TESTS ON THE SPLITTING FAILURE CAPACITY OF THE BOTTOM RAIL DUE TO UPLIFT IN PARTIALLY ANCHORED SHEAR WALLS

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ABSTRACT: The authors have developed a new plastic design method for wood-frame shear walls at ultimate limit state. The method is capable of calculating the load-carrying capacity of partially anchored shear wall, where the leading stud is not necessarily anchored against the uplift. In fully anchored shear walls, the leading stud needs to be anchored in some kind of hold downs to resist both the uplift and the bottom rail fixed by anchor bolts to resist the horizontal shear forces. In partially anchored shear walls, where hold downs are not provided, the uplifting force is resisted by the sheathing-to-framing joints along the bottom rail. Hence, it is important that the bottom rail is anchored to the floor or foundation by anchor bolts and, therefore, able to transmit the forces to the structure below. Because of the eccentric load transfer, transverse bending is developed in the bottom rail and splitting of the bottom rail can occur. In order to use the plastic design method, a ductile behaviour of the sheathing-to-framing joints must be ensured. In this paper, results of tests on the splitting failure capacity of the bottom rail due to uplift in partially anchored shear walls are presented. Specimens with both single and double sided sheathing were tested, varying the size of the washer, pith orientation of the bottom rail and anchor bolt position along the width of the bottom rail. The aim of the tests was to evaluate the influence of these parameters in order to avoid the splitting failure of the bottom rail. Two types of brittle failure modes occurred during testing: (1) a crack opening from the underneath surface along the bottom rail and (2) a crack opening from the edge surface of the bottom rail along the line of the sheathing-to-framing joints. These failure modes were mainly dependant on the washer size and the location of the anchor bolt. The results show that the distance between the edge of the washer and the loaded edge of the bottom rail has a decisive influence on the maximum load and the failure modes of the bottom rail.

KEYWORDS: Timber shear walls, Partially anchored, Sheathing-to-framing joint, Bottom rail, Cross-wise bending, Splitting of bottom surface, Splitting of edge surface

1 INTRODUCTION

Light frame timber shear walls are vertical structural elements designed to carry the dead and lateral loads, received from horizontal roof and floor diaphragms, and to transfer them to the foundation. In EC5 two methods are given to design shear walls: method A which can be only applied to shear walls with a tie-down at their ends and where the stud at the end of the wall is directly connected to the construction below, and method B where the stud at the end of the wall is free to move and the bottom rail is anchored to the substrate. In the test standard EN 594 [1], the test method to be used in determining the racking resistance is given. Källsner and Girhammar [2] have presented a new plastic design method of wood-framed shear walls at ultimate limit state. This method allows the designer to calculate the load-carrying capacity of shear walls partially anchored where the leading-stud is not anchored against the uplift. The tests described in this paper are part of this research.

The anchorage system of shear walls is provided from anchor bolts and hold downs. Prion and Lam [3] pointed out the importance to understand the difference between hold downs and anchor bolts. Anchor bolts provide

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horizontal shear continuity between the bottom rail and the foundation. Hold downs serve as vertical anchoring devices between the vertical end studs and the foundation. When hold downs are not provided, the bottom row of nails transmits the vertical forces in the sheathing to the bottom rail (instead of the vertical stud) where the anchor bolts will further transmit the forces into the foundation. Because of the eccentric load transfer, transverse bending is created in the bottom rail and splitting may occur.

In order to be able to use the plastic design method proposed by Källsner and Girhammar (2005), a ductile behaviour of the bottom rail and the joints must be ensured. Brittle failure modes in the bottom rail can be avoided using large washers (square or rectangular) at the anchor bolts. Large washers influence the eccentricity of the carried load.

In this paper, results from the testing of bottom rails are presented with the aim to evaluate the influence of the anchor bolt position along the width of the bottom rail, the size of the washer and the orientation of pith on the failure mode and the maximum load.

2 MATERIALS AND METHODS

2.1 MATERIALS

The specimens were built by hand by using rails of Spruce (Picea Abis) rail of length 900 mm with a cross section of 45×120 mm, joined with a hardboard sheet of 900×500 mm by nails 50×2.1mm.

2.2 TEST SET UP

The bottom rail was fixed to a steel plate with two anchor bolts. To tighten the bolts a torque moment of 50 Nm was used. A rigid square or rectangular washer was inserted between the bottom rail and the head bolt throughout all tests. Its size and shape varied from the set tested. A hydraulic piston was attached to the upper panel using a C shaped steel beams and four bolts Ø16 inducing a tensile force. The testing arrangements are shown in Figure 1.

3 RESULTS AND CONCLUSIONS

The test results show that the size of the washer and the position of the bolt have a significant influence on the maximum load and the failure modes. Two splitting types of failure modes occurred during testing: (1) splitting of the underneath surface of the bottom rail due to cross-wise bending according to Fig. 2a and (2) splitting of the edge surface of the bottom rail due to tensile forces from the sheathing-to-framing joints according to Fig. 2b. The third failure mode that occurred was yielding and withdrawal of the sheathing-to-framing joints according to Fig. 2c. This plastic type of failure mode is the one assumed in the plastic design method.

Figure 2: Failure modes found during the tests.

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