BEHAVIOUR OF SANDWICH PLATE SYSTEM IN BRIDGE DECKS

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Abstract : The demand for lighter steel bridges is always sought after. Manufacturers are always searching for new solutions to decrease the weight of bridges and to improve the service life without compromising bearing capacity. Possible modifications are replacing the conventional orthotropic steel deck with a steel sandwich deck for improved weight and performance. 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 and it does not need closely spaced stiffeners and is relatively fatigue insensitive. In this paper, eight types of steel polyurethane sandwich plates are analyzed and tested under universal testing machine.

***IndexTerms* - polyurethane, elastomer, SPS, Sandwich Plate system, bridge deck**

I. INTRODUCTION

A bridge deck is the roadway, or the pedestrian walkway, surface of a bridge, and is one of the structural element of the superstructure of a bridge. The deck may be constructed of wood, concrete and steel. The deck may be covered with asphalt or and concrete. The concrete deck is the integral part of the bridge structure in the form of 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 system comprised of two steel plates bonded to a solid elastomer core, has been proposed for bridge decks. The use of an elastomer core has a number of advantages. The elastomer core prevents the steel plate from buckling. Also, the steel plates are entirely reinforced so that intermediate stiffeners are not required. Another advantage of a sandwich plate system is that the size of each steel plate and the core can be adjusted to any desired thickness based on the structural load requirements. A sandwich plate bridge deck has advantages over a reinforced concrete deck. The concrete bridge deck is heavier than the sandwich plate deck. A considerable amount of cost can be reduced by using a sandwich plate bridge deck panel. The savings come from the increased stiffness of the composite deck, ease of construction, and savings in repair costs over the life time of the structure.

A bridge deck using sandwich plate panels has been proposed as a replacement to traditional reinforced concrete bridge decks. A perimeter box consists of steel is constructed and the elastomer is injected using standard pumping equipment. The transverse ends of the box are cross stringers. To construct the bridge, the cross stringers are bolted to steel girders and the panels are bolted to each other. After the bolts are pretension, a groove weld is placed in the field to develop full composite action.

II. Literature survey:

Kennedy et al. (2002), has discussed the need for a lightweight, cost efficient bridge deck for movable and military bridge decks. Traditional steel plate orthotropic bridge decks are costly because of the type and amount of welding required. A traditional steel box girder is compared to a stiffened sandwich plate box girder and a sandwich plate used box girder. In their study, only the effects of traffic loads were examined on the different deck configurations. Stiffened sandwich plates and sandwich plate system without stiffeners both gave good results than steel box girder. They concluded that the system as described above is an attractive alternative to traditional bridge decks due to reduced welding and ease of erection [1].

K V Ramakrishnan, Dr P G Sunil Kumar (2016), Considering the high strength to weight ratio, ease of construction, blast and ballistic properties of the material, availability of a flush surface etc., SPS has been widely used in building bridges, stadiums, floors, blast walls etc. Sandwich plate panels have also been used in ship repair as an overlay on existing structures, converting them conventional steel to sandwich plates. The use of complete hull structure made of SPS is not easy. Upto the date, there is no detailed study about ship hull sandwich panel is available just beacause of the non-availability of proper design tools for the sandwich panel system [2].

Chenglin Shan (2017), The buckling of steel-polyurethane sandwich bridge deck is studied 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. According to author, thickness of the sandwich panel must be selected first prior to the spacing of the longitudinal stiffening ribs in order to save the material and reduce the work load [3].

Gopichand et al.(2012), The sandwich panel model in PRO/e is efficiently imported into ANSYS workbench structural analysis is done and max stress is observed at top face.. For increase of 4% weight, the strength is increase to 66% and increasing the number of curved waves (3 waves to 4 waves) the strength increases effectively [4].

Endrit Beneus (2014), The results from the optimization analysis indicated that steel sandwich panels can be optimized to have increased stiffness relative to the weight or decreased weight relative to the stiffness of a conventional steel orthotropic panel. Results from FEM analysis provided the largest effective flange width for the bridge with the stiffer SSP deck and the smallest effective width for the orthotropic bridge. According to author, larger the effective width of bridge, bridge is stiff. Conclusion is that the orthotropic deck was not utilized very efficiently [5].

3. Experimental work:

Following materials are used in sandwich plate system:

MS Steel plates:

Mild steel plates are used as face material for sandwich plates. Upper layer and bottom layer is mild steel plates.

Elastomer:

Polyurethane elastomer is a thermosetting polymer used as a core material for sandwich plate. Middle layer of the plate is made up of this elastomer. Two types of elastomers are used namely HP (clear) and PF (white).

Fig. 1 Sandwich plate panel

This test is carried out in universal testing machine. Sandwich panel supported by both sides is to be loaded by applying point load. Three point flexure test is carried out. Total 8 specimens are tested.

Table 1. Properties of materials

Properties	Steel	Polyurethane PF white	Polyurethane HP clear
Density (kg/m^3)	7850	1500	1250
Young's modulus (GPa)	200	75	75
Poisson's ratio	0.3	0.42	0.47
Curing period (hrs)	-	24-30	24-30

Table 2. Specimen details for 1st phase testing

Sr. No.	Specimen	Steel plate thickness (mm)	Core thickness (mm)	Name of polyurethane
1	5-25-5	5	25	HP (clear)
2	5-25-5	5	25	PF (white)

Table 2. Specimen details for 2nd phase testing

Sr. No.	Specimen	Steel plate thickness (mm)	Core thickness (mm)	Name of polyurethane
1	5-25-5	5	25	HP (clear)
2	8-25-8	8	25	HP (clear)
3	8-25-5	8,5	25	HP (clear)

Table 3. Specimen details for 3rd phase testing

Sr. No.	Specimen	Steel plate thickness (mm)	Core thickness (mm)	Name of polyurethane
1	5-30-5	5	30	HP (clear)
2	8-30-8	8	30	HP (clear)
3	8-30-5	8,5	30	HP (clear)

4. Fabrication of steel Sandwich plates:

Firstly, polyurethane elastomer is taken which is available in liquid form. To make it hard hardener is to be added in it. 25% of hardener is to be added in polyurethane liquid and mixed it thoroughly for 2 to 3 minutes. Further two mild steel plates of 5 mm thickness are taken of same size i.e. 150mm X 150mm and polyurethane is then poured in between those two plates maintaining the core thickness of 25mm. All the eight number of plates are fabricated in the same manner as above and are kept at dry place for settling. Setting time for polyurethane is 24 hrs. to 30 hrs. Only precaution that should be taken is to avoid water contact with polyurethane up to 24 hrs. from mixing the hardener.

5. Results

Table 4. Comparison of results for 1st phase

Sr. No.	Specimen	Max Load (kN)	Deflection from software analysis (mm)	Deflection from testing (mm)
1	5-25-5	70	7.4	5.4
2	5-25-5	55	11.21	8.1

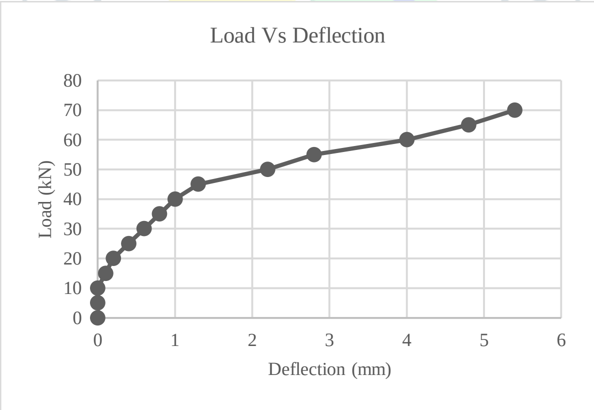

Fig. 2 Load Vs Deflection curve for Specimen 1 from 1st phase

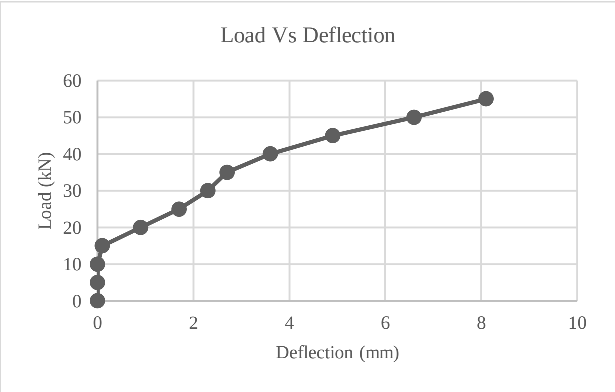

Fig. 3 Load Vs Deflection curve for Specimen 2 from 1st phase

Table 5. Comparison of results for 2nd phase

Sr. No.	Specimen	Max Load (kN)	Deflection from software analysis (mm)	Deflection from testing (mm)
1	5-25-5	40	17.63	19.8
2	8-25-8	95	19.68	16.5
3	8-25-5	75	19.85	17.4

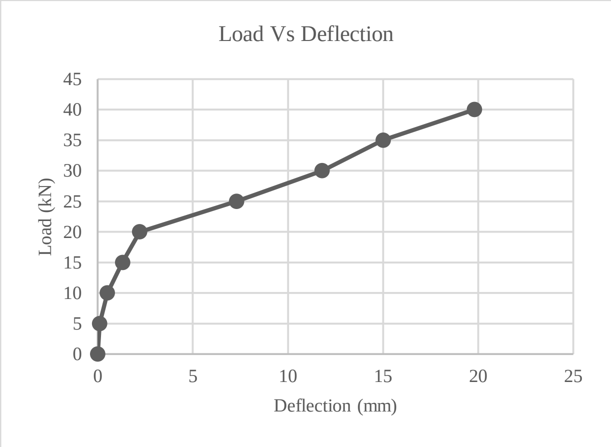

Fig. 4 Load Vs Deflection curve for Specimen 1 from 2nd phase

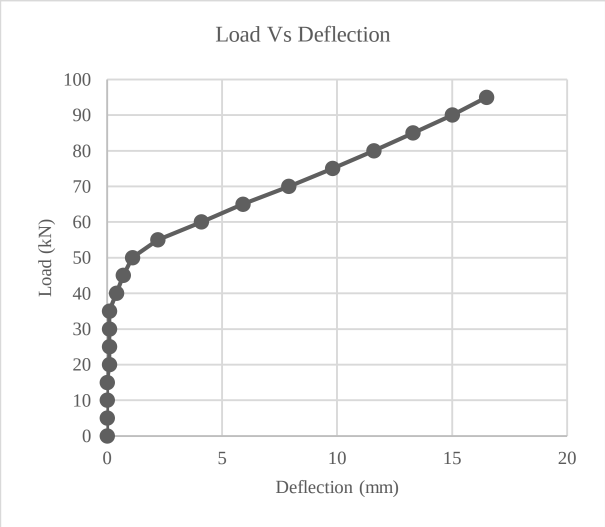

Fig.5 Load Vs Deflection curve for Specimen 2 from 2nd phase

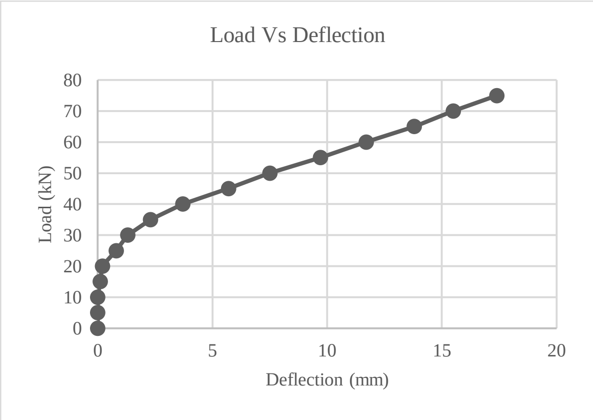

Fig. 6 Load Vs Deflection curve for Specimen 3 from 2nd phase

Table 6. Comparison of results for 3rdphase

Sr. No.	Specimen	Max Load (kN)	Deflection from software analysis (mm)	Deflection from testing (mm)
1	5-30-5	50	17.54	15.6
2	8-30-8	110	21.11	18.3
3	8-30-5	75	21.77	18.1

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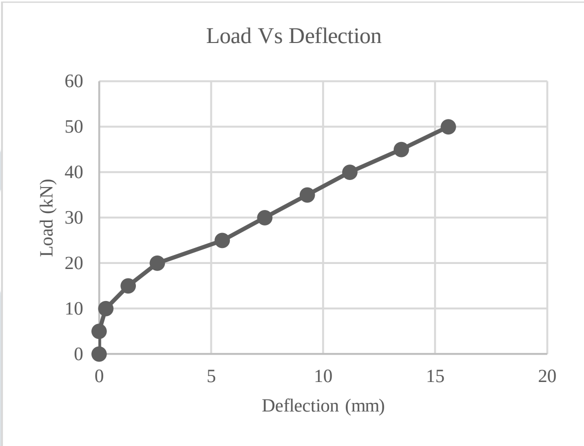

Fig. 7 Load Vs Deflection curve for Specimen 1 from 3rd phase

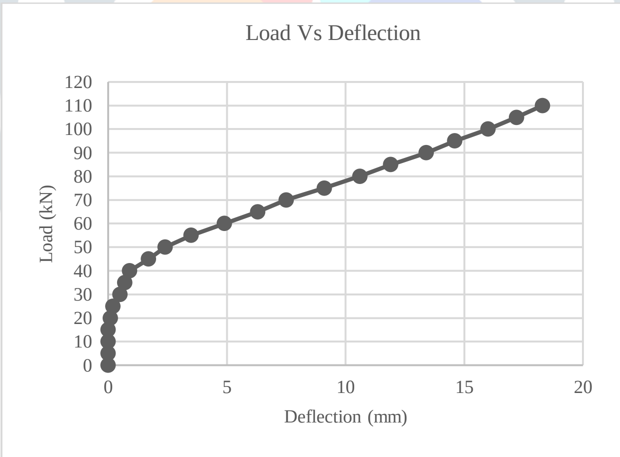

Fig. 8 Load Vs Deflection curve for Specimen 1 from 3rd phase

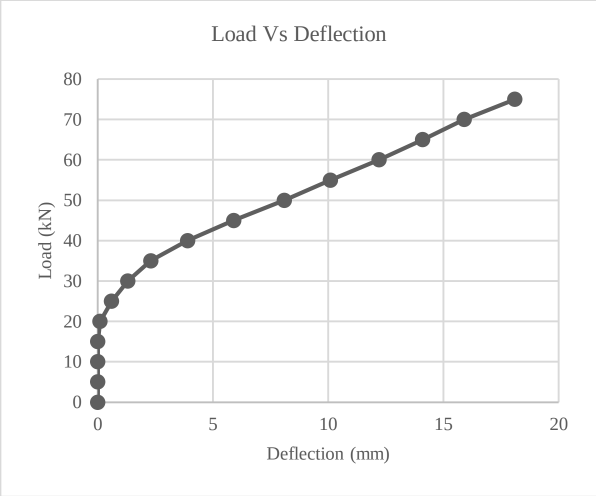

Fig. 9 Load Vs Deflection curve for Specimen 1 from 3rd phase

All the eight specimens of sandwich plate system have been analyzed using ANSYS Mechanical APDL 16.0 and a same specimen were tested under universal testing machine of capacity 1000 kN and after comparing the results it is found that results varies between 10% to 15%. ANSYS shown deflection little more than actual testing deflection.

6. Conclusion:

1. Fabrication of the sandwich plate panels is very easy and as they are prefabricated, they are easy to install.
2. As Sandwich plate system have thermosetting polymer as a elastomeric core, plate becomes fire resistant and less temperature stresses are induced in it.
3. Density of a polyurethane elastomer is very less as compared to steel, so it is light weight member.
4. Polyurethane elastomer is cheaper than that of mild steel plates, so it is cost efficient method for constructing bridge decks. Also the weld length in the sandwich plate panels is less as compared with orthotropic deck or stiffened plates. It saves the cost of welding.
5. Polyurethane elastomer have damping characteristics so use of it as core material in sandwich plate system makes deck impact resistant.
6. Optimum configuration of sandwich plate panel can be considered as the 8-30-5 from the present study.
7. Stiffened plates in bridge deck can be replaced by sandwich plate system.

7. References:

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