Timber Shore Testing Program

held at

Coventry University - June 2005

Aberdeen - October 2005

Coventry University -
November 2005

Prepared for:

New Dimensions
ODPM

December 2005

MANAGEMENT SUMMARY

1. The full scale tests demonstrated that the BS 5628 design code is valid in predicting the failure load of the T-Spot and the Laced Post Shore.

2. Failure by timber crushing in both shores occurs before buckling thus providing adequate warning of impending failure by the generation of splitting and cracking noises.

3. Nailed joints perform adequately whether hand driven or power driven nails are used.

4. Cribs are considered satisfactory for heights of 1 metre or less. Laced Post Shores should be adopted for support heights in excess of 1 metre.

5. The working load for cribs should be half that as the calculated safe load as defined by BS 5628.

6. When T-Spot, Laced Post shores and cribs emit audible cracking noises, the building should be immediately vacated and the shoring provisions re-evaluated.

GENERAL

As part of the timber shoring provisions for Urban Search and Rescue, it was agreed that the recommendations relating to the use of British Species Timber and shore configurations should not only be calculated theoretically but also these calculations should be vindicated by selected full scale destructive testing.

Three shoring configurations were agreed to be tested, which were:

1. T-spot shore.
2. Laced post shore.
3. Four point support crib.

In addition to these full scale shoring systems, we also tested some nailed joints to determine the performance and load carrying characteristics of wire hand driven nails as compared to those machine driven by nail guns.

The tests were initially held at Coventry University in their structures laboratory and was supervised by Glanville Consultants together with selected members of the Fire Service. The timber was obtained locally and was a C16 grade softwood. The shoring rigs were built by the Fire Service personnel and tested by the technician staff at the University.

The initial tests in June were successful and conclusive for the nailed joints, T-Spot and the Laced Post shore. The crib stack test was inconclusive owing to the significant compression of the stack under load where the jack was unable to provide sufficient travel to produce useful and meaningful results.

We were aware of testing equipment in Aberdeen whereby the load is applied through a series of pulleys. In consequence, the problems associated with limited jack travel would be eliminated. A test on a single crib stack was planned and completed in October.

As a result of this Aberdeen test, further tests were undertaken at Coventry University in November.

NAILED JOINTS

A testing configuration was agreed for testing nailed joints which essentially put the nails into double shear.

The joints carried far in excess of the load that was permitted for such a nail configuration as set out in the British Standard. It became quite clear that failure of the joint should be identified as the point at which the deflection reached a practical level at which the joint had rotated or given to such an extent that the structure (jointed by such connections) would become unviable.

It is not possible to quantify the results in terms of the load capacity per nail but there are certain important and broad conclusions that can be drawn.

Those conclusions essentially relate to the difference in performance between a joint formed using wire nails which are hand driven using a hammer and those which are power driven using a nail gun.

It was quite clear from the tests that the difference between the performance these nail systems was negligible and that either could be adopted without any detriment to the load carrying capacity of the nailed joint.

T-SPOT SHORE

The T-Spot Shore was designed such that it would fail in crushing of the sole and header plates prior to buckling of the vertical member taking place. According to the British Standard for structural timber, the working loads for crushing and buckling were calculated to be 24kN and 32kN respectively. The anticipated failure loads were assumed at 3 times the working loads (as implied in the codes of practice) which would produce failure loads of 72kN in crushing in 96kN in buckling.

Three tests were undertaken on three separate T-Spot shores. At between 40kN and 45kN for all 3 shores, audible sounds of timber crushing and splitting could be heard. Further load was applied and whilst this additional load promoted further sounds, the shoring system continued to carry further load which continued to crush the header and sole plate. Failure by buckling of the vertical member occurred at 83kN in two tests and 114kN for the remainder. It is worth observing that the failure at 83kN occurred at a substantial knot in the timber at half post height and which prompted failure at this level, whereas the 114kN failure load represented buckling of a relatively unblemished piece of timber.

The conclusion from this testing was that the T-Spot Shore behaviour reflected accurately the theoretical design predictions from the code of practice. The tests showed that a linear response of load was maintained up to approximately twice times the working load at which time cracking and other audible noises could be distinctly heard. Further load application created an increase deflection versus load resulting from continued crushing of the sole and header plates. Failure ultimately occurred by buckling of the vertical member.

Recommendation

It was recommended that a T-Spot Shore be constructed using 100 x 100 millimetre cross section C16 Timber to a maximum height of 2.5m (which will ensure crushing type failure) and that the loading assessment should be made on a 25kN (2.5 tonnes) load per shore. When audible noises from the installed shores are heard then this will indicate that this shore is sustaining approximately twice its working load (5.0 tonnes) and the building should then be immediately vacated to re-assess the behaviour of the building and why progressive increased loading continues to occur.

LACED POST SHORE

As with the T-Spot shore the laced post shore is designed to fail in crushing rather than buckling. As such this system will sustain a working load of 96kN, with failure predicted at 288kN by crushing of the header and sole plate beneath the four braced vertical members.

The load/deflection/audible noise criteria was identical of that of the T-Spot shore, whereas the noise started to occur at approximately twice the working load condition and therefore the recommendation is as for the T-Spot shore, whereby where noises are heard then the building should be vacated.

Recommendations

Its recommended that the laced post shore be constructed using 100 x 100mm C16 timber to a maximum height of 5m (4.8m being the maximum length of timber available). The laced post shoring system all sustain a maximum load of 100kN (10 tonnes) and the building must be evacuated when audible cracking and creaking noises are heard from the shoring system.

CRIB STACK

Coventry University - June 2005

A 3 metre high, 4 point bearing stack was constructed using sixty 100mm square saw cut C16 timbers each member being 1.2 metres in length. This provided a stack of 1.0 metre width with 100mm overlap at corners. These dimensions were selected since they complied with the US FEMA recommendations for crib construction.

The true timber dimensions were 95mm square and taking account of this bearing area would yield a safe working load (according to BS 5268) of 87.5kN (8.75 tonnes).

The crib was loaded equally at each corner but was unable to attract any significant load owing to the compressibility of the system (as predicted in the FEMA recommendations) and the limited travel available within the loading jack.

Aberdeen - October 2005

The availability of a testing rig at Aberdeen which could provide unlimited travel for the loading had been identified by the Grampian Fire Service and had been previously used by them in some early testing on laced post shores.

The load was applied by chain pulleys connected to load cells and four such pulleys were employed to apply the load equally to each corner of the crib stack through a grillage of steel beams.

The crib stack was constructed using sixty four 95mm square C16 timber giving a total stack height of 3 metres.

The crib sustained loading increments linearly up to a load of approximately 10 tonnes after which loading some members commenced to split and crush. These local failures distorted the shape of the stack such that it developed a significant “bowed” vertical shape. It was decided that to maintain equal loading increments to each corner would accelerate this distortion, promoting a buckling failure and in consequence, we decided to load the stack in such a way that such buckling was prevented.

The stack continued to accept further total load until at 15 tonnes, the nature of the crib was such to cause safety concerns as to its stability and it would not accept any further load without excessive and (considered) dangerous compression.

The condition of most timbers at this load was that they were all distorted in some way either by crushing or splitting or a combination of the two. Some timbers were appearing to ‘rotate’ within the stack as a result of uneven deformation. At this ‘failure’ load, the stack had compressed 473mm ie. 15.6% of its original height. It was considered that at this degree of distortion, the crib could not be considered viable nor providing an acceptable environment for USAR activities.

Coventry University - November 2005

The result obtained in Aberdeen caused concern as to the potential use and recommendation pertaining to cribs and it was decided to undertake further failure testing at Coventry University.

To avoid the problem with limited jack travel, 1 metre high cribs were to be tested. Since all cribs fail by crushing of the timber, the load carried by a 3 metre high crib should be identical to that of 1 metre except that the compressibility would be reduced and (it was hoped) problems with stack instability would be avoided. C16, 95mm square timbers, 1.2 metres long were adopted as for all previous testing.

The first two tests yielded identical results with the crib remaining stable and linear up to a load of 9 tonnes when the timbers begin to crack, split and distort. The loading was increased with significant compression taking place until it reached 14 tonnes when the stack was considered to be so distorted that its viability was severely compromised.

A third test was undertaken using 95 x 40 timbers laid with the 95mm faces in contact. It was though that this configuration would be more stable and that the timber would resist twisting and splitting more readily.

This proved not to be the case with cracking and splitting taking place at a load of 9 tonnes with a sustained failure load of 14 tonnes. However, the members were more stable within the stack and further loading promoted considerable deflection with the crushed timber fibres were so tightly compressed together that the loading was tending to pick up. This configuration carried 15.5 tonnes at a compression of 400mm ie. 40% reduction in height.

Discussion

The results from Aberdeen and Coventry would seem to show that the breakdown of the crib stacks begins to occur at the working load as predicted by BS 5628 calculation. Deterioration takes the form of cracking and splitting to the projected timbers outside the plan area of the crib combined with crushing of the timber where they are in contact one with the other. After this condition is reached, the crib begins to compress more rapidly as this load is increased with failure being defined when the viability of some timbers is severely compromised. This condition was at a load of 15 tonnes in Aberdeen and 14 tonnes at Coventry which taking account of the inherent variability of timber, is a remarkably consistent result. Failure is at 160% of the calculated working load, at which load the timbers began to crack and split.

The current concern is that if the failure of individual timbers starts to occur at working load, how does this compromise the stability of the stack, particularly if this has an aspect ratio of 3 (FEMA maximum). The result from Aberdeen would tend to support the view that the inconsistent timber properties would cause stack instability and would be a serious concern, particularly if the load it is attempting to support is also unstable, as it may likely be in a partially collapsed building. This would tend to be supported by the December testing at Coventry University where cribs with an aspect ratio of 1.0 (ie. 1 metre high by 1 metre plan dimension) showed signs of instability after "working load" had been exceeded.

The results of the tests cause concern about the adoption of cribs for support of damaged buildings.

Failure is too close to the working load condition as defined in BS5628 by the permitted bearing stress multiplied by the area of timber in contact which is also adopted in the FEMA documentation. It also seems that if the crib has to compress by up to 300mm for it to sustain load, then this represents an unacceptable condition in terms of the stability of the building or mechanism it is intended to support. This degree of compression also generates instability for cribs with an aspect ratio of 3.

Recommendation

1. Since cracking and splitting occurs at a load which is deemed to be the "working load" when calculated using BS 5628 design recommendations, the true working load condition should be half of that calculated and set at 4.5 tonnes. This is entirely consistent with the recommendations for the T-spot and Laced Post shore whereby a building is evacuated and the shoring reassessed for these latter two systems when the noises of timber splitting and cracking occur at twice working load.

2. Laced post shores are more efficient and effective than crib stacks and do not become unstable as a result of timber variability. They should be used wherever possible and we understand they can be built to a minimum vertical height of 1 metre.

3. Cribs should be used to support loads where the crib height is 1 metre or less. At this dimension, laced post shores cannot easily be inserted and the potential instability of a crib with a large aspect ratio is avoided.

DOCUMENTATION

BS 5268-2 : 2002

FEMA National US & R Response System

APPENDIX 1 - LOAD DEFLECTION CHARACTERISTICS OF

1. The T-Spot Shore
2. The Laced Post Shore
3. 4-Point Bearing Crib