FULL-SCALE FIRE TESTS OF POST TENSIONED TIMBER BEAMS

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KEYWORDS: Post Tensioned Timber Construction, Fire Performance, Furnace Test

1 ABSTRACT

Whilst timber is the material of choice for the residential markets in New Zealand and Australia, the commercial markets are dominated by steel and concrete. Post-tensioned timber construction positions timber as a competitive alternative in the commercial buildings market, particularly in multi-storey and long span industrial constructions. Post-tensioned timber construction has many benefits over steel and concrete; buildings can be constructed quickly and with substantially smaller lifting equipment, it is easy for contractors to work with, and timber has the added advantage of being “sustainable” and “green”, which are increasingly becoming more important in the global climate.

Post-tensioned timber construction (PT timber) is an adaptation of the mature technology of post tensioned pre-stressed concrete. PT timber is made with large timber cross sections, constructed from glue laminated timber (glulam) or laminated veneer lumber (LVL). The timber is post tensioned with (unbonded) high strength steel bars or wire tendons which are run through a cavity within the member and fixed to steel anchorages at the end of the frame. The post-tensioning can be run through multiple bays of a frame at once and, when stressed, form the primary beam-column connections. This means that many connections can be made at once (Figure 1).

PT timber has many advantages over steel, concrete, and traditional timber. Post tensioning can be used to reduce deflections of timber beams and allows for smaller cross-sections to be used compared to standard timber beams made from glue laminated timber or laminated veneer lumber. In seismic designs the post tensioning serves to re-centre connections, eliminating residual displacement. Energy dissipation can be achieved with easily replaceable mild steel energy dissipators. Also, as the mass of PT timber is much less than reinforced concrete, the forces the structure is exposed to would be much less, given a comparable acceleration.

As with any timber construction there is a common perception of increased risk when exposed to fire, when compared to incombustible materials such as concrete or steel. While the fire performance of heavy timber members is well established, PT timber has a number of complicating factors which can lead to some unfavourable failure mechanisms. Complications include the inclusion of a cavity within the timber member and the use of high strength steel tendons. A small rise in tendon temperature can result in substantial relaxation of the post-tensioning force due to the geometrical and material properties of the tendon and the tendon restraint conditions.

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Figure 1: demonstration of multiple beam column connections with post tensioning (Red line represents steel tendon and anchorage)
This paper describes a series of full-scale furnace tests on loaded post tensioned LVL beams (Figure 2). Each beam was designed to exhibit a specific failure mechanism when exposed to a standard (ISO834) fire. In addition to the beams a number of steel anchorage protection schemes were also investigated. These include; wrapping the ends in kaowool, using intumescent paint, covering the anchorage with fire rated plaster boards, and covering the anchorage with timber (LVL).

This paper reports the results of the full-scale tests including temperature distributions through the timber members during the tests, the temperatures reached within the cavity and of the tendons suspended within the cavity, the relaxation of the tendons during the test and a summary of the anchorage protection details and their effectiveness. Recommendations for the design of both post tensioned timber members and associated anchorages are also provided.

Figure 2: Cross sections of the post tensioned timber beams, which were used in the furnace tests.

Figure 3: Full-scale, post tensioned timber beam and anchorage detail furnace test.