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Finite Element Technology for Steel-Elastomer-Sandwiches

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Orthotropic bridges are widely used in today's street infrastructure, especially when large spans have to be bridged. They consist of steel deckplates with attached - typically longitudinal - steel stiffeners and transverse cross-beams.

Unfortunately many existing bridges do not concur with today's best practices. Typically the recommended minimum thickness of the steel and asphalt layer is not met and the largest allowable stiffener separation is exceeded. This shortcoming usually manifests in cracks and failure of the welded connection between the deckplate and the stiffeners.

The described premature failure of orthotropic bridges creates a demand for refurbishment and improvement of the existing bridges. One possible solution is the sandwich plate system (SPS). This system consists of two steel plates with a polyurethane core in between. Extensive measurements of specimen with various geometries were carried out in a previous research project [1]. The chosen geometry was afterwards applied to a German motorway under severe traffic.

Previously the numerical prediction of the plates was done using a "quasi-3-D"-model in which 4-node shell elements were linked with trusses forming a cantilever beam. The separation of the shells represented the thickness of the deckplate, i.e. all 3 layers. The stiffness of the trusses and shells were chosen such that they approximate the shear and bending stiffness of the composite. The described approach led to predictions which were in good agreement with the experimental results.

The drawback of this method is that the mechanical properties of the composite have to be known, the material parameters of the constituents and the geometry alone are not sufficient. This is a consequence of each truss representing multiple layers. It is unclear whether introducing shells at each layer interface and trusses between all the neighbouring shells could alleviate this restriction. Even if the truss stiffness could be derived directly from material parameters and geometry rather than from a parameter fit, other problems still remain. For instance, implementing full 3-D material models is difficult since trusses are 1-D elements and shells are 2-D elements. Other problems arise in the context of large deformations.

In order to improve these aspects, the orthotropic plate is modelled using solid-shell and solid-beam element formulations recently developed in [2], [3]. These are 8-node reduced integration elements with a variable amount of integration points in one (solid-shell) or two axes (solid-beam). This allows the separate modelling of each layer with its physical thickness and material properties, thus avoiding the “smearing” of mechanical and structural parameters. The solid-beam and solid-shell elements used in this survey also feature assumed natural strain (ANS) and enhanced assumed strain (EAS) formulations. In combination with reduced integration and hourglass stabilization this is amongst others useful to avoid volumetric locking, as it happens with near-incompressible materials such as polyurethane.

Concluding, a numerical investigation is carried out and the predictions are compared with experimental results.

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