



Design and construction failures caused Singapore tunnel collapse

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INADEQUATE TEMPORARY works and design and construction errors led to the fatal collapse of Singapore's deepest ever cut and cover tunnel, the public inquiry into the disaster heard last week.

The collapse hit a 110m section of tunnel being constructed for Singapore Mass Rapid Transit's new Circle Line, adjacent to the six lane Nicoll Highway.

Four workers died when steel struts supporting the excavation's diaphragm walls failed, causing the tunnel to cave in on 20 April last year. Part of the highway was also destroyed.

The disaster was triggered by the failure of a connection between horizontal struts and waling beams, which between them supported the diaphragm walls, the inquiry heard last week.

The explanation was given as part of a summary of evidence submitted to the Committee of Inquiry in Singapore.

The general causes of the collapse were agreed last month by client the Land Transport Authority (LTA), main contractor Nishimatsu-Lum Chang joint venture (NLC), NLC's designer Maunsell Asia, NLC project engineer Paul Broome, base slab subcontractor L&M, strutting subcontractor Kori, diaphragm walling subcontractor Bachy Soletanche, project insurer Aviva, LTA project directors Ng Seng Yoong and Sripathy, and Singapore's Ministry of Manpower.

Although the general collapse scenario is agreed, the details are being disputed by the contractor and the LTA (see boxes).

In all, nine out of 10 levels of temporary horizontal struts had been installed to hold the diaphragm walls apart during cut and cover tunnel works.

These connected with horizontal walers running along the tunnel walls (see box overleaf).

The catastrophic failure started at the ninth level strut-waler connections, 30m below ground, and only 3m above formation level, the Committee of Inquiry heard.

Yielding of the level nine ctions allowed the diaphragm wall to deform, overloading struts in levels above, causing them to buckle.

This triggered a progressive collapse of the tunnel walls.

The failure was rapid. Only an hour elapsed between failure of the first strut-waler connection and total collapse of the excavation.

Overloading of the temporary works coincided with the excavation of a sacrificial prop installed using jet grouting

methods just below the ninth level struts.

NLC admitted to the inquiry that failure of the temporary works resulted from underdesign and inappropriate detailing of the strut-waler connections.

NLC's design engineers misinterpreted building code BS5950, said counsel for NLC Philip Jeyarentnam.

This resulted in the adoption of smaller than required steel sections for the struts, reducing redundancy in the design.

But this design deficiency was made drastically worse by omission of load spreading splays at the ends of the struts during construction (see diagram).

The contractor's failure to include these crucial structural components in the strut-waler connection was not picked up during routine works supervision the inquiry heard.

Consequently, the entire axial load of each strut was directed into the waling beam through a single point of contact.

Forces of 4,000kN to 4,600kN were being channelled through a detail designed with a capacity of 2,551kN.

Laboratory testing and infinite element analysis of identical strut-waler connections after the collapse revealed an actual ultimate capacity of 4,030kN-4,260kN.

Overloading of the connections led to buckling of the waler web in several locations before the collapse occurred.

The inquiry was told that NLC replaced waler web plate stiffeners with a C-channel stiffening detail - a 'C' shaped piece of steel commonly used in Nishimatsu's home country Japan.

All parties agreed that the sudden failure of this detail on the level nine strut-waler connections caused the collapse.

But there is intense disagreement between the parties over why this detail should have failed so suddenly and dramatically.

Head of the Committee of Inquiry, Judge Richard Magnus, is expected to reach a decision on who was to blame for the collapse later this month.

The Land Transport Authority's expert witness, Benaim director of geotechnical engineering Richard Davies, will be speaking about the Nicoll Highway collapse and inquiry at NCEI's Megatunnels conference, Wednesday 18 May.

Details: www.megatunnels.com, tel: (020) 7505 6944.