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DESIGN EQUATIONS FOR DOWEL EMBEDMENT STRENGTH AND WITHDRAWAL RESISTANCE FOR THREADED FASTENERS IN CLT

Shawn Kennedy[1], Alexander Salenikovich[2], Williams Munoz[3], Mohammad Mohammad[4]

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1 INTRODUCTION

Cross-laminated timber (CLT), which was developed in Europe in the early 1990's, is getting a great success in timber construction. This product is lifting timber buildings to new heights. Unfortunately, development of CLT in Canada is lagging behind Europe. Lack of experience and methods for design with CLT is partly the reason. The CLT design properties are different from those of sawn timber and glued-laminated timber because two orthogonal grain directions are combined in the same cross-section, which may particularly have influence on the design of connections with large diameter dowels. The purpose of this project is to develop predictive equations for dowel embedment and withdrawal strength for threaded fasteners in CLT.

2 BACKGROUND

Uibel & Blaβ [1][2] studied the load carrying capacity of fasteners and proposed design equations for CLT panels produced in Europe. Follesa *et al.* [3], Munoz *et al.* [4] and Joyce and Smith [5] studied lap and spline connections between floor and/or wall elements. Recently, major efforts in Canada have been brought forward for the development of CLT engineering design guidelines, which resulted in publication of the CLT Handbook (Canadian Edition [6] and US Edition [7]). However, these past studies lack experimental validation of proposed design equations for fastenings in Canadian-made CLT. The research project described in this paper is aiming at filling the gap and putting forward proposals for the adoption in the Canadian timber design standard CSA O86 [8].

3 METHODOLOGY

The test program conducted jointly by FPInnovations and Université Laval [9] included dowel embedment and withdrawal tests on 3-ply and 5-ply CLT manufactured in Quebec and British Columbia and made of Spruce-pine-fir. Fasteners under study were lag screws of six diameters (6.4 mm to 19.1 mm) and self-drilling screws of three diameters (6.0 mm, 8.0 mm and 12.0 mm).

Axial withdrawal tests were performed in accordance with European standard EN 1382 [10] using fasteners inserted perpendicular to the plane side and to the narrow side of the CLT panels. Dowel embedment tests were performed in accordance with ASTM D5764. Fasteners were inserted perpendicular to the plane side and to the narrow side of the panels and loaded parallel, perpendicular and at 45° angle to the grain direction of the face layer of CLT panel.

4 RESULTS

4.1 AXIAL WITHDRAWAL

The experimental data obtained for the two Canadian CLT products have been compared with predictive equations from three references:

1. European CLT withdrawal equations adapted to CSA O86 format in the CLT Handbook Canadian Edition [6];
2. NDS [11] withdrawal equation for lag screws recommended in the CLT Handbook US Edition [7] and adapted to the CSA O86 format; and
3. CSA O86 wood screw withdrawal equation [8].

Comparison of the test data gathered to date revealed that the CSA O86 wood screw withdrawal equation gave the best level of prediction for withdrawal resistance of lag screws and self-drilling screws.

4.2 DOWEL EMBEDMENT

The experimental data obtained for the two Canadian CLT products have been compared with predictive equations from three references:

1. European CLT dowel embedment equations adapted to CSA O86 format in the CLT Handbook Canadian Edition [6];
2. NDS [11] dowel bearing equations recommended in the CLT Handbook US Edition [7] and adapted to the CSA O86 format; and

[1] Shawn Kennedy, Université Laval, 2425 rue de la Terrasse, Quebec, Canada. Email: shawn.kennedy.1@ulaval.ca
[2] Alexander Salenikovich, Université Laval, Quebec, Canada
[3] Williams Munoz, Nordic Structures Bois, Montreal, Canada
[4] Mohammad Mohammad, FPInnovations, Ottawa, Canada

3. CSA O86 dowel embedment equations [8].

The dowel embedment equations in these references depend on the fastener diameter, timber density (or relative density) and, for fasteners of larger diameters, the loading direction relative to the wood grain, except that the NDS equation is independent of the fastener diameter for the loads parallel to the grain. Preliminary analysis of the test data collected to date suggests that the dowel embedment strength is independent of the fastener diameter in any direction of loading. Also, the difference between the resistance values parallel and perpendicular to grain is significantly less than it is currently assumed in the CSA O86 equations. For this reason, revised dowel embedment equations will be proposed for potential adoption in the Canadian timber design code.

5 CONCLUSIONS

Experiments conducted as part of this research project were aimed at verification of various predictive equations for dowel embedment and withdrawal resistance of threaded fasteners in CLT. The test data obtained to date on fasteners between 6.0 mm and 19.1 mm in diameter suggest that current CSA O86 equation for axial withdrawal of wood screws can be safely applied to fasteners inserted in the plane side of CLT panels. For the dowel embedment strength, revised equations will be proposed, which should be independent of the fastener diameter and much less dependent on the loading direction than it is currently assumed in the Canadian timber design code.

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