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Title:	Edge Spacing of Pegs		

Introduction

One of the failure modes that controls the strength of a mortise and tenon joint loaded in tension is splitting perpendicular to the grain of the mortise cheeks. If the pegs are positioned too close to the loaded edge, a splitting failure can occur prior to the full shear strength of the pegs being developed.


Figure 1 Splitting failure

There are currently no provisions in the ***National Design Specification (NDS)*** for analytically evaluating splitting strength perpendicular to the grain. The NDS does have prescriptive requirements for minimum edge distance for bolts. An edge distance of 4D is required at a loaded edge, where D is the bolt diameter. The requirements only apply to steel bolts and are overly conservative for wood pegs.

There are provisions in ***TFEC 1-2010 Standard for Design of Timber Frame Structures*** for establishing minimum edge distances for wood pegs based on the equivalent bolt method. The NDS edge spacing requirements are applied to the diameter of the smallest steel bolt capable of resisting the applied wood peg load rather than to the actual peg diameter. This method yields conservative results, and is not based on a rational evaluation of structural performance.

There are provisions in the ***Eurocode 5*** and also in the Canadian standard ***CSA 086*** for evaluating the splitting strength of a timber perpendicular to the grain at a bolted connection. These provisions have a long history of reliable performance when applied to bolted connections in softwood glulam timbers. It was not known if these provisions were applicable to timber frame joinery using solid sawn timbers. The Timber Frame Engineering Council (TFEC) has sponsored research at Virginia Tech to determine if these provisions can reliably be applied to timber frame construction.

Research

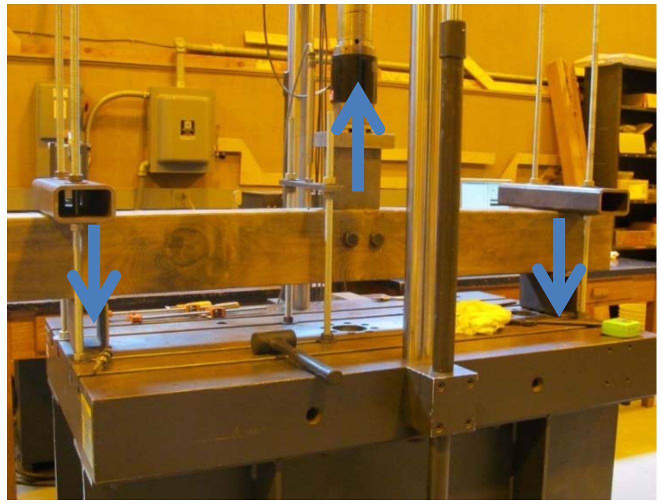


Figure 2 Test setup

The research was conducted by Professor Daniel Hindman at Virginia Tech, Blacksburg, Virginia. Mortised timber test specimens were cut from Douglas Fir, Eastern White Pine, and White Oak timbers. Steel tenons with steel pins were used in the testing to preclude failure modes other than splitting of the mortise timber.

The test setup is shown in the photo to the right. The specimens were tested to failure. Splitting perpendicular to the grain was the failure mode. Edge distances tested ranged from 1 inch to 3 inches.

The test results were compared to the ***CSA 086*** provisions for splitting perpendicular to the grain as well as to other fracture mechanics methods. The test results for Douglas Fir and Eastern White Pine specimens correlated well with the ***CSA 086*** provisions. The White Oak specimens demonstrated substantially higher resistance to splitting than the softwood specimens. This is not unexpected since Oak species have significantly higher tension perpendicular to the grain strength than other wood species.

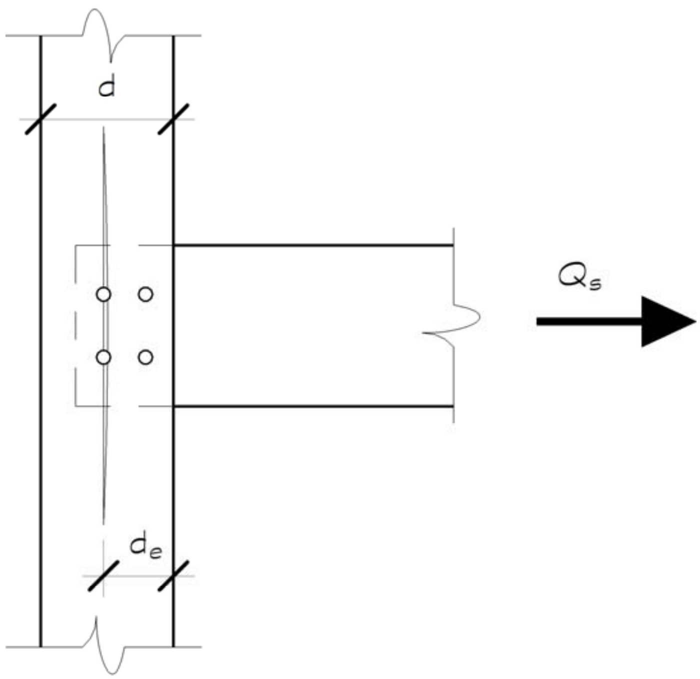
The ***NDS*** does not include strength values for tension perpendicular to the grain, but the ***Wood Handbook*** published by the Forest Products Society does. Tension strength perpendicular to the grain varies very little in commonly used softwood species, with average values of 250 psi, while Oak species have average values of 750 psi. The higher tension strength perpendicular to the grain for Oak species is explained by the presence of medullar ray cells that provide tensile strength in the radial axis.

Structural Design

The design equation from ***CSA 086*** has been converted from metric to inch-pound units. The empirical constant has been adjusted to convert from Limit States to Allowable Stress design.

When evaluating the splitting perpendicular to the grain resistance, the edge distance that is significant is the distance from the edge to the furthest peg, not the closest. This is different from the prescriptive edge distance provisions contained in the ***NDS***. The number and diameter of fasteners does not influence the results.

The provisions are not applicable to joints that are in close proximity to the end of the mortised timber such as at the top of a post. If the end distance is less than 2d, proceed with caution!



$$Q_S = C_D C_t K_{sp} t \sqrt{\frac{d_e}{1-\frac{d_e}{d}}}$$

Q_S	Splitting resistance (pounds force)
K_{SP}	Empirical constant - 500 for oak species, 200 for all other species
t	net thickness at mortise (inches)
d_e	edge distance furthest from loaded edge
d	member depth
C_D	load duration factor
C_t	temperature factor

Reference

Edge Spacing of Pegs in Mortise and Tenon Joints by Daniel Hindman prepared for TFEC

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