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Vessel Collision Analysis with Cable-Stayed Bridge Considering different Tower's Bracing System

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الملخص العربى :

تحدث تصادم السفن مع الجسور في جميع أنحاء العالم ، مما يؤدي إلى خسائر فادحة وخسائر كبيرة في الممتلكات وضرر بيئي. العديد من أنظمة أرصفة الجسور ضد حوادث السفن هي تقنيات مختلفة متاحة لتقليل ومنع مثل هذه النفقات. باستخدام نموذج محاكاة ديناميكي واضح لتحليل العناصر المحدودة ، يقدم هذا البحث تحقيقا حدوديا لأنظمة تقوية متعددة لرصيف جسر مثبت بالكابل. بالنسبة للعديد من طرق التدعيم لرصيف الجسر ، تم إجراء تحليل حدودي لفحص تأثير قوة تأثير السفينة على جسور **Tatara** المثبتة بالكابلات ، بامتداد مركزي يبلغ **890** مترا ، وحالات التحميل بقيم متنوعة لسرعة السفينة ، وحمولة الحمولة الساكنة من السفينة. وفقا لنتائج هذه الدراسة ، يفضل استخدام تقنيات التحليل الديناميكي ، ونظام التدعيم الأكثر فاعلية هو الذي له تأثير على التشوه الكامل للجسر لأنواع مختلفة من الجسور ، وأفضل نظام يتمتع بقدرات كبيرة على امتصاص الطاقة.

Abstract:

Vessel collisions with bridges occur all around the globe, resulting in massive losses, significant property loss, and environmental harm. Several systems for bridge piers against vessel accidents are various techniques available for reducing and preventing such expenses. Using an explicit dynamic finite-element analysis simulation model, this research presents a parametric investigation for multiple bracing systems for the pier of a cable-stayed bridge. For numerous bracing methods for the bridge's pier, a parametric analysis was conducted to examine the effect of vessel impact force on Tatara cable-stayed bridges, with a centre span of 890 m, cases of loading with varied values of vessel velocity, and deadweight tonnage of the vessel. According to the findings of this study, dynamic analysis techniques are preferred, and the most effective bracing system is one that has an influence on the entire deformation of the bridge for various types of bridges, and the best system has great energy absorption capacities.

Keyword: Numerical Simulation, Cable-stayed Bridge, Vessel Collision , Ansys Program.

7- INTRODUCTION

The probability of vessel bridge collision is a important aspect in the design of bridges against vessel collision [AASHTO 2009; European Committee for Standardization (CEN) 2002]. As mentioned by Kunz (1998), vessel collisions with bridges are rarly events and occur randomly and are affected by various complex conditions. Lack of statistical data for describing the complex accident scenarios, the precision obtained with advanced but costly model only remains of theoretical interest. A pragmatic way includes simplified models established using statistical information of global parameters, as proposed by AASHTO's code (AASHTO 2009), Eurocode (CEN 2002), and Kunz (1998).

Karlsson et al. (1998) verified the validity of a simplified model used in the Oresund link project by comparing the reported accidents and the predicted results. Dai et al. (2003) verified the validity of AASHTO's code and proposed a new simplified model based on the statistical data of vessel-bridge collisions for inland waterways in China.

The potential of a vessel-bridge collision is often influenced by channel meandering, seasonal changes in water levels, and waterway barriers. These critical aspects, however, are not explicitly addressed in the existing simple models for calculating the potential of a vessel bridge collision. Despite the fact that Gucma was aware of the issue, he did not provide any practical simplified models, instead opting for simulation approaches (Gucma 2003, 2009; Sand and Petersen 1998). The Joint Committee on Structural Safety (JCSS 2001) proposed a general framework for estimating the potential of risk for vehicle collisions, helicopter collisions, and vessel collisions based on general probabilistic mathematics, however this was general.

The AASHTO guide specification (AASHTO 2009) lists the following physical protection systems for bridge piers: fender systems, pile supported systems, dolphin protection systems, island protection systems, and floating protection systems. Each pier protection system is designed for a specific use. The vessel absorbs the impact energy and may be damaged in an unusual vessel collision if the protective system's force resistance is larger than the vessel crushing force (Svensson2009).

This category includes dolphin and island protection systems. However, because it poses a threat to vessels, aggravates scour, and raises water flow velocities to disperse the initial vessel kinetic energy, this form of stiff protective device may need to be reconsidered. When the protective system's resistive force is smaller than the vessel crushing force (AASHTO2009), the impact energy is absorbed predominantly by the protective system's inelastic deformation.

Fender, pile supported, and floating protection systems belong to this category. S vensson (2009) outlined the development of bridge pier–protection systems against vessel collision over the last 25 years, including 18 protection systems available worldwide. A summary of existing protective fender systems for bridge piers used in the United States and other countries, including six major types, was reported by Voyiadjis et al. (2008).

In recent years, floating framed-steel fender systems have been incorporated on to bridge piers with substantial water level variations. Fig.1 presents an application example in Huangshi Bridge, China (Sun2007), where the protection system absorbs vessel impact loads by elastic and plastic deformation of its members. The floating elevation automatically adjusts as the water level changes in the channel. It can be seen as a combination of the steel fender and floating protection systems, because the traditional fender system is designed to be located directly on bridge piers whereas the floating protection system usually has floating pontoons anchored to the bridge piers.


(a)

(b)

Fig. 1. (a) Floating framed steel fender system (reprinted from Sun 2007, with permission); (b) Huangshi Bridge (image by Sun Zhen)

8- TATARA CABLE-STAYED BRIDGE AS A CASE STUDY

Many cable-stayed bridges could be used could be used for our case study to discuss the above mentioned iterative technique. However, it may be more convenient to choose a general and realistic case. The below information is the most closed to the Tatara Cable-Stayed Bridge:

The “Tatara Bridge” is cable stayed bridge, with 890 m center span. (Fig. 2, 3) showing the Tatara Bridge’s general arrangement for the main tower and the main girder section are shown in (Fig. 4, 5), respectively. (Honshu-Shikoku, 1996)

The main tower height is 220 m and designed as an inverted Y shape. The cross section shape section having corners cut for efficient wind stability and better landscaping. For material properties G= 8.10E+06 t/m2, E= 2.10E+07 t/m2, TC= 1.20E-05).

The main girder spans consist of three spans, 270 m, 890 m, and 320 m, and the total bridge length is 1480 m. Post tension concrete girders are installed for each end spans of both side and the side span is shorter than the center span which is considered as counterweight girders to resist negative reaction. This cable stayed bridge thus uses a steel and PC connection girder. The total width of the bridge is 30.6 m, including a road of motorized bicycles and pedestrians for sidewalk. The girder height is 2.7 m. It uses flat box girders attached with vertical stiffeners to ensure wind stability. (prestressed concrete sections properties is 1.22E+06 t/m2, E= 2.80E+06 t/m2, TC= 1.00E-05 and steel sections properties is G= 8.10E+06 t/m2, E= 2.10E+07 t/m2, TC = 1.20E-05).

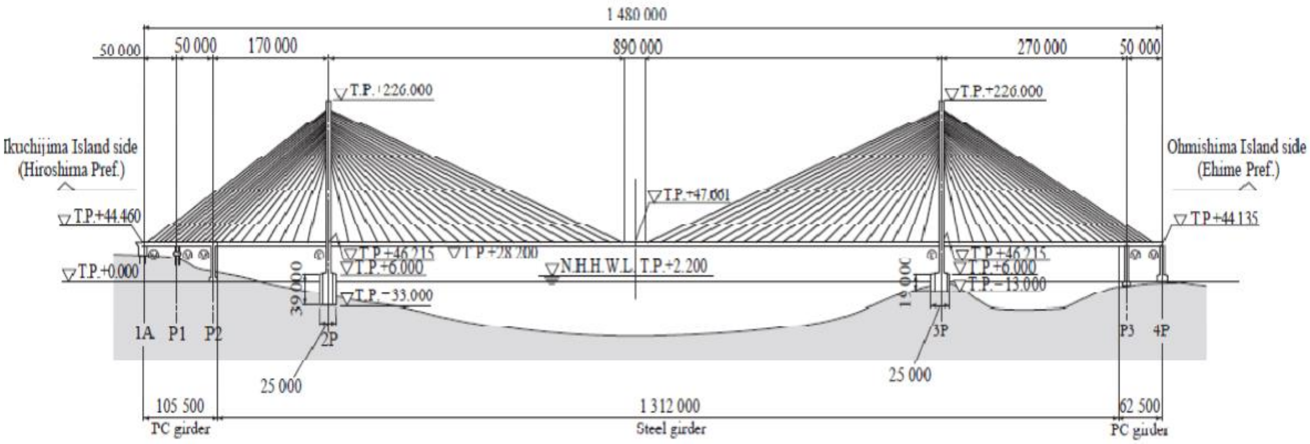
Cables installed with 21 level and two-plane multi-fan cables (maximum cable length around 460 m. Cables of the bridge have indented surfaces in the polyethylene cable coating, the same as dimples on a golf ball, to resist vibration caused by both windy and rainy weather (rain vibration). The cables Material Properties is E= 2.00E+07 t/m2, TC= 1.20E-05.

Different codes were adopted to cover all Aspects. The first concern is overall stability of the girder, different modes of instability was considered and checked for each section of the girder by utilizing the results of an eigenvalue analysis. The ultimate capacity of all sections was checked by adopting an interaction equation of the Japanese code (JSCE). 1987 (Attia, 1997).

The ultimate strength of the flange has been evaluated based on British code (5400), 1983. Meanwhile, the ultimate strength of the web has been checked by equations of the American code (AISC), 1978. Furthermore, a large deformation analysis was conducted to compare the results with the elastic analysis results.

The complete three-dimensional simulation model for Tatara cable-stayed bridge was developed as a similar to the Japanese bridge model.

Fig. 2. Tatara Cable-Stayed Bridge



(Note) T.P. : Mid-tide in Tokyo Bay (unit : m)
N.H.H.W.L : Nearly highest tide level (unit : m)

Fig. 3. General arrangement Tatara Cable-Stayed Bridge

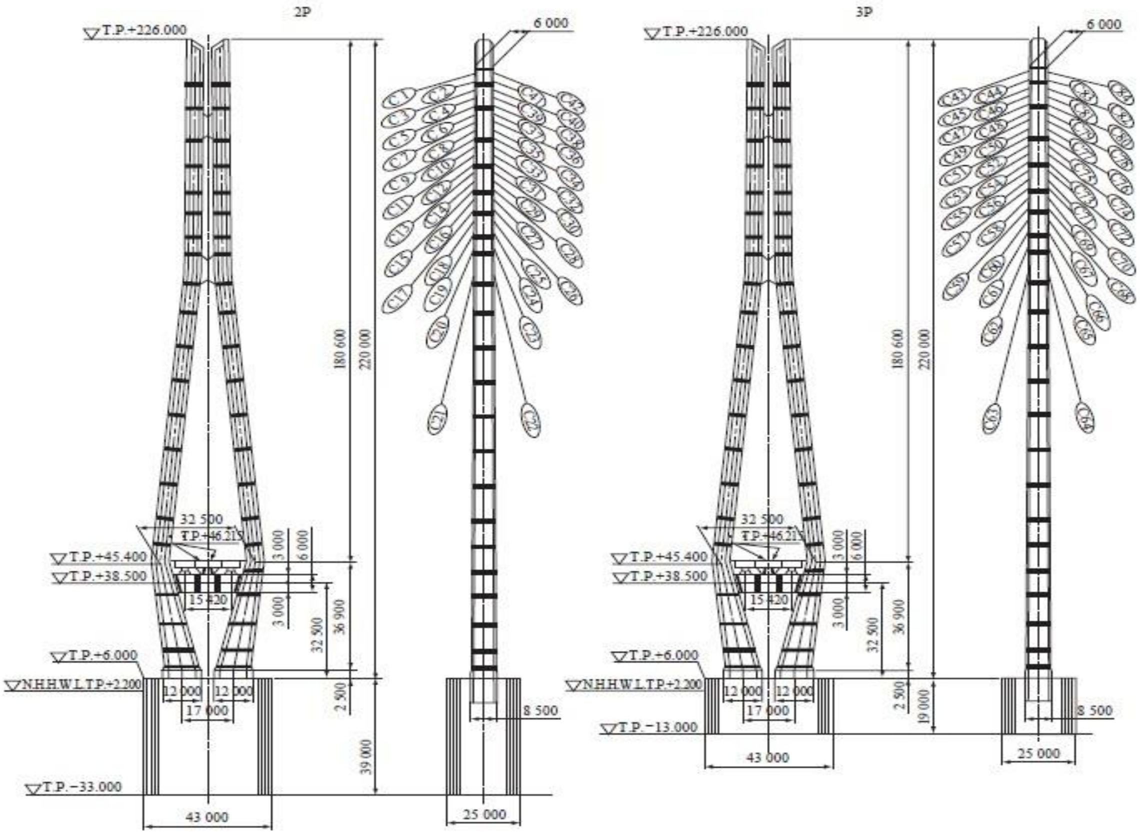


Fig.4. General Arrangement (Main Tower)

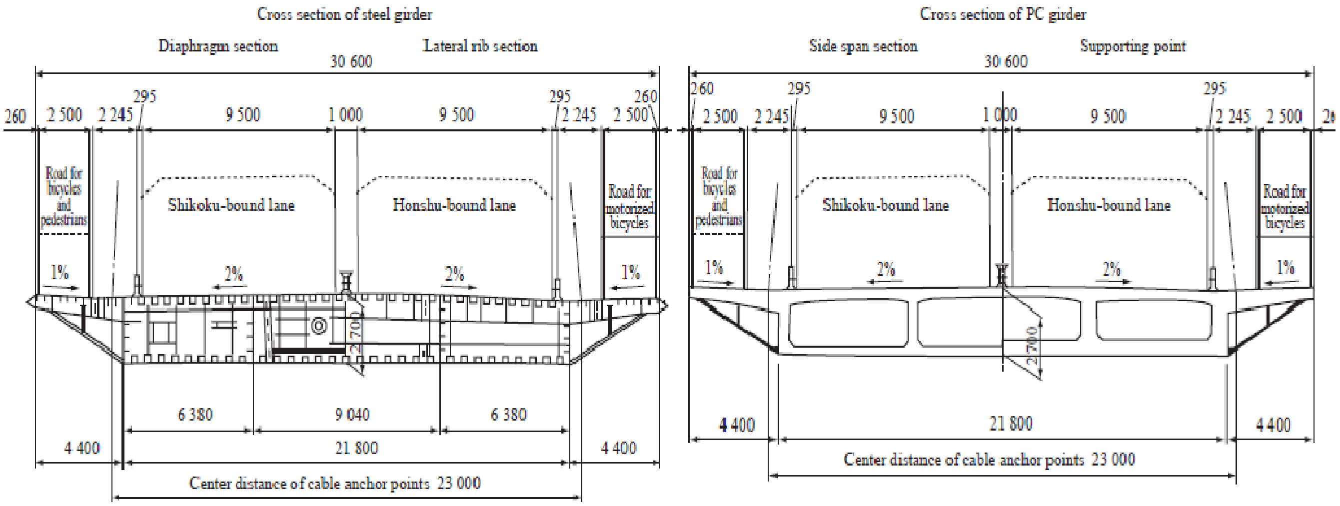


Fig.5. General Arrangement (Main Girder)

9- COMPARATIVE STUDY OF BELOW-DECK TOWER SHAPE

Impact parametric study is performed showing the response of Tatara cable-stayed bridge under impact force for different types of bridge piers' structural system under bridge's girder and how it is affected by different factors, as follow:

The effect of Vessel Velocity and the effect of Deadweight Tonnage of the Vessel.

The following figures are showing the different types of the bridge piers' structural system under the bridge girder, as follow:

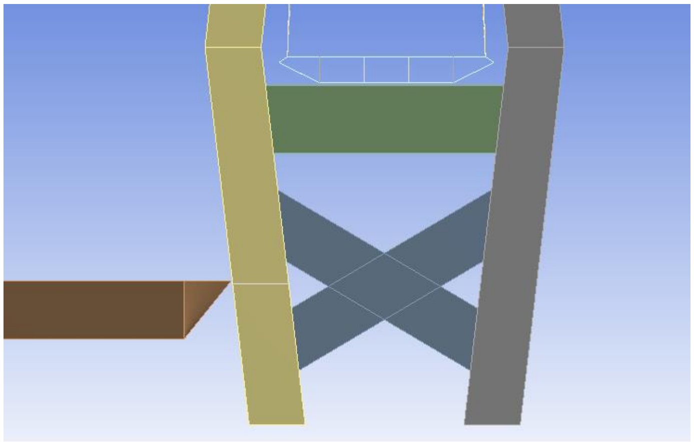


Fig.6. Shape (X-Truss) Below Deck of Bridge

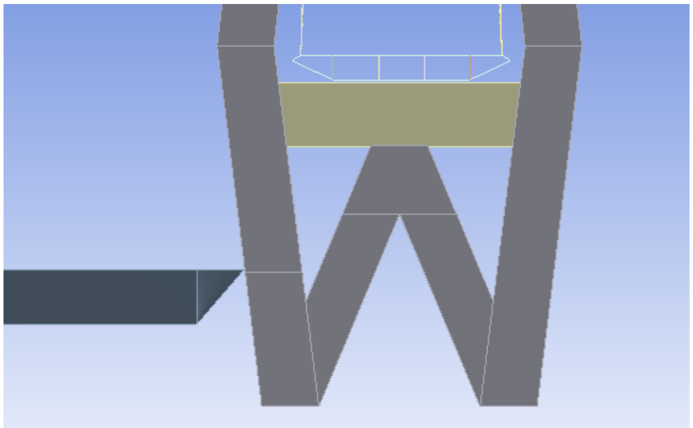
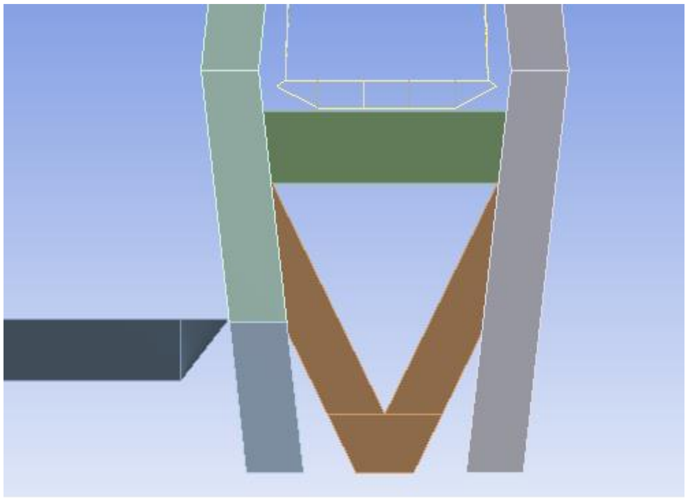


Fig.7. Shape (A-Truss) Below Deck of Bridge



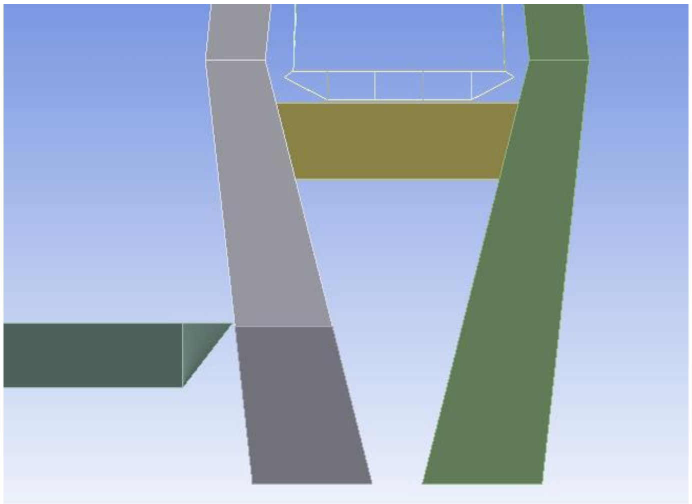


Fig.8. Shape (V-Truss) Below Deck of Bridge

Fig.9. Shape of (Large Base) Below Deck of Bridge

10- RESULTS AND DISCUSSION

For the results, a comparison study was done between the findings of a three-dimensional dynamic simulation model. For each investigated bridge, the influence of vessel velocity and dead weight tonnage on the displacement at the top of the bridge pier was evaluated. The results of the analysis indicated the influence of the impact load on the displacement at the top of the bridge pier for several types of bridge pier systems with varying values of vessel velocity and dead weight tonnage.

The following data represent an analysis of the influence of vessel velocity and dead weight tonnage on displacement.

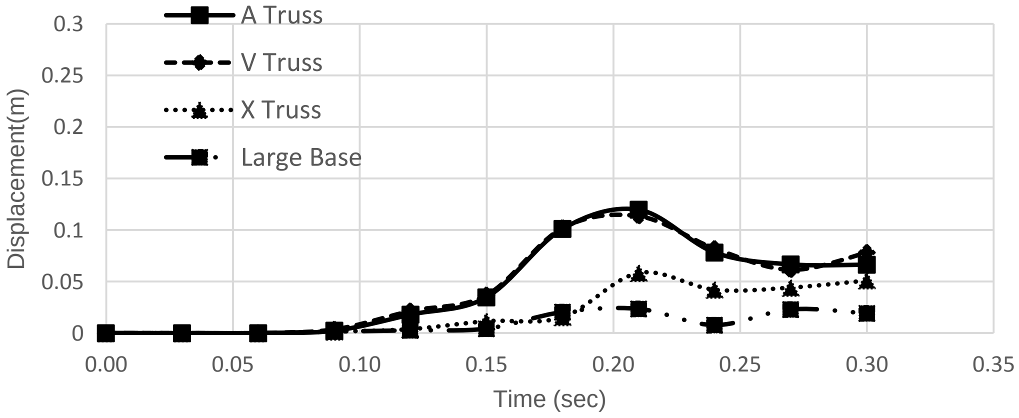


Fig.10. Displacement of bridge pier due to Vessel Velocity (4 m/s) for different types of bridge pier systems

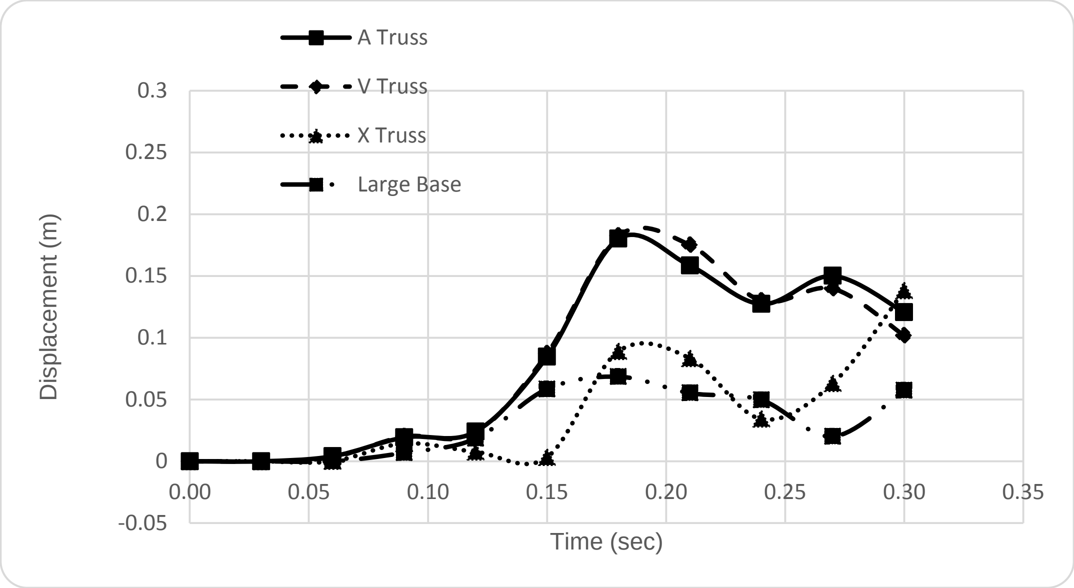


Fig.11. Displacement of bridge pier due to Vessel Velocity (8 m/s) for different types of bridge pier systems

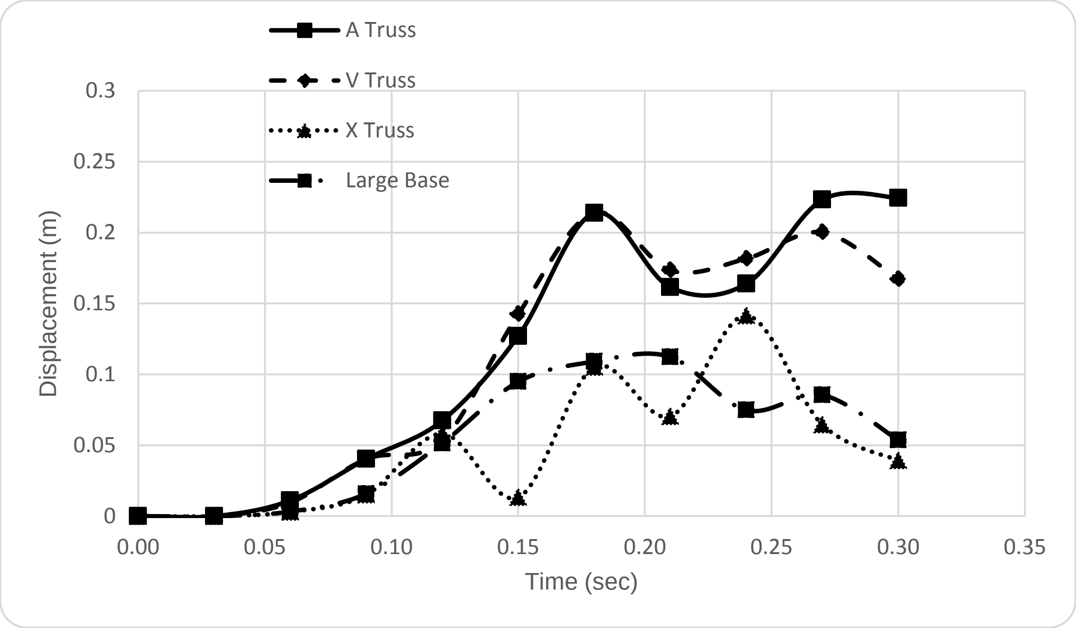


Fig.12. Displacement of bridge pier due to Vessel Velocity (12 m/s) for different types of bridge pier systems

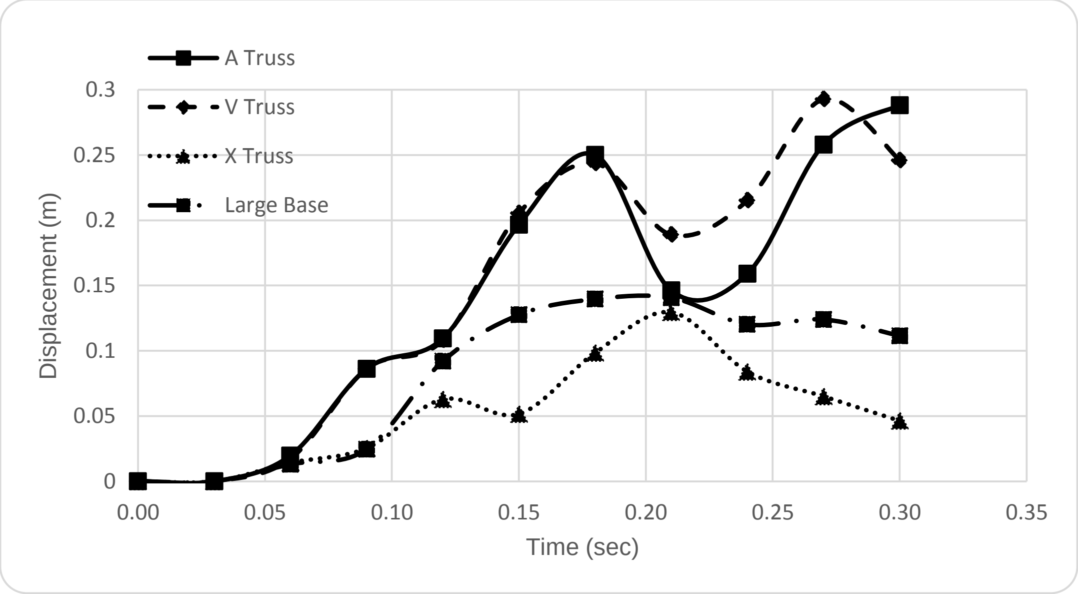


Fig.13. Displacement of bridge pier due to Vessel Velocity (16 m/s) for different types of bridge pier systems

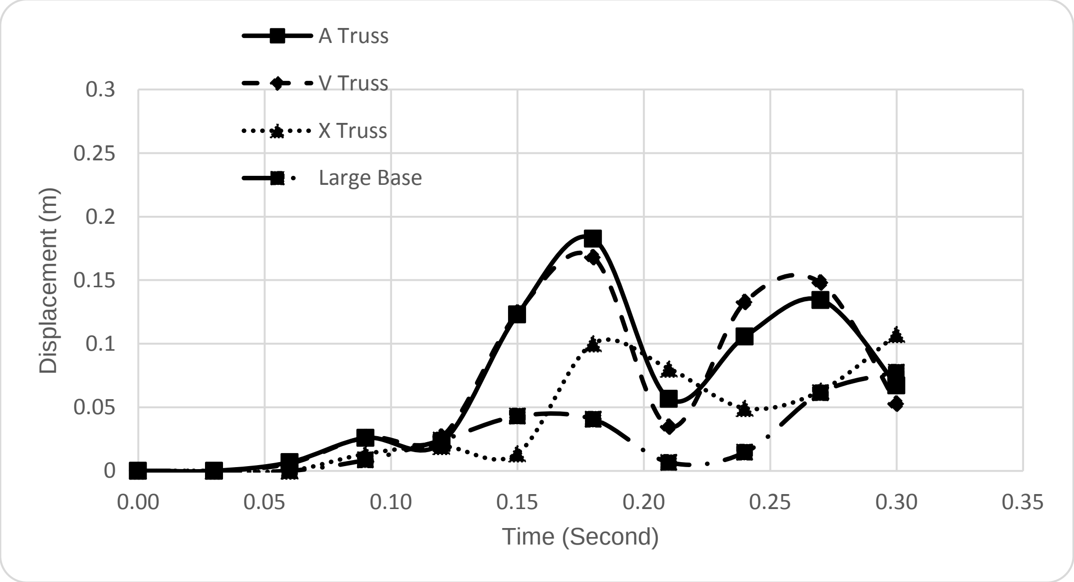


Fig.14. Displacement of bridge pier due to Dead Weight (1000 tons) for different types of bridge pier systems

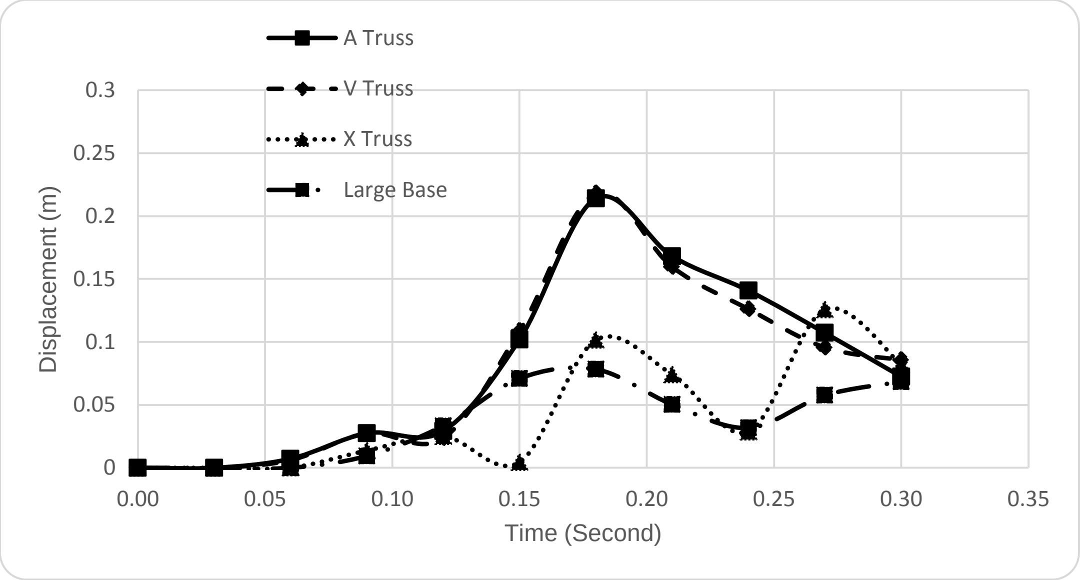


Fig.15. Displacement of bridge pier due to Dead Weight (2000 tons) for different types of bridge pier systems

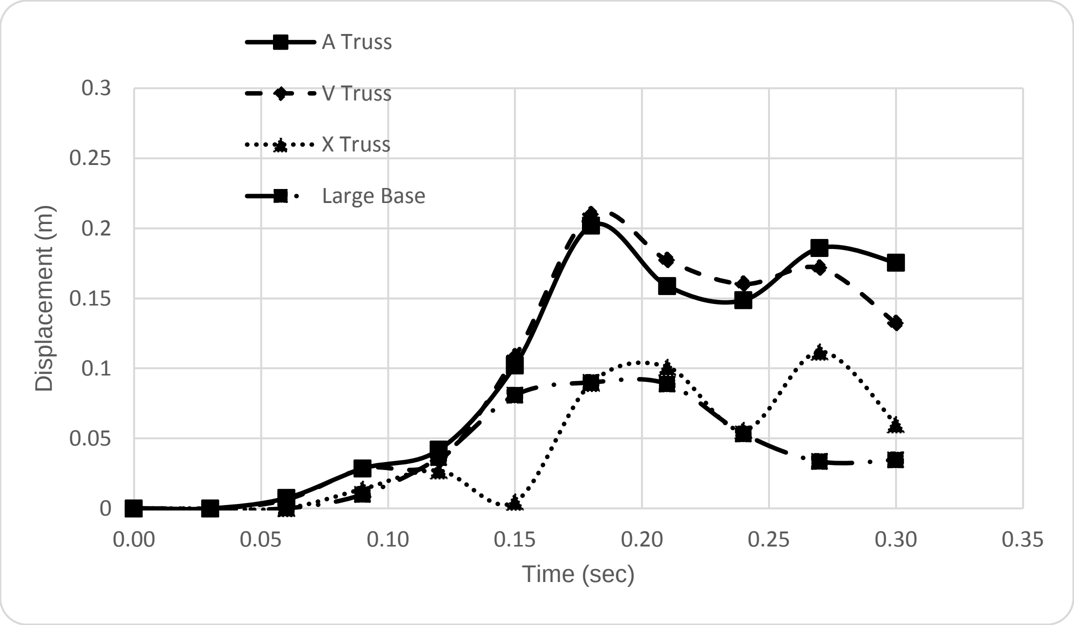


Fig.16. Displacement of bridge pier due to Dead Weight (3000 tons) for different types of bridge pier systems

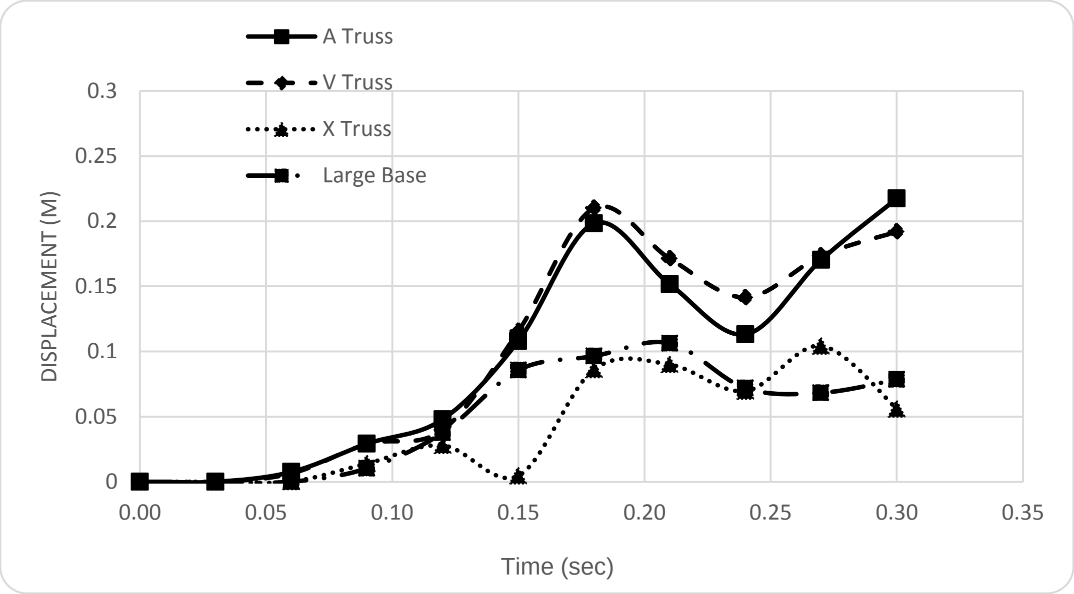


Fig.17. Displacement of bridge pier due to Dead Weight (4000 tons) for different types of bridge pier systems

11- CONCLUSIONS

The following conclusion may be formed based on the parametric investigation between the findings of the three-dimensional dynamic analysis utilizing Finite elements analysis simulation model for different types of bridge pier structural systems:

1- A variety of structural systems might be employed to prevent vessel collisions and reduce total bridge displacement.

2- As vessel velocity rises, the bridge pier displacement rises as well.

3- As the deadweight tonnage of the vessel increases, the bridge pier displacement increases.

4- The original design with large base dimensions is the preferred structural solution for bridge pier under the bridge girder.

5- The bridge displacement behaviour for V-truss and A-truss shapes is very similar.

12- The bridge displacement behaviour for X-truss and big base shapes is quite closed.

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