

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

A finite element model is introduced to investigate the effect of angle thickness on the behavior of a double angle connection. Three angle sections, L5x3x1/4, L5x3x3/8, and L5x3x1/2 sections, were studied under axial tensile loads, shear loads, and combined axial tensile loads and shear loads. The load-displacement relationship and the moment-rotation relationship of the double angle connection were developed under these three loading conditions in this research.

Two experimental tensile tests were conducted to verify the results of the 3D finite element model under axial tensile loads. Two angle sections, L5x3x1/4 and L5x3x1/2 sections, were used in these experimental tests.

A simplified angle model is introduced to simulate the complex angle behavior and to calculate the initial stiffness of a double angle connection. To save the time and the cost of the computer required in the analysis, an equivalent spring model is suggested in this research. The angle specimen properties are used in the two spring elements which have the same stiffness under each loading condition.

The results of the 3D finite element model and those of experimental tests and simplified models are used to obtain appropriate parameters for Richard's formula.

5.2 CONCLUSIONS

5.2.1 3D Finite Element Model Analysis

The parameters in Richard's formula, such as K , K_p , R_0 , and n , can be obtained from a regression analysis of the load-displacement curve and the moment-rotation curve of the 3D finite element model. Considering these parameters, it was found that the initial stiffness, K , of a double angle connection is mainly dependent on the value of $(t/b)^3$. Similarly, the reference parameter, R_0 , is also proportional to $(t/b)^2$ for each case.

To verify the results of the 3D finite element model, two experimental tests were conducted for two angle sections under axial tensile loading. Compared to the load-displacement curve of the experimental test, the 3D finite element model gives good results for the L5x3x1/4 double angle connection. Even though the load-displacement curve of the L5x3x1/2 angle test shows a discrepancy with that of the 3D finite element model, the suggested 3D finite element model can be accepted as a good model for the analysis of a double angle connection.

5.2.2 Simplified Model Analysis

Because the initial stiffness of the simplified angle model shows good agreement with that of the 3D finite element model under axial tensile loading, the simplified model can be considered as a good replacement for the calculation of the initial stiffness of various angle sections.

Compared to the results of the 3D finite element model, those of the equivalent spring model give a good approximation with the parameters obtained for Richards' formula

under axial tensile loading and shear loading. Thus, the equivalent spring model can be an acceptable substitution.

If the parameters in Richard's formula are known for a certain section, the load-displacement relationship and the moment-rotation relationship for various angle sections can be easily obtained by using the equivalent spring model with the findings on the relationship between Richard's formula parameters and angle thicknesses which were discussed in Section 5.2.1. This will be helpful for designers to understand the behavior of a double angle connection under initial loading.

5.3 RECOMMENDATIONS

- i) If the computer costs for the analysis of a double angle connection are of no concern, it is recommended to include the contact forces between the bolt shanks and the bolt holes to show the effects of those phenomena.
- ii) Because the inflection points of the outstanding leg of an angle play an important role, it is recommended to include the effects of washers in the development of a 3D finite element model.
- iii) Because the equivalent model uses basically the results of a 3D finite element model and the regression technique for each spring stiffness, it is recommended to develop a more general procedure which is based on the geometric properties of a double angle connection for various loadings.
- iv) Because this research has only been conducted to show the effects of angle thickness, it is recommended to include the effects of gage distance for future study for various loadings.