UNIVERSITI TEKNOLOGI MARA

FINITE ELEMENT INVESTIGATION ON THE STRUCTURAL RESPONSE AND PERFORMANCE OF HYBRID GLULAM COLD-FORMED BOLTED CONNECTIONS ROOF TRUSSES

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ABSTRACT

The collapse of solid timber roof truss is normally associated with uncertainty in the quality of timber. Therefore, engineered timber product such as glulam or LVL has been used. The use of glulam in Malaysia is still limited. For the use of glulam as roof trusses, some modifications are recommended. As the glulam from tropical hardwood is heavier than the glulam from softwood, therefore the use of a hybrid roof truss system is a way forward. This investigation reports on the structural performance of hybrid truss systems consisting of cold-formed steel and glued-laminated timber (glulam) by experimental and finite element model. A comprehensive finite element model for analysing and predicting the load-carrying capacity of hybrid roof trusses is developed and presented. By incorporating the glulam and steel cold-formed properties as well as different joint configurations and connections, the model characterizes the variability of the components to predict the response load-carrying capacity. An extensive experimental program has been designed to achieve the objectives of this study which includes experimental investigations in determining the mechanical properties of constitutive materials, joint connections, and roof trusses as well as the development of finite element modelling and analysis. In the first experimental programme, a series of tests were conducted to determine the strength properties of the glulam namely, compressive, tensile, bending, and torsional tests. The embedment strength test for compression parallel to grain and perpendicular to the grain, as well as the bending test of the connectors (bolts) were also performed to evaluate the embedment strength and dowel yield moment. The second experimental programme performed joint isolation tests for web to chord bolted joints with different configurations. Three bolted connections in isolation were examined: a) glulam and glulam tension splice; b) glulam and cold-formed with two different angle connections, and c) Glulam and glulam loaded perpendicular to the grain. In the third experimental program, Finite Element models were developed for glulam elements (beam, compression, and tensile test specimen) and splice joint in tension. The strength and stiffness of the joint connection, as well as the categories of joint failure, were discussed in accordance with EC5. The failure mode was determined as category (g) for double shear connection. In the fourth experimental program, the reduced-scale fink-type hybrid roof truss was fabricated and tested experimentally. Detailed finite element models of reduced-scale roof truss were performed to simulate the experimental hybrid glulam cold-formed. The finite element model included advanced features such as contact non-linearity and orthotropic material non-linearity. The result of the model was validated and corroborated against the experimental result and the error found was less than 1%. The developed finite element models of reduced-scale hybrid truss were employed in a parametric assessment to highlight the influence of steel plate geometric, thickness, and the 3-D finite model demonstrated material considerations and the behaviour of the truss. As the finite element strength model developed for reduced scale hybrid roof truss has been calibrated and verified, the last experimental program is to model the full-scaled hybrid roof truss and full-scaled glulam roof truss with a span of 18 m by simplification of the 2-D model. The maximum displacement of a hybrid truss is higher than the Glulam truss by 10%, and the weight is reduced by approximately about 13% from the whole glulam truss. The hybrid glulam cold-formed roof truss has a high potential to replace existing prefabricated timber and cold-formed roof trusses.

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