APPENDIX A—Thick and thin end plate behaviour

The recommended design model used in this DESIGN GUIDE is what is called a 'thick end plate' model. Such a model is also used in Reference 6 and the reason that the 'thick end plate' model is used in this publication is because the bolts are the critical elements in the Australian structural steel environment due to the restricted range of high strength bolts to AS 1252 (Ref. 10) available—basically M20 and M24 only are available.

In the alternative 'thin end plate' model, bolt prying forces are assumed to occur, thus reducing the capacity of the bolts to carry applied tension due to bending moment. In general, use of a 'thin plate model' will increase the bolt size required by one diameter and reduce the endplate thickness by one size for the same design bending moment (see comparative designs in Reference 13).

The following brief explanation of these two models is based on References 6, 13, 14 and 15, which should be consulted for more detailed information.

The analysis of how the bolts and the end plate behave in a moment end plate connection is based on the Kennedy method. The method is simply explained by using the split-tee analogy wherein a tee consisting of a flange is bolted to a rigid support and attached to a 'web' through which tension is applied to simulate the tension flange area of a beam at the end plate connection. The three stages of 'flange' (= end plate) behaviour are as shown in Figure 31.

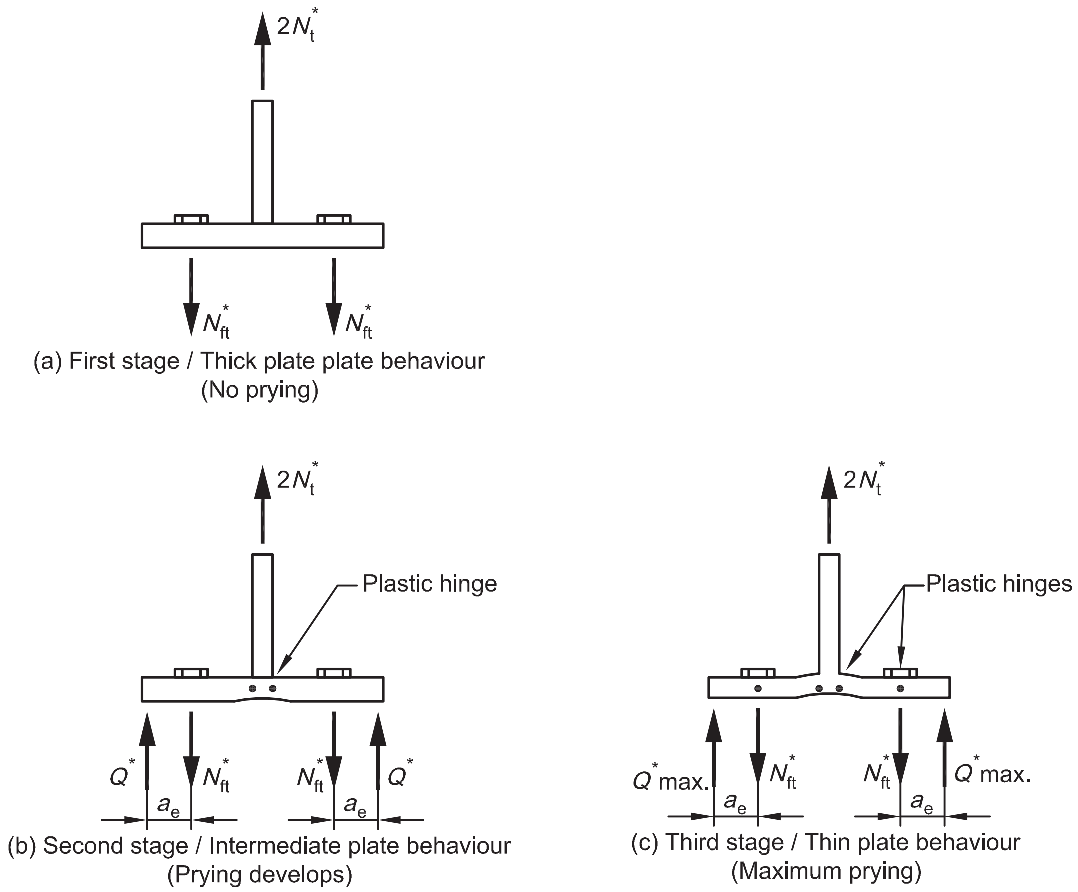

FIGURE 31 END PLATE BEHAVIOUR IDEALISATION (after Ref. 13)

At lower levels of load, the flange behaviour is termed 'thick plate behaviour' where there are no plastic hinges in the plate and no prying force. As the applied load is increased, two plastic hinges form at the centreline of the flange and prying forces develop. At a greater applied load level, two additional plastic hinges form and 'thin plate behaviour' develops while the prying force is at its maximum.

For all stages of plate behaviour, the Kennedy method predicts the bolt force as the sum of the appropriate portion of the applied load and the prying force ($N^*_{tf} + Q^*$). The higher the level of prying force, the less the applied load that can be carried by the bolts.

Borgsmiller and Kennedy (Ref. 14) proposed a simplified method for the design of bolted moment end plate connections. The primary assumptions are that the end plate must substantially yield to produce prying forces in the bolt and that only the maximum value of the prying force need be considered—this eliminates the need to evaluate the intermediate stage behaviour. This is the 'thin plate' model and will minimise end plate thickness.

Conversely, if the end plate is thick enough, no prying action occurs and the bolts are loaded in direct tension. This 'thick end plate' design model will minimise the bolt diameter required or will allow the maximum design bending moment to be carried for a given bolt size.

Borgsmiller and Kennedy (Ref. 14) examined test results and concluded that the threshold when prying action begins to occur is at 90% of the full strength of the plate. If the applied load is less than this value, the plate behaves as a thick plate and no prying need be allowed for in the design of the bolts. Once the applied load exceeds this figure, the plate behaves as a thin plate and the maximum prying force should be allowed for in the connection.

The 'thick plate model' adopted in the recommended design model of this DESIGN GUIDE for the design of the bolts and the end plate follows the Borgsmiller and Kennedy requirements. DESIGN CHECK NO. 4—Design capacity of bolts at tension flange—makes no allowance for prying forces while DESIGN CHECK NO. 6—Design capacity of end plate at tension flange—requires that the design moment capacity of the end plate be 1.11 (= 1.0/0.9) times the design moment capacity of the bolt group. The plate is hence thicker than it otherwise might be for a 'thin end plate' model. The design capacity of the end plate is based on a yield line analysis on the basis that it will eventually yield but not before the bolts have failed.

In order to use the 'thin plate model' as a method of design rather than the 'thick plate model' adopted in the recommended design model, the following changes to the recommended design model are required.

(a) DESIGN CHECK NO. 4

Allowance has to be made for prying and the recommended approach is that given in Reference 13 which determines the allowance for prying for interior and exterior bolts in end plate connections and provides a revised formulation for ϕM_{bt}. Note that this formulation does not allow for the presence of any axial force so that the allowance for axial force given in DESIGN CHECK NO. 4 should be included if any axial force is present.

A simpler but approximate method is to allow for maximum 30% prying by reducing the value for ϕM_{bt} to 0.75 times the value shown in DESIGN CHECK NO. 4. 30% is a suggested upper limit on prying force in References 2 and 4.

(b) DESIGN CHECK NO. 6

For this Design Check, simply delete the '1.11' term under 'Design requirement' as there is no longer any requirement to have the plate thick enough so that its strength is 1/0.9 times the required strength in order to ensure thick plate behaviour. Hence, the design requirement becomes $\phi M_{pt} \geq \phi M_{bt}$, but need not exceed ϕM_s.

DESIGN GUIDE 10

Bolted moment end plate beam splice connections

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Design Guide 6: Seated connections
Design Guide 11: Welded beam to column moment connections
Design Guide 12: Bolted end plate beam to column moment connections
Design Guide 13: Splice connections

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