BLIND BOLTED COLLAR PLATE CONNECTIONS TO UNFILLED HOLLOW SECTION COLUMNS

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ABSTRACT

This paper presents the results of an experimental program in which a blind bolted collar plate connection to an unfilled hollow section (HS) column was tested in tension under static loading. The collar plate connection which connects beam flanges to the side face of HS columns is proposed as an alternative connection to a typical face connection, i.e. the extended endplate connection or the T-stub connection (with T-stubs connecting the top and bottom flanges of the beam to the face of the column). The collar plate connection was found to be much stiffer than a typical face connection in the tension region. Comparison of the test results and three dimensional finite element (FE) modelling indicates that the FE analysis\textsuperscript{[1]}s can be used to predict the connection behaviour with sufficient accuracy. The preliminary investigations for collar plate connection show promising results and form the basis for the development of other blind bolted side connections for applications in the low rise construction industry.

1. INTRODUCTION

The application of hollow sections in low rise structures has traditionally been hampered by access constraints to provide for a fully bolted connection. This may now be overcome by using a blind bolting system requiring access to one face only. The most common types of blind bolted moment connections are the extended end plate connection and the T-stub connection which are connected to the face of the column, also known as face connection in this paper. Increasing endplate thickness can evidently enhance the stiffness of the connection. However this is only true up to certain endplate thickness beyond which stiffness of the connection is dominated by the flexibility of the column face. The inherent flexibility of the hollow section (HS) column face compromises the face connection stiffness. To date, there has been no research reported on blind bolted connections attached to the sides of HS columns. This paper explores the feasibility of connecting to the sides of HS with blind bolts as an alternative to a typical face connection to achieve a higher stiffness.
2. EXPERIMENTAL PROGRAM

2.1. Test specimen
A blind bolted collar plate specimen was tested and the methodology and results are described in this paper. The test specimen was constructed to simulate the tension region of a proposed collar plate connection. Details of the specimen are shown in Figure 1. The specimen comprised of 150×150×6mm SHS column and a collar plate of 20mm thick. A thick collar plate was chosen to eliminate flexibility of the collar plate. Four Grade 8.8 M16 ONESIDE bolts (Ajax Fasteners-Australia) with sleeves were used to connect the collar plate to the steel tube. Details of the blind bolt and the simple installation procedure are given in Fernando [2] and Ajax Fasteners website [1]. The sleeves used in this experiment had tight tolerances to the bolt holes, and the effect of varying this tolerance was investigated in the FE sensitivity studies discussed in Section 4.2. The bolts in the specimen were tensioned to a snug tight condition.

![Figure 1: Details of the test specimen and instrumentation](image)

2.2. Experimental setup and instrumentation
Loading was applied to the test specimen via the stem of the collar plate by gently increasing the load up to failure. Linear Variable Displacement Transducers (LVDTs) were mounted on the specimen relative to the ground to record the deformation of the collar plate, tube face and relative movement between the collar plate and tube side wall. Strain gauges were placed at the bottom face of the SHS tube to measure the strains of the bottom tube face. Illustration of the instrumentation for the test specimen is shown in Figure 1.

A digital photogrammetry survey technique with accuracy of 0.03mm was also employed in this test. The photogrammetry survey first records original coordinates of the targets in the unloaded condition. Subsequent surveys were taken when the load was applied to the specimen to record the new coordinates of the targets at each load level. By analysing consecutive overlapping photographs at each load interval, the topographic information for the specimen can be established. Photogrammetry targets were placed on the collar plate and around the HS tube.
3. TEST RESULTS

3.1. Collar plate connection strength and failure mode
A 20mm thick collar plate was employed in the test to reduce the flexibility and potential for failure of the collar such that the focus of the investigation was on the SHS tube. In typical low-rise constructions in Australia the columns tend to be of small size compared to the beams. Hence, the strength hierarchy at the joint is such that the column is expected to reach its capacity before the connection or the beam. An initial upper bound estimate of the tension force transferred by the collar plate can be made by dividing the column section bending capacity by the beam depth. For a 150x6mm Grade350 SHS column and a 300mm deep beam (sizes commonly used in the low rise construction industry) this would correspond to a tension force of 170 kN. The connection would also have to comply with deformation limits recommended by the International Institute of Welding [3]. Connection deformation should not exceed 1% of the column width at the serviceability limit state and will be no more than 3% of the column width at the ultimate limit state.

At low levels of applied load, there was not much observable deformation in the specimen. As the load was gradually increased to the collar stem, the collar plate slowly separated from the tube face. While this occurred, the face of the collar plate remained flat; no bending of the collar plate was observed. At a load of 400kN, the LVDT on the collar plate recorded a rapid increment of displacement while the load remained constant, indicating that the specimen had failed. It was observed that the bottom face of the tube had buckled in compression while the connection remained intact. Figure 2 shows the tube after failure has occurred with buckling of the tube bottom face and elongation of the bolt holes due to localised bearing of the bolts on the tube side wall.

3.2. Deformation of collar plate and tube face
Figure 3 shows the displacements recorded by LVDTs on the collar plate. At a load of 400kN, when the bottom face of the tube buckled, considerable deformation was recorded by the LVDTs. The deformation limits recommended by the International Institute of Welding (IIW) [3] are also included in Figure 3. The serviceability limit state deformation of 1% column width corresponded to an estimated load of 140kN in the specimen, while a load of 260kN was estimated at the ultimate limit state deformation of 3% column width. Hence the 170kN ultimate design tension load for the collar stem discussed in section 3.1 governs the design.
instead of the recommended ultimate limit state deformations which indicates that the collar plate connection has very high stiffness.

![Figure 3: Load vs. displacement for collar plate](image)

At the estimated ultimate load of 170kN, the average relative movement between the tube and the collar side plate was approximately 0.5 mm. This is remarkably stiff behaviour but it can be explained by the fact that there was very little difference in the slip of the bolts due to the tight tolerances for the holes, sleeves and bolts.

![Figure 4: 3-dimensional FE model (half symmetry)](image)

### 4. FINITE ELEMENT ANALYSIS

A three-dimensional finite element model was created in ANSYS 11.0 to represent the blind bolted collar plate connection to the unfilled SHS column. The FE model takes into account material and geometric non-linearities and complex contact interactions between various surfaces. Surface to surface contact elements with friction coefficient of 0.25 were employed in the FE model. Taking advantage of symmetric conditions along the longitudinal and...
transverse planes, only a quarter of the test specimen was modelled. A half-symmetry finite element model of the collar plate connection is shown in Figure 4 (for ease of visualisation). Load was applied to the stem of the collar plate and a line of support was provided at the end of the tube simulating support conditions during the experiment.

4.1. Comparison between the FEM analysis and test results
Comparisons between the deformations recorded using the photogrammetry surveys of the collar plate during the test and the prediction from the FE model are made in Figure 5. In this figure, Experiment-S and N denote a photogrammetry target on the southern and northern sides of the specimen respectively. The prediction from the FE model of the collar plate deformation agrees well with the experimental results.

![Figure 5: Comparison of FE and photogrammetry results for collar plate displacement](image)

4.2. Sensitivity analysis
A brief sensitivity analysis is presented here to investigate the influence of the tolerance between the bolt sleeves and the bolt hole. The tight tolerance between the outer diameter of sleeves and bolt holes provided a very tight fit for the connection which is not practical for
most cases. A 2mm standard bolt hole tolerance which is typical for bolted connections with bolt size smaller than M24 as recommended by AS4100 [4], was employed in the sensitivity analysis. The bolts were pretensioned up to 70% of the bolt yield load (70kN) in the model. The model is predicted to have a similar initial stiffness and ultimate strength to the model with snug tight bolts with tight tolerances as can be seen in Figure 6.

5. SUMMARY AND CONCLUSIONS

A collar plate blind bolted connection to unfilled SHS column in the tension region has been tested. The findings from the tests and FE modelling are summarised below:

1) The results show that the stiffness of the collar plate blind bolted connection in the tension region is not compromised by the flexible HS column face deformation normally observed in a typical face connection.

2) The tight tolerance provided by the bolt sleeves contributes to the connection stiffness. For industry practice it is recommended that standard bolt hole tolerance of 2mm is provided between the outer diameter of the sleeves and bolt hole. The bolt should be pretensioned to prevent slip under serviceability loading. The effectiveness of pretensioning the ONESIDE blind bolts on site is currently under investigation.

3) 3-D non linear FE modelling developed for the collar plate connection can replicate the behaviour of the test specimen successfully. FE model with 2mm standard bolt hole tolerance with bolts pretensioned to 70% yield load, displayed similar initial stiffness as the model with tight tolerance for the sleeves with snug tight bolts.

4) The experimental and analytical work presented in this paper provides a basis for further study on developing a range of blind bolted moment connections for hollow section columns.

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7. REFERENCES
