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Verification of vessel collision simulation with cable stayed bridge using ASSHTO Guide Specification

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الملخص العربى:

تعتبر دراسة تصادم السفن للجسور التي تسمح بالممرات المائية الصالحة للملاحة أمرا بالغ الأهمية للتحقيق لأنه يؤثر على التكلفة الكاملة للجسور. "طريقة تصميم مواصفات دليل **AASHTO**" ، والتي توفر طريقة حساب يدوية بسيطة لتقدير "قوة تأثير مكافئة" ، هي المعادلات الأولية للنظر في هذه القوى. مطلوب حساب دقيق لأحمال التأثير المنقولة إلى أرصفة الجسر من أجل تصميم فعال من حيث التكلفة. في حين أن قوة الاصطدام ديناميكية ، فإن أحكام تصميم الجسر الحالية تستند إلى تقديرات السلوك الهيكلي الثابت والأدلة التجريبية المحدودة. بالنسبة لتصادم السفن ، يتم إعداد دراسة مقارنة بين المنهجيات التحليلية الثابتة والديناميكية. بالنسبة لتصادم السفن بقيم متفاوتة للكتلة **(DWT)** وسرعة السفينة ، يتم إعداد دراسة مقارنة بين المنهجيات التحليلية الثابتة والديناميكية. موضوع هذه الدراسة هو تأثير قوى تأثير السفينة على نوع الجسر المثبت بالكابلات. يتم تطبيق قوة التأثير على برج الجسر عند النقطة فوق مستوى الماء. تم إجراء دراسة تحقق لمقارنة تأثير قوة تأثير السفينة على الجسور المثبتة بكابل **Tatara** ، تمت دراسة قيم مختلفة للتحميل بقيم مختلفة لسرعة السفينة والوزن الثقيل للسفينة لنموذج تحليل محاكاة ثابتة وديناميكية لهيكل الجسر باستخدام برنامج أنسيس. كشفت النتائج أن نموذج تحليل المحاكاة الديناميكية لهيكل الجسر باستخدام برنامج **ANSYS** تم التحقق منه وتفوقه على قوة التأثير الساكنة المكافئة في مواصفات دليل **AASHTO** ، مما يدل على قيود استخدام معادلة **AASHTO** للقوة الساكنة المكافئة.

Abstract:

The study of vessel collisions for bridges that allow for navigable waterways is crucial to investigate because it affects the entire cost of the bridges. The "AASHTO Guide Specifications Design Method," which provides a simple manual calculation method to estimate an "equivalent impact force," is the preliminary equations for considering these forces. An accurate calculation of the impact loads imparted to bridge piers is required for cost-effective design. While the collision force is dynamic, present bridge design provisions are based on static structural behaviour estimates and limited experimental evidence. For vessel collisions, a comparison study is prepared between static and dynamic analytical methodologies. For vessel collisions with varying values for mass (DWT) and vessel velocity, a comparison study is prepared between static and dynamic analytical methodologies. The influence of vessel impact forces on the type of cable-stayed bridge is the subject of this study. Impact force is applied to the bridge tower at the point above water level. A verification study was conducted to compare the effect of vessel impact force on Tatara cable- stayed bridges, different values of loading with different values of the vessel velocity and deadweight tonnage of the vessel were studied for Static and dynamic simulation Analysis model of bridge Structure using ANSYS program. The findings reveal that the dynamic simulation analysis model for bridge structure utilizing the ANSYS programme is verified and superior to the equivalent static impact force in the AASHTO Guide Specifications, demonstrating the limitations of employing the AASHTO equation for equivalent static force.

Keyword:, Vessel Collision, Numerical Simulation, Cable-stayed Bridge AASHTO Guide Specifications.

1- INTRODUCTION

Due to a wide variety of conditions, including pilot faults, mechanical failures, and severe environmental conditions, bridge structures crossing navigable coastal or inland rivers are vulnerable to vessel collision. Bridge damage, destruction, or collapse may be unavoidable in the event of a vessel collision. Between 1951 and 1988, Harik et al. (1990) investigated 79 bridge collapses in the United States, finding that 19 of them were caused by a vessel collision. Wardhana and Hadipriono (2003) studied 59 U.S. bridge failures attributed to collisions between 1980 and 2000; 10 failures were a result of vessel collisions. Furthermore, 31 major bridge collapses worldwide have resulted from a vessel collision, with a total loss of 342 lives between 1960 and 2002 (AASHTO 2009). In general, for bridges spanning navigable waterways, vessel collision presents a serious threat to public safety.

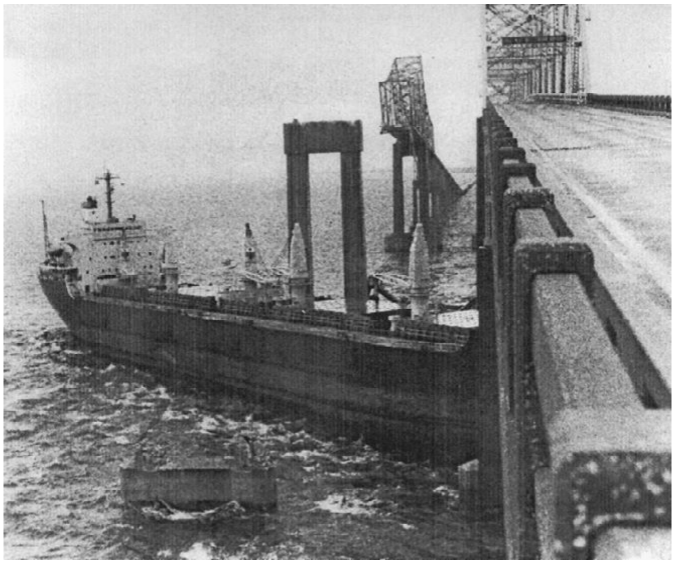


Fig. 1. The 1980 collapse of the Sunshine Skyway Bridge

The following figures demonstrate the findings of a verification investigation between the results of a three-dimensional dynamic analysis model and the values displacements for the analyzed situations of loading for equivalent static impact loads. The findings of the investigation revealed the effects of various loading scenarios on impact loads. The result of the vessel velocity, deadweight tonnage for the displacements of the top of tower was investigated for each studied bridge. The gravitational dead loads and the initial prestressing cable force has the basic case of loading of the Tatara Cable-Stayed Bridge according to analyzing a three-dimensional model and the values of displacements of studied cases of loading for the impact loads are shown in the following figures For verification the result of the vessel velocity and deadweight tonnage of the vessel on the displacement of the bridge tower. The effect of the factors in the impact load formula on the longitudinal displacements of the top tower of the cable-stayed bridges increases with the increasing in the velocity and dead weight tonnage, but the effect of the factors in the impact load formula on the vertical but Transversal displacements of the top tower of the cable-stayed bridges independent with the increasing in the velocity and dead weight tonnage.

2- AASHTO GUIDE SPECIFICATION DESIGN METHOD

Vessel Collision Energy

The kinetic energy of a moving vessel to be absorbed during a non-eccentric collision with a bridge pier shall be taken as:

$$KE = 500 C_H M V^2 \text{..........................equation(1)}$$

Where: KE =vessel collision energy (J)

M =vessel displacement tonnage (Mg)

C_H = hydrodynamic mass coefficient

V=vessel impact velocity (m/sec.)

The vessel mass, M, shall be based upon the loading condition of the vessel and shall include the empty mass of the vessel, or the mass of water ballast for vessels transiting in an empty or lightly loaded condition. The mass for barge tows shall be the sum of the mass of the tug/tow vessel and the combined mass of a row of barges in the length of the tow.

The hydrodynamic mass coefficient, CH shall be taken as shown in following Table: 1

If under keel clearance exceeds 0.5xdraft	$C_H = 1.05$
If under keel clearance is less than 0.1xdraft	$C_H = 1.25$

Values of C_H may be interpolated from the range shown above for intermediate values of under keel clearance. The under keel clearance shall be taken as the distance between the bottom of the vessel and the bottom of the waterway.

Ship Collision Force on Pier

The head-on ship collision impact force on a pier shall be taken as:

$$P_s = 1.2 \times 10^5 V \sqrt{DWT} \qquad \text{………………equation (2)}$$

Where: Ps =equivalent static vessel impact force (N)
DWT= deadweight tonnage of vessel (Mg)
V =vessel impact velocity (m/sec.)

The determination of the impact load on a bridge structure during a ship collision is complex and depends on many factors as follows:

- Structural type and shape of the ship's bow.
- Degree of water ballast carried in the forepeak of the bow,
- Size and velocity of the ship.
- Geometry of the collision, and
- Geometry and strength characteristics of the pier.

3- 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.

To cover various aspects, several codes were used. The first concern is the girder's overall stability. Using the findings of an eigenvalue analysis, alternative modes of instability were examined and evaluated for each part of the girder. The ultimate capacity of all sections was determined using a Japanese code interaction equation (JSCE) 1987 (Attia, 1997).

The flange's ultimate strength was determined using British code (5400) 1983. However, equations from the American code (AISC) 1978 have been used to test the web's ultimate strength. In addition, a significant deformation study was performed to compare the results to those of the elastic analysis.

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

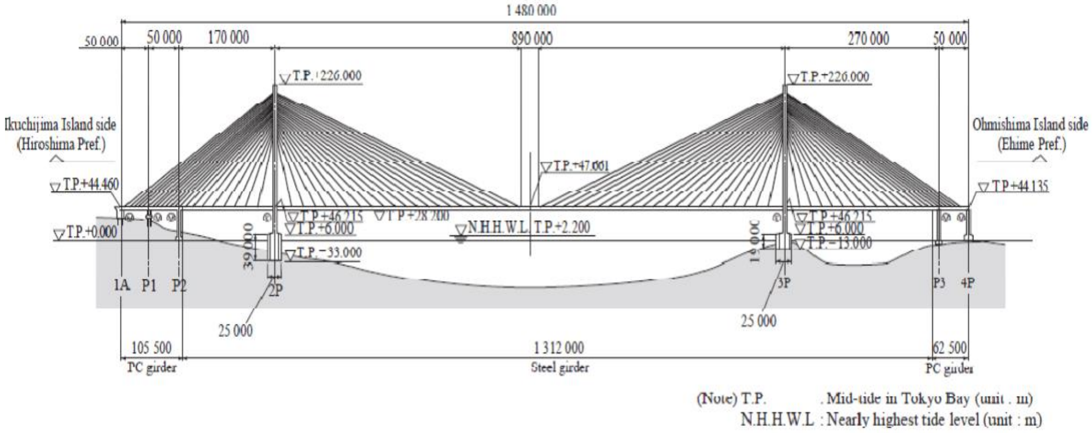


Fig. 3. General dimensions of Tatara Cable-Stayed Bridg

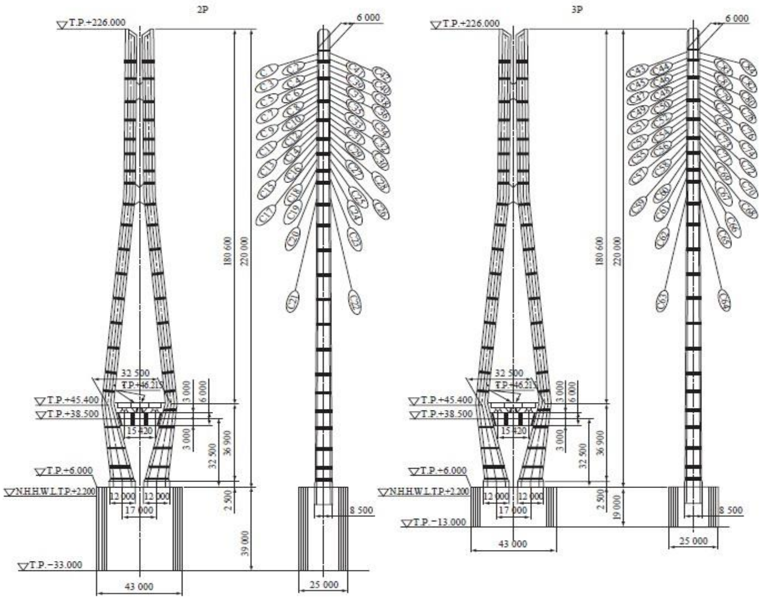


Fig.4. General Dimensions of the Main Tower

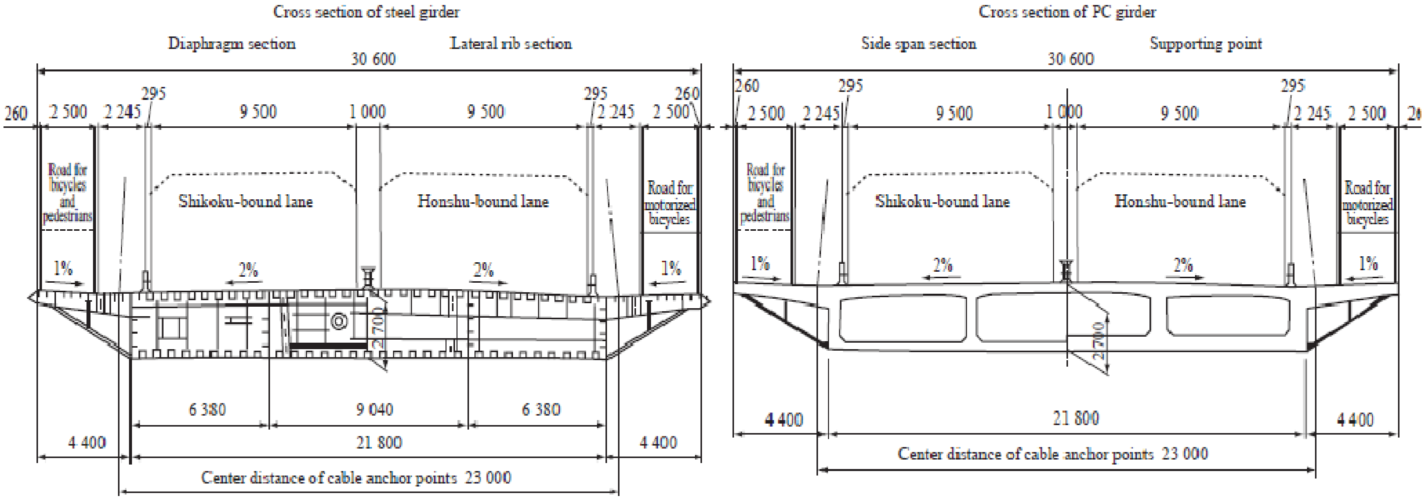


Fig.5. General Dimensions of Main Girder

4- FINITE ELEMENT MODEL

Many dynamic structural problems require the analysis to prescribe time varying parameters such as load, displacement or time histories of ground acceleration. However, in some cases such parameters cannot be determined ahead of time. For dynamic Bridge structure analysis under vessel impact, the impact load is a function of the structure and soil characteristics and is therefore unknown prior to analysis (Consolazio and Cowan, 2005).

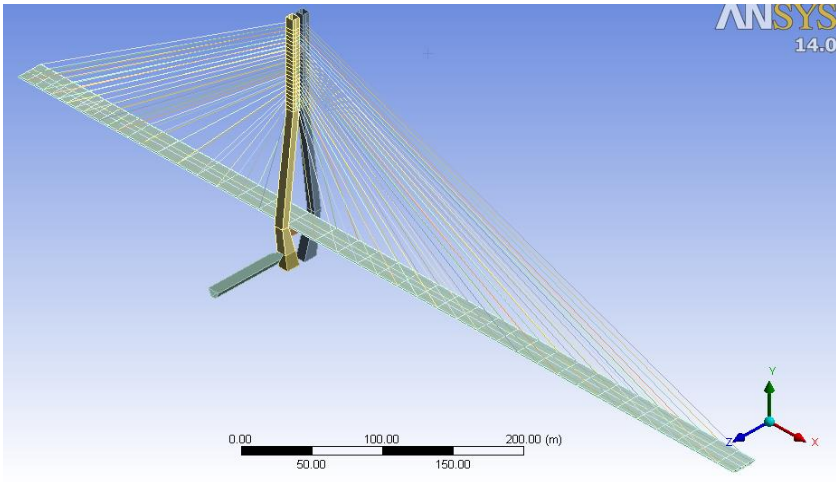


Fig.6. Three-Dimensional Finite Element Model of Tatara Bridge

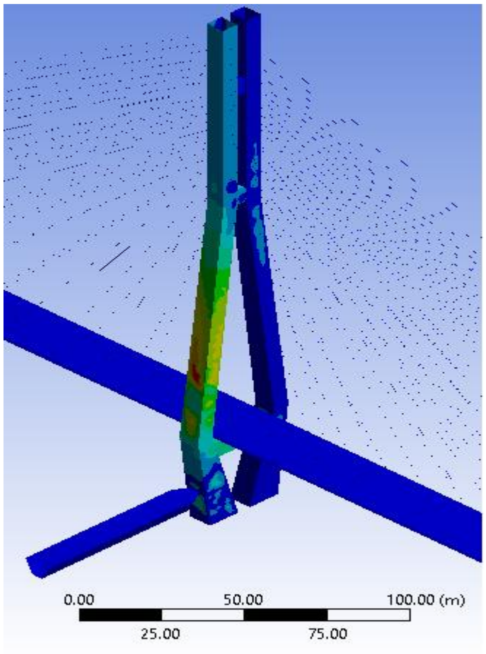


Fig.7. Finite Element Analysis Displacement due to Dynamic Loa

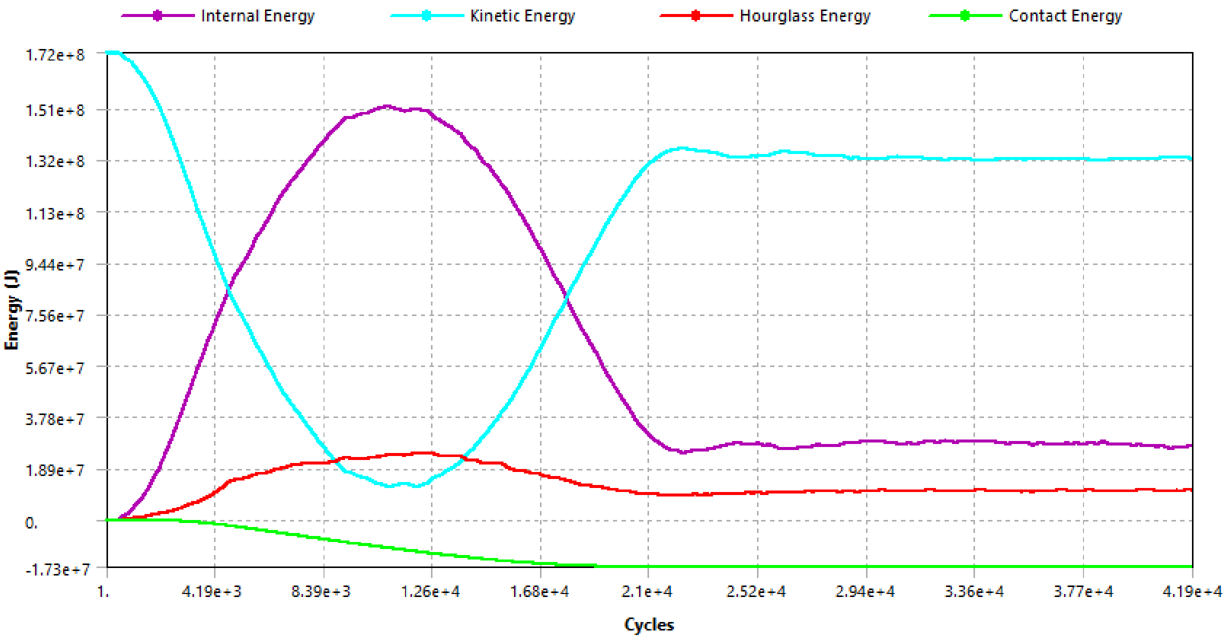
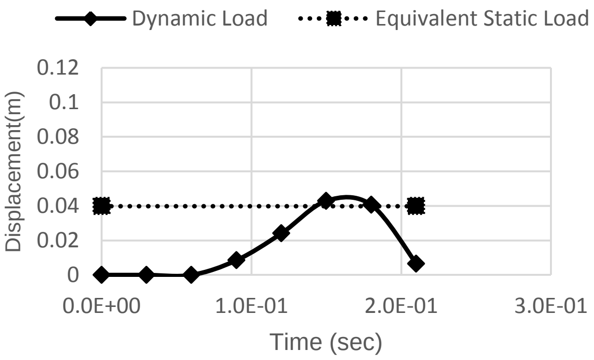


Fig.8. Energy Distribution due to Dynamic Impact Load

5- RESULTS AND DISCUSSION

A verification study has been conducted between the results of three dimensional dynamic simulation model and the values of displacements of studied cases of loading for the equivalent static impact loads are shown in the following figures.

The results of analysis showed that the effect of the different cases of loading for the impact loads. The effects of the vessel velocity, deadweight tonnage on the displacements of the tower was investigated for each studied bridge



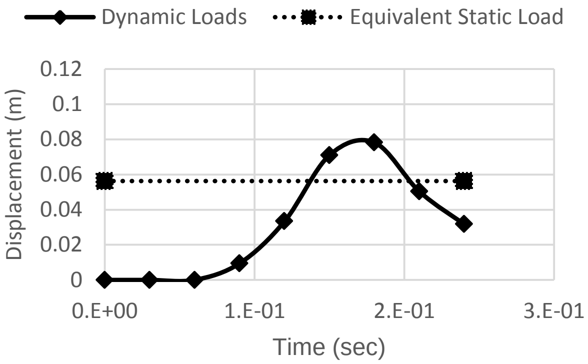
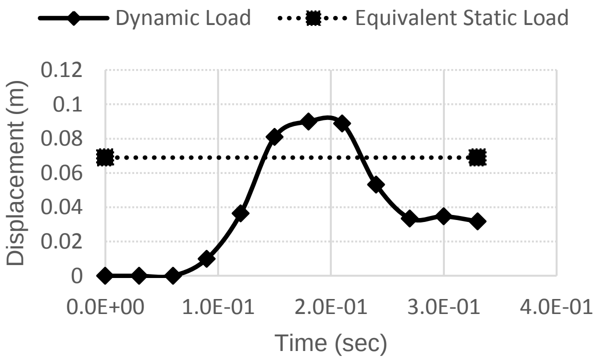


Fig.9. Displacement at the Top of Tower due to Dynamic and Static Load for Dead Weight 1000 ton

Fig.10. Displacement at the Top of Tower due to Dynamic and Static Load for Dead Weight 2000 ton



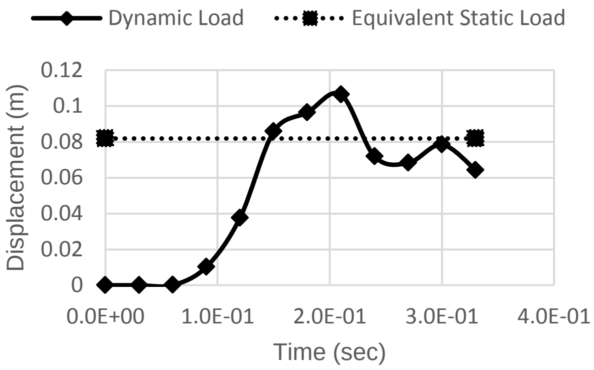


Fig.11. Displacement at the Top of Tower due to Dynamic and Static Load for Dead Weight 3000 ton

Fig.12. Displacement at the Top of Tower due to Dynamic and Static Load for Dead Weight 4000 ton

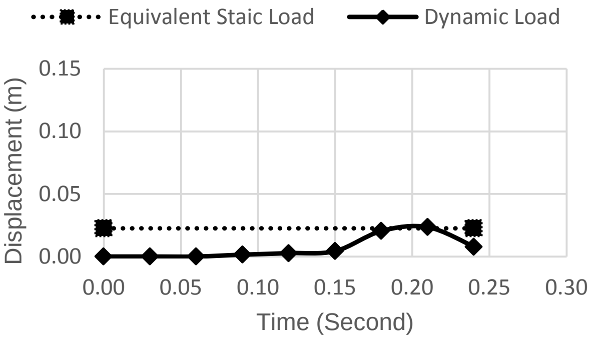


Fig.13. Displacement at the Top of Tower due to Dynamic and Static Load for Vessel Velocity 4 m/s

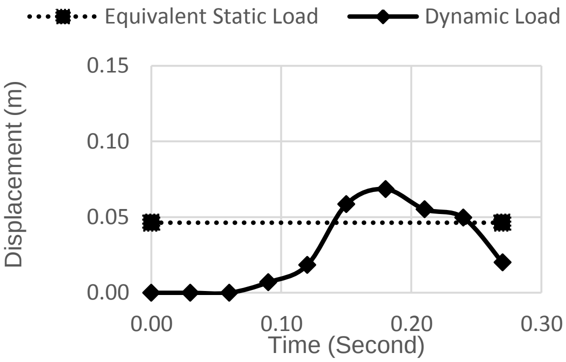


Fig.14. Displacement at the Top of Tower due to Dynamic and Static Load for Vessel Velocity 8 m/s

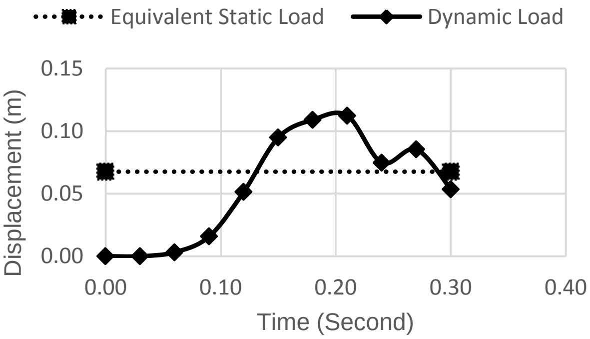


Fig.15. Displacement at the Top of Tower due to Dynamic and Static Load for Vessel Velocity 12 m/s

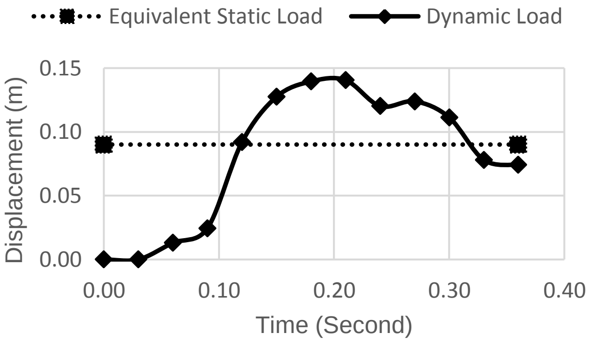


Fig.16. Displacement at the Top of Tower due to Dynamic and Static Load for Vessel Velocity 16 m/s

6- CONCLUSIONS

The following conclusion can be drawn based on the verification study between the results of the three-dimensional dynamic analysis using the Finite element analysis model and the values of loading displacements for the equivalent static impact force using the "AASHTO Guide Specifications Design Method:

1- The Finite elements dynamic analysis using ANSYS program is verified with "AASHTO Guide Specifications".
2- For small values of dead weight tonnage, the displacement of the tower due to the equivalent static impact force is larger than the same in the simulation analysis dynamic force.
3- The displacement of the tower due to the equivalent static impact force is lower than the same in Finite elements analysis dynamic force for large values of dead weight tonnage.
4- The displacement of the tower due to the equivalent static impact force is bigger than the same in Finite elements analysis dynamic force for modest values of vessel velocity.
5- The displacement of the tower due to the equivalent static impact force is smaller than the same in Finite elements analysis dynamic force for large values of vessel velocity.

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