inch
	Overall Breadth	314.96 inch
Material Property	Ex	$2.9*10^7$ lbf/in^2
	Ey	$2.9*10^7$ lbf/in^2
	Density	$7.33*10^{-4}$ lbf·sec2/in^4
	Poisson ratio	0.3

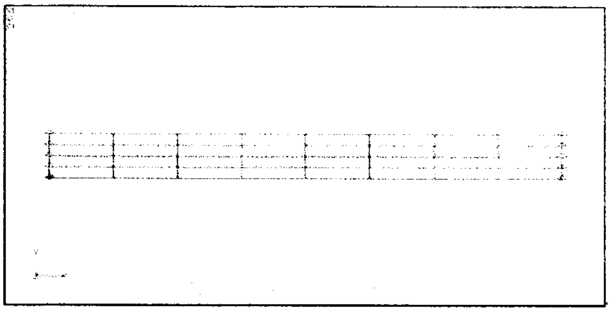

Fig. 6 Boundary Conditions

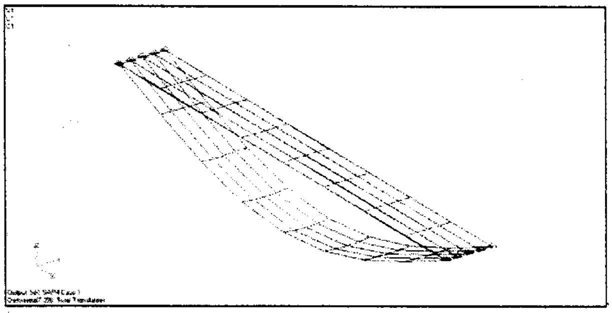

Fig.7 Deformed Shape and Maximum Deflection

CASE 2

The geometric properties of the model of the bridge employed here are listed in Table 4. Fig. 8 shows the boundary conditions of the bridge. Fig. 9 shows the deformed shape of the bridge, in case of DB-24 loading condition and shows the maximum deflection at mid span.

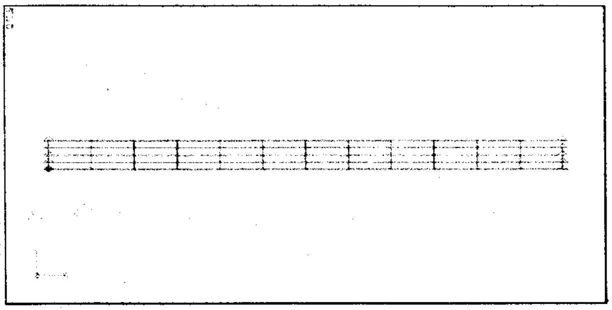

Fig. 8 Boundary Conditions

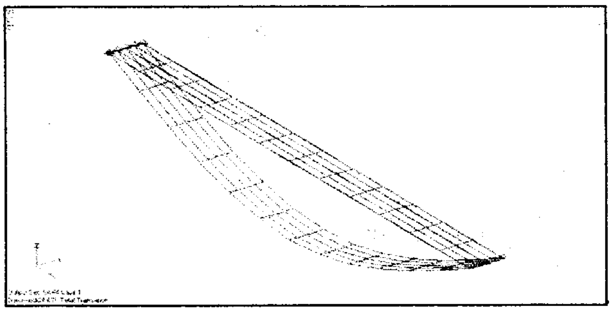

Fig.9 Deformed Shape and Maximum Deflection

4.3 Analysis Results

Based on the FEM analysis, the 2 cases of the proposed bridge are well in the viewpoints of the structural integrity. Table 5 and Table 6 shows the results of the structural analysis and safety factors for the case of 80m, 120m span bridge, respectively

Table 5 Structural Analysis Results for L=80m

	Case 1	Case 2
Loading	DB-24 w/o Impact	DB-24 with Impact
Max. Def.	7.39 inch	9.238 inch
max	10791 psi	13489 psi
Safety factor	3.34	2.67

Table 6 Structural Analysis Results for L=120m

	Case 1	Case 2
Loading	DB-24 w/o Impact	DB-24 with Impact
Max. Def.	24.63 inch	30.79 inch
max	15801 psi	19752 psi
Safety factor	2.28	1.82

4.4 Design of piers

Based on the loadings due to the wave, the sectional property of the vertical column of piers is determined. The Morison equation is employed here for the analysis and the design of the columns. The loading configuration of the column is shown in Fig. 10. The diameters of 7, 5, 3, 2 m are chosen for the analysis. And the stability of the column is checked based of the Euler buckling load criteria.

Following Table 7 shows the analysis results.

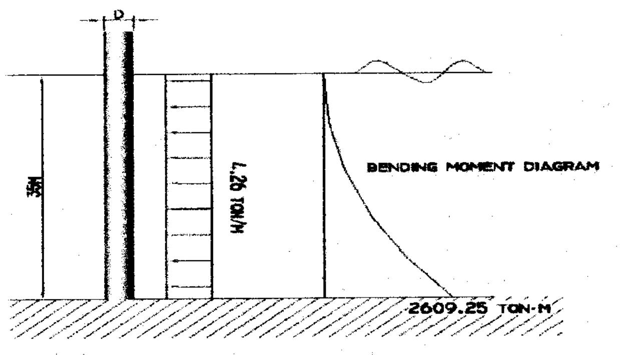

Fig. 10 Wave load to Vertical Cylinder. D=3m

Table 7 Analysis Results

	7m	5m	3m	2m
FD (ton)	329.36	235.26	141.16	94.10
FM (ton)	365.24	186.35	67.08	29.82
F_{max} (ton)	430.62	272.16	149.03	96.46
W (ton/m)	12.3	7.78	4.26	2.76
I (m^4)	117.86	30.68	3.98	0.785
σ_x (ton/m^2)	223.72	388.30	813.70	2153.50
τ_{xy}(ton/m^2)	14.92	18.49	21.09	40.96
σ_1(ton/m^2)	224.71	398.18	814.24	2154.28
P_{cr}	465585	121196	15722	3101

The best column is chosen as D=3m, and final configuration of the lower part of the bridge is shown in Fig. 11

5. Final Configuration of the Bridge

Based on the analysis and design process, final configuration of the whole bridge is obtained as shown in Fig. 11 through Fig. 14

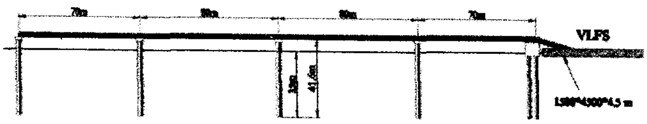

Fig. 11 Final Configuration of the Bridge Profile

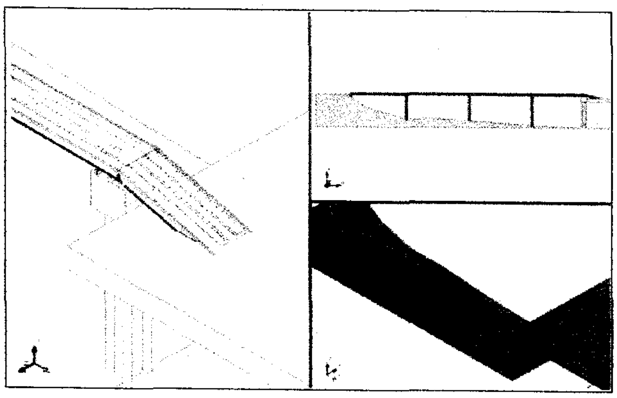

Fig. 12 Connecting part of Bridge 1

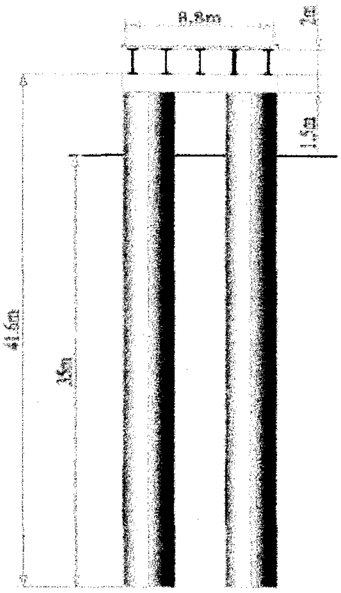

Fig. 13 Lower part of Bridge

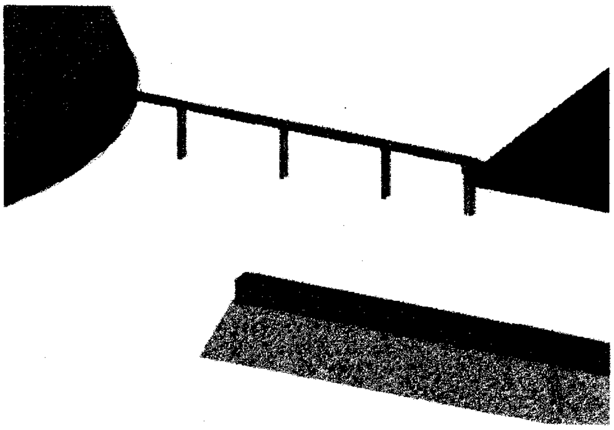

Fig. 14 Final view of Bridge and Breakwater

6. Conclusions

For the design of a bridge connecting to VLFS, fundamental design and analysis procedures as well as the basic calculations are documented. A final bridge dimensions and configurations are proposed. The proposed scheme and the procedure can be applied at the early design stage of a bridge that connects the shore and the VLFS. This study can be used as the design guidelines of the connecting bridge for the special case.

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