Chapter Eight

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORKS

Chapter 8: CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORKS

8.1 CONCLUSIONS MADE FROM EMBEDMENT STRENGTH TEST SERIES

- EC 5 recommendations predict the embedment strength of local timber species reasonably well with a little discrepancy between the EC5 predictions and the experimental results.

- Difference between EC5 predictions and experimental results increase with increasing of bolt diameter for parallel to grain loading.

- Difference between EC5 predictions and experimental results decrease with increasing of bolt diameter for perpendicular to grain loading.

- Results of linear regression analysis also verify above-mentioned conclusions.

- Equation 6.1 and Equation 6.2 are proposed to be used for the determination of embedment strength of local timber species.

- Proposed new model does not have a considerable effect on either joint strength or the failure pattern of joints tested in joint strength test series.

8.2 CONCLUSIONS MADE FROM JOINT STRENGTH TEST SERIES

- European Yield Model provides more realistic design method than other empirical and analytical models, which are used to design, nailed and bolted timber joints, considering the effects of all geometric and material parameters.

- As a whole, EYM seems to be good in predicting the strength and the failure patters of joints tested.

- EYM predicted every type of failure patterns for the joints tested in this test programme.

- Every type of failure patterns were observed for the joints loaded in parallel to grain direction.

- Only failure patterns of mode 1b, mode 2 and mode 3 were observed for the joints loaded in perpendicular to grain direction.

- It seems that the EYM predictions for failure mode are reasonably good because percentage of joints, which were predicted accurately by the EYM, is close to 50%.

- The best accuracy of prediction of failure pattern is with the bearing failure of central member (mode 1b).

- Thus the EYM can be regarded as good for predicting the joints, which fails due to bearing failure than the bending failure.

- Experimental joint strengths were predicted well by EYM when thickness ratio is close to unity.

- Factor of Safety increases in considerable level when increasing the main member thickness while keeping the side member constant in thickness.

- Some of these factors of safety are too high and resulting in more conservative design.

- Although the experimental strength of the joint increases in considerable level with increasing of the thickness ratio, EYM predictions are almost same for every thickness ratio when considering a particular bolt diameter and side member thickness.

- It seems that the effect of central member thickness on the strength of joint is not critically considered by the EYM theory.

- Although the joints which have larger central member thickness were predicted to fail in mode 2 and mode 3 failure types, in which central member thickness is less critical factor, they were failed in mode 1b failure type, in which central member thickness is more critical factor.

- This behaviour was not observed by early researches. Most of early researches were conducted using unique thickness ratio (side to central) that is equal to 2.0.

- A modification factor based on the joint geometry is proposed to reduce this discrepancy between prediction and experimental results and bring the average factor of safety approximate to 2.0, which brings the factor of safety of the joint to a reasonably conservative value.

- Equation 7.4 can be used to calculate the modification factor according to the ratio of central member thickness to bolt diameter (t_2/d) and this modification factor independent from member density, member thickness and loading direction.

- After modifying the EYM predictions using the proposed modification factor, the average factor of safety is around 2.0 and thus the design has reasonably conservative factor of safety value.

8.3 RECOMMENDATIONS FOR FURTHER WORKS

- Proposed model for embedment strength (Equation 6.1 and Equation 6.2) is based on the experimental results obtained from this test series. Therefore, it is necessary to conduct a verification test programme with a wide range of parameters that affect the embedment strength to check the reliability of this proposed model and carry out necessary modifications.

- Specimens of embedment strength test were loaded in parallel and perpendicular to grain directions only. Applicability of Equation 3.25 can be further checked by conducting embedment strength tests varying the loading angle from 0^0 to 90^0.

- Only side members of the joints, in which the joints tested in perpendicular to grain direction, were subjected to the loading in perpendicular to grain direction. Therefore, it is necessary to expand the test programme as central members too are subjected to perpendicular to grain loading.

- Because of the concept of applying an adjustment factor based on joint geometry has not been proposed by earlier researchers, it is strongly recommended to carry out further investigation with wider range of joint geometry.

- Further, this research programme used lower bolt diameters and member thickness although much larger size bolts and very thick members are often used in the construction industry. Internationally, bolts of the size of more than 50mm are also used with suitable member sizes for heavy constructions. Therefore, it is required to check the applicability of EC5 recommendations to the joints made form local timber species with these larger bolts sizes too.

- Also, to develop the proposed adjustment factor, this test programme used only local timber species, which belongs to hardwood category. Therefore, it is necessary to carry out more researches with both softwood and hardwood categories to reach a reliable decision.

- This test programme was limited to the two local timber species. Because, number of species tested in this research programme is not enough to reach a reliable decision, conducting a further test programme with other timber species, in which density ranges from low to high, is required.

- It is recommended to conduct joint strength tests loading both side and central members in the directions other than parallel and perpendicular to grain.

- For future test programmes, it is necessary to select joints geometries such the way that there is a wide range of central member thickness for a particular bolt diameter and side member considered. This is required to carry out analysis plotting the normalized joint strength against the t_2/d ratio.

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