SANDWICH PLATE SYSTEM IN BRIDGE DECK – A REVIEW

Himanshu V. Mahajan, Prof. S. R. Parekar

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Abstract:- *A new deck concept which has been developed over recent years is that of the steel sandwich panel (SSP) deck. A SSP deck is composed of two thin face plates separated by a corrugated core which results in high relative stiffness to weight ratio. The SSP concept can reach a weight reduction of up to 50% of conventional steel profiles, have improved fatigue resistance due to the connections being laser welded, and save on construction time due to production being automated. The sandwich plate system, comprising two (steel) flange plates bonded to a continuous elastomer core or web, forms a much stiffer and stronger system than a single steel plate, doesn't need closely spaced stiffeners and is relatively fatigue insensitive.*

Keywords: Sandwich Plate, deck slab, Polyurethane Elastomer

1. Introduction

A bridge deck or road bed is the roadway, or the pedestrian walkway, surface of a bridge, and is one structural element of the superstructure of a bridge. The bridge deck may be constructed of steel, concrete or wood. Sometimes the deck is covered with asphalt concrete or other pavement. The concrete deck may be an integral part of the bridge structure (T-beam or double tee structure) or it may be supported with I-beams or steel girders. There are different types of bridge decks such as bridge decks with stiffened plates, orthotropic bridge deck, closely spaced ribs deck, bridge deck with steel girders etc. A sandwich plate was used instead of traditional stiffened steel plate for ship hulls and decks. After the successful completion of numerous ship repairs and new construction, a sandwich plate was proposed for use in civil engineering applications such as bridge decks and floor systems due to the cost effectiveness of the product.

2. Literature Survey:

Kennedy et al. (2002) discuss the need for a lightweight, cost efficient bridge deck for movable and military bridge decks. Traditional steel plate orthotropic bridge decks are costly due to the type and amount of welding required. A traditional steel box girder is compared to a stiffened sandwich plate box girder and a composite core sandwich plate box girder. Only the effects of traffic loads were checked on the different deck configurations. Both sandwich plate alternatives were more cost efficient and satisfied the required ultimate, fatigue, and serviceability limit states. They concluded that sandwich plate is cost efficient and beneficial due to less welding and ease of erection.

A technical bulletin published by Lloyd. S. Register (2000) found that the Sandwich Plate System has many advantages over a stiffened steel plate in maritime applications. They determined a composite sandwich plate distributed stress over a larger area than a conventional steel plate for a double-hull oil tanker design. Due to elimination of stiffened plates, crack formation is rare. Also, the simplified structural system was easier to coat and maintain; other advantages of a sandwich plate are the integrated acoustic and thermal insulation and increased impact resistance.

Intelligent Engineering (2002) prepared a technical report for the Austrian Military where a 5-40-5 Sandwich Plate System Bridge Deck Panel was used to replace a traditional stiffened bridge deck panel. The 5-40-5 numbering indicates the thickness of the steel plate, elastomer core, and steel plate, respectively, in millimeters. Three static tests were performed on the 5-40-5 sandwich plate system in Ludwigshafen, Germany, and the results showed the sandwich plate panel carried 1.29 times the design load applied at the maximum eccentricity. A fatigue test was conducted to 5 million cycles without any cracks forming. A finite element analysis was performed using ANSYS and a discrepancy of only 7% was found between the experimental and predicted deflections. The experimental strains were found to be in reasonable agreement with the analytical model, and there was no sign of creep during any of the experimental testing. Prior to the fatigue testing, an asphalt wearing surface was applied to the deck no evidence of debonding was found between the steel plate and elastomer core at the completion of fatigue testing. Intelligent Engineering determined that the 5-40-5 Sandwich Plate System design to be acceptable, and to perform better than a stiffened steel plate deck.

Intelligent Engineering (2004) conducted an analytical study using a 6-40-6 SPS for the top flange of a box girder for the proposed Mexico City Elevated Ring Road. Due to the soil conditions in Mexico City, a light, cost efficient alternative to a traditional reinforced concrete deck is required. The structural design was based on the Canadian Highway Bridge Code

(2000a), and all the code requirements were met. A finite element model was created to determine the local behavior of the guard rail structure, the SPS bridge deck, and the longitudinal weld group. They concluded that the dead weight of the structure would be reduced by nearly 50% using the Sandwich Plate System. The reduction in dead weight reduces the load transferred to the foundation as well as reduces the earthquake forces applied to the structure.

Intelligent Engineering (2004) performed static and dynamic tests on the Shenley Bridge in the municipality of Saint-Martin, Ontario, Canada. The Shenley Bridge was the first bridge to be constructed using the system described above as the bridge deck. A test truck with a weight of 519 kN (117 kips) was used in five different testing configurations, causing a maximum bending moment of 1398 kN-m (95.8 kip-ft). This was approximately 20% of the maximum moment that could be applied to the bridge deck. A finite element analysis was performed using ANSYS and the measured strains and deflections were found to be in good agreement with the predicted values. To meet the requirements established by the Canadian Highway Bridge Design Code, a dynamic test was also conducted. The first mode due to bending occurred at 5.8 Hz, and the second mode caused by torsion occurred at 6.0 Hz. The Shenley Bridge exhibited a damping ratio of 0.8% for the first bending mode. When compared to a reinforced concrete deck with the same 200 mm (7.87 in.) thickness, the sandwich plate bridge deck is 57% lighter, and the stiffness is greater than a traditional orthotropic bridge deck resulting in less deflection and deck curvature.

Wolchuk (1990) investigated weld cracks on three European orthotropic bridge decks. The Haseltal and Sinntal Bridges in Germany developed cracks in the welds joining the steel deck to the V-shaped ribs. The cause of the cracks was not due to fatigue, but to weld shrinkage occurring immediately after the weld cooled. Wolchuk (1990) concluded that the best welders and welding sequence could not have prevented the cracks from forming between the deck and discontinuous ribs. Wolchuk (1990) also examined weld cracks in the Severn Crossing Bridge in the United Kingdom, and he found the cracks were caused because fillet welds were used in lieu of 80% penetration welds. The fillet welds caused the connection between the ribs and cross beam to experience eccentricity, which increased the propensity for fatigue cracks.

Chenglin Shan, The buckling of steel-polyurethane sandwich bridge deck is studied via experiment and nonlinear numerical calculations, the authors first analyzed the stress distribution of key points of a three-span continuous bridge deck with sandwich structure in the state of buckling and then analyzed the influence of the changes of several size parameters on the buckling modes and the critical loads. The results show that when the sandwich bridge deck is compressed, the closer to the middle section in mid-span, the greater the longitudinal compressive stress on the steel faceplate, but the smaller the longitudinal compressive stress on the bottom of the stiffening ribs. The longitudinal stresses on the steel faceplate and the bottom of the longitudinal stiffeners are unevenly transversely distributed near the ends of the applied force, but the stresses are gradually uniform near the mid span section. When this kind of sandwich bridge deck is designed, first its thickness should be decided, and then adjust the spacing of the longitudinal stiffening ribs in order to reduce workload and save material.

According to A. Gopichand et al., SPS floor had higher natural frequencies with its first natural frequency to be around 6 times more than that of simple plate floor. They have performed Modal Analysis in order to calculate natural frequencies. The 3D floor assembly is modeled in Pro-E and model is imported in ANSYS workbench.

As mentioned by Hesham Tuwair et al., Three different types of polyurethane foam combination were considered for the inner core, and the most suitable system was recommended for further prototyping. These combination consisted of high-density polyurethane foam (Type 1), a bidirectional gridwork of thin, interconnecting GFRP webs that is filled with polyurethane foam which have low-density (Type 2), and trapezoidal-shaped, low-density polyurethane foam utilizing GFRP web layers (Type 3). The facings of the three cores consisted of three plies of bidirectional E-glass woven fabric within a compatible polyurethane resin. Several types of small-scale experimental 17 investigations were conducted. The results from this study indicated that the Types 1 and 2 cores were very weak and flexible making their implementation in bridge deck panels less practical. The Type 3 core possessed a higher strength and stiffness than the other two types.

3. Conclusion:

Following points can be summarized from the literature review:

1. Steel Polyurethane Steel (SPS) Plates are good replacement for the stiffened plates used for bridge decks.
2. Natural Frequency of Sandwich plate system is more than that of traditional plates.
3. When compared with reinforced concrete deck, Steel Polyurethane steel sandwich plate proves to be lighter.

References

1. D. J. L. Kennedy, R. A. Dorton and S. D. B. Alexander, "The Sandwich Plate System For Bridge Decks"- International Bridge Conference, 10-12 June 2002, Pittsburgh, USA, pp 01-04.

2. Lloyd. S. Register (2000) "Provisional Rules for the Application of Sandwich Panel Construction to Ship Structure" a technical bulletin, pp 03-11.

3. A. Gopichand, G. Krishnaiah, Diwakar Reddy. V, N. V. S. Shankar, "Modal Analysis of a Steel Sandwich Plate System (SPS) Floor"-International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 11, November – 2013 ISSN: 2278-0181, pp 3002-3004.

4. Intelligent Engineering (2004), "Report on Shenley Bridge in the municipality of Saint-Martin", Ontario, Canada, pp 56-63.

5. Intelligent Engineering Canada Limited. (2003) " SPS Bridge Deck Plates For Mexico City Elevated Ring Road, Intelligent Engineering Canada Limited, Ottawa, ON.

6. Wolchuck, Roman. (1990) "Lessons From Weld Cracks In Orthotropic Decks on Three European Bridges", Journal of Structural Engineering, American Society of Civil Engineering, Vol. 116, No. 1, 75-84.

7. Intelligent Engineering (2002), "Report on the Austrian Military Sandwich Plate System Bridge Deck", pp 12-16.

8. Chenglin Shana, Yuhua Yib, "An experimental and numerical study on the behavior of a continuous orthotropic bridge deck with sandwich construction", Thin–Walled Structures (2017), pp 138-144.

9. Hesham Tuwair et al., "Evaluation of sandwich panels with various polyurethane foam-cores and ribs", Composites(2015).