Theoretical and numerical approach to calculate the shear stiffness of metal deck
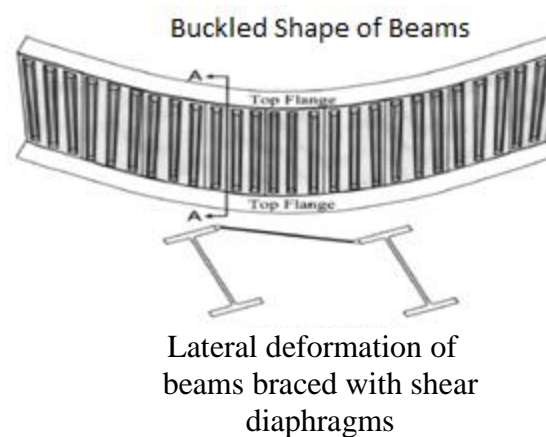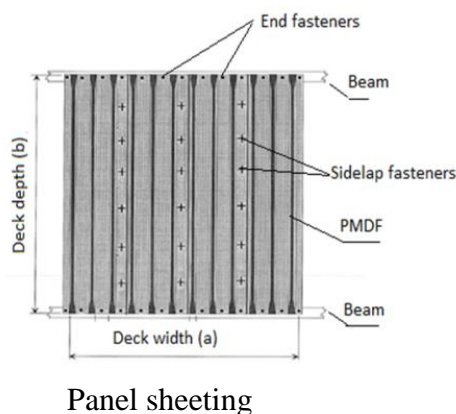
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A good estimation of shear rigidity against lateral moving for corrugated metal deck forms will improve the understanding of stabilizing potential of metal deck forms in bridge systems. Shear forces of fasteners between bridge girders and metal deck forms are also important to properly benefit metal decks as shear diaphragm.

Metal deck forms

Metal deck forms are used in building application as a lateral beam bracing. In bridge applications, metal decks can be used to support the weight of wet concrete of bridge decks (especially in steel girders with trapezoidal cross section) during construction phase. However, they are not relied on as lateral bracing. The behavior of corrugated metal deck forms as shear diaphragm in bridge system, to resist the lateral moving of girders under construction loads needs more investigations. Therefore, a good prediction of metal decks' shear stiffness will provide better understanding of the stabilizing potential of metal deck forms system in bridge application.

Panel sheeting

Lateral deformation of beams braced with shear diaphragms

Shear rigidity

Based on definition used in EuroCode, shear diaphragm is a general term for one or more shear panels which resists in-plane displacements because of shear. Currently, the more proper method
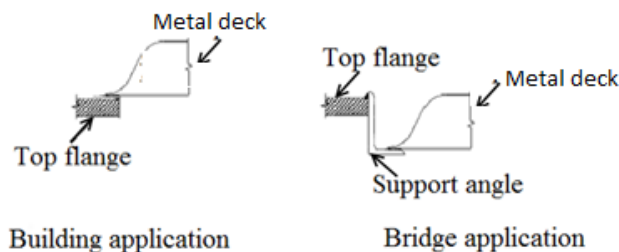
to estimate the shear stiffness of metal decks is utilizing experimental tests. Therefore, a numerical method, as alternative, is of interest to economically compute a reasonable estimation of shear stiffness of metal sheets

European Recommendations (ECCS)

The procedure that is found in the European Recommendations (ECCS) to calculate the shear stiffness of corrugated metal deck was based on building applications. Thus, a modification on this procedure is required to be useable in the bridge application.

The differences between the building application and bridge system metal deck forms should be considered to calculate shear the stiffness according to ECCS. The main differences are:

   a) The use of purlins, as perpendicular members, in the building application.
   b) The ends of metal decks profile are open in building application while the decks in the bridge system are closed-end.
   c) Metal decks are applied directly on the top flange of the beams in the building application; however the support angles, as it is shown in figure below, are used to attach metal decks to girders in the bridge system.

Building application   Bridge application

Total shear flexibility of deck forms that are used in the bridge applications will be described as the summation of components of the various factors involved. The main flexibility components considered include: shear deformation of metal sheet, distortion of corrugation profile, and the slip of the sheet-to-beam fasteners and seam connections. For bridge system, assuming that the beams are rigid, the flexibility due to axial deformation of beams can be ignored. There are no purlins in the bridge applications so the flexibility due to fasteners deformation in the sheet to purlins can be neglected.

An investigation was conducted at LTH, Lund University, to calculate the shear stiffness for several panels sheeting with variation in dimensions and boundary conditions. The primary objectives of this study are:

   1) To determine the effect of the open and closed-end metal deck forms on effective shear stiffness.

2) A comparison of the shear stiffness value in building application to the shear stiffness value in bridge application.
3) An examination of the effect of the span length and sheet thickness on shear stiffness
4) An examination of the effect of the overall panel width on shear stiffness
5) A comparison of the results of shear stiffness obtained from SDI Manual recommendations, the ECCS Recommendation, to the results that were computed by Finite Element Method (FEM).
6) Determination of procedures to allow an approximate determination of shear stiffness using Finite Element Modeling.

Fasteners' shear forces

Suitable structural connections are used to transmit diaphragm forces to the main steel members, the sheeting should be attached with fasteners which can carry shear forces without reliance on friction or bending of the fasteners themselves. The relation between lateral applied load due to lateral torsional buckling and the forces on the fasteners was derived as a result of the study conducted at LTH. The distribution of fastener forces across panel width and the effect of some parameters such as: span length between beams, panel width and the thickness of sheet were also investigated.

Results of study

The calculated results indicate that using SDI Manual's procedure will result in more reasonable stiffness values than using ECCS Recommendations' procedure. ECCS procedure generally results in considerably smaller shear stiffness, this could be attributed to the differences of values of the coefficients, as slip coefficient and warping constant, that were used in calculations. Although the results of the three methods that were used in the shear stiffness investigations are different comparatively. The results show that the effect of parameters: sheet thickness, length of span and overall panel width on the shear stiffness is similar in spite of the method that was used.

Moreover, the study showed that the variation in the sheet thickness lead to a minor effect on the fastener forces; forces would be increased in the fasteners that fasten thinner sheets. The investigation showed that using side lap fasteners to attach the adjacent sheets will result in a reduction of approximately 65% in the forces that act on the end fasteners. The fastener forces distribution investigation for panel sheeting with different spans indicated a reduction in the fastener force that act on the fastener when the length of span is increased.