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DESIGN EQUATION FOR WITHDRAWAL RESISTANCE OF THREADED FASTENERS IN THE CANADIAN TIMBER DESIGN CODE

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KEYWORDS: Lag screws, wood screws, self-drilling screws, glued laminated timber, sawn timber.

1 INTRODUCTION

The 2009 edition of Canadian standard for engineering design in wood (CSA O86) [1] provides two different design equations for wood screws and lag screws, which are, in turn, different from those in the American “National design specification for wood construction” (NDS) [2] and from the overseas codes. The purpose of this project is to study the withdrawal resistance of various types of threaded fasteners in timber and to propose a unified design equation for the Canadian timber design code.

2 BACKGROUND

The NDS design values for wood screws originate from the data collected by Fairchild [3] as early as in 1926 when over 10 000 wood screws were tested in seven species of wood. The NDS design equation for lag screws is based on the work of Newlin and Gahagan [4] who tested 233 fasteners of different diameters in 5 wood species in 1938. A modified version of this equation was adopted in CSA O86 for lag screws in the form of a table. In 1997, McLain [5] expanded the data base using tests conducted later by various American researchers and proposed new equations based on nonlinear regression analysis for wood screws and lag screws. In 2009, the McLain’s equation for wood screws was adopted in CSA O86. More recently, Gehloff [6], Abukari *et al.* [7], and Baek *et al.* [8] conducted independent investigations on the withdrawal strength of self-drilling screws.

3 MATERIALS

The experimental program conducted jointly at FPInnovations and Université Laval [9] and at McGill University ([7], [10]), included withdrawal tests on lag screws and self-drilling screws using sawn timber and glued laminated timber of Canadian species. The sawn timber and glulam products were generously provided by manufacturers from Quebec Province and British Columbia and included Douglas-fir sawn timber, Spruce-pine glulam and Douglas-fir glulam. All wood specimens were conditioned to 65 ± 5% of relative humidity and 20 ± 2°C temperature prior to testing. Lag screws of six diameters (from 6.35 mm to 19.01 mm) were commodity off-shelf products, while self-drilling screws of three diameters (6, 8 and 12 mm) were supplied by European producers. Two lengths of penetration were examined for each diameter of fastener.

4 METHODOLOGY

All fasteners were inserted perpendicular to grain of wood respecting the minimum end and edge distances in compliance with the European standard EN 1382 [11]. Wood samples with fasteners that required pilot holes were predrilled to 70% of the nominal diameter. Fasteners were inserted using pneumatic tools and all tests were performed within 24 hours from insertion. In compliance with the European standard EN 1382 [11], wood samples were fixed to the test set-up and fasteners were pulled out with a hydraulic actuator at a constant cross head speed of 1 mm/min and 0.5 mm/min for lag screws and self-drilling screws, respectively. Test stopped after the resistance decreased to 80% of the peak load. After testing small samples were cut from the specimens to determine local specific gravity and moisture content of each specimen.

5 MAIN RESULTS

5.1 LAG SCREWS

The following test data have been considered in the analysis of the withdrawal resistance of lag screws:

1. Kennedy [9]: D-Fir, n = 120
2. Abukari [10]: Nordic Lam, n = 120
3. Newlin & Gahagan [4]: N. white pine, Redwood, Douglas-Fir, Yellow pine, White oak, n = 233
4. McLain [5]: SPF, SYP, n = 88
5. Simpson Strong-Tie [12]: DFL, n = 130

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The experimental values were compared with the predictions using the following design equations:

1. CSA O86-09 [1]: Wood Screws
2. CSA O86-09 [1]: Lag Screws
3. NDS-2012 [2]: Lag Screws
4. NDS-2012 [2]: Wood Screws
5. McLain [5]: Lag Screws

Equation [1] revealed the best level of prediction for withdrawal resistance of lag screws. Figure 2 shows comparison of experimental mean values adjusted to standard load duration with predicted values by Equation [1]. A coefficient of variation of 30% was assumed.

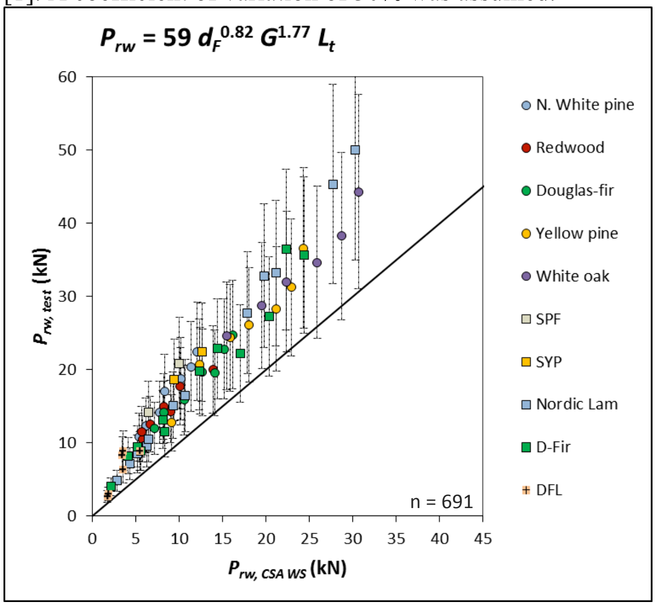

Figure 2: *Comparison of experimental data and predicted data for withdrawal of lag screws (Equation [1])*

5.2 SELF-DRILLING SCREWS

The following test data have been considered in the analysis of the withdrawal resistance of self-drilling screws:

1. Abukari [7]: Nordic Lam, D-Fir, n = 1261
2. Gehloff [6]: D-Fir. L, SP, Hemlock, n = 360
3. Simpson Strong-Tie [12]: DFL, n = 130
4. Baek et al. [8]: Sugi, n = 200

With all 4 projects, 2430 experimental data points were collected and compared to the equations shown in section 5.1. Similar to lag screws, Equation [1] was found to produce the best fit with the test data (see Figure 3).

6 CONCLUSIONS

The CSA O86 [1] equation for wood screws showed the best prediction for withdrawal resistance of lag screws and self-drilling screws in sawn timber and glued laminated timber. A proposal was made to the CSA O86 technical committee to apply the equation to all threaded fasteners. Further research will investigate the withdrawal resistance of threaded fasteners in cross-laminated timber.

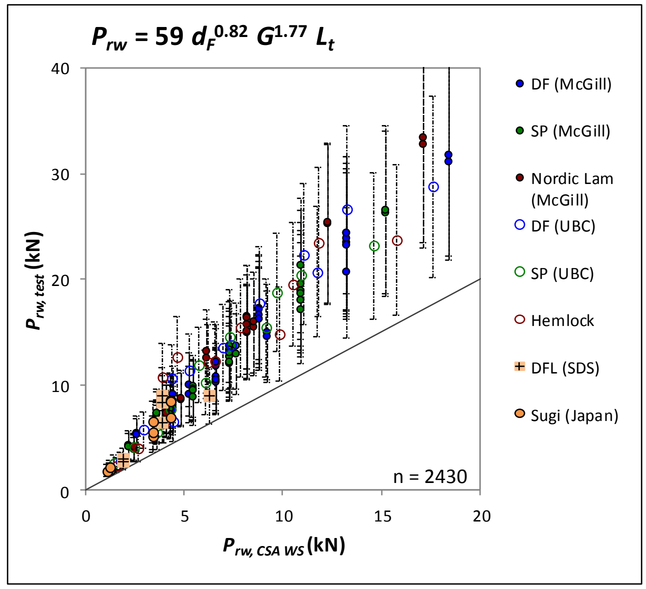

Figure 3: *Comparison of experimental data and predicted data for withdrawal of self-drilling screws (Equation [1])*

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