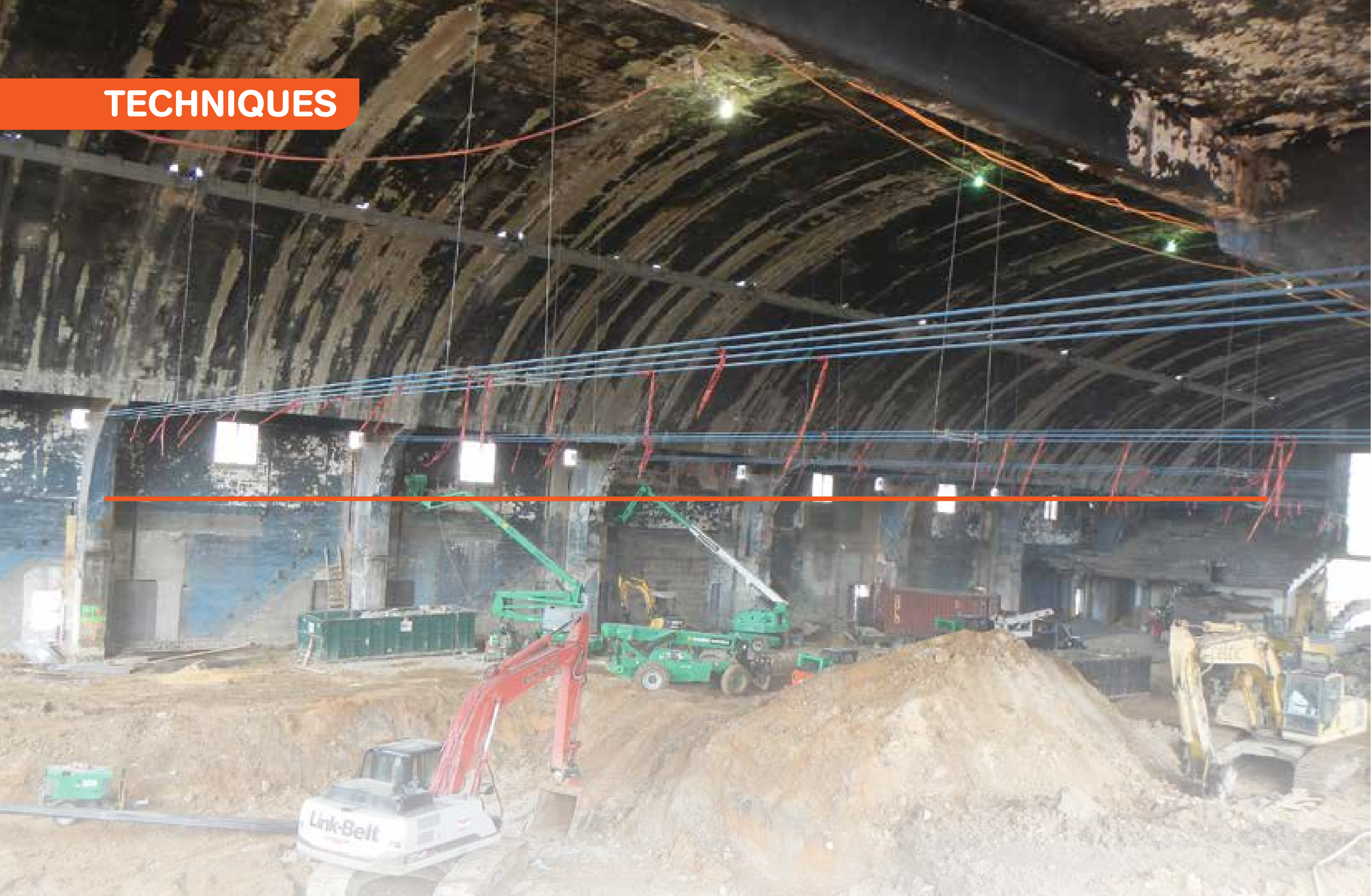

NOVEL POST-TENSIONING TECHNIQUE IN HISTORIC REFURBISHMENT

In modern construction, post-tensioning (PT) is a widely accepted method for providing reinforcement, especially where longer spans are required. Even so, you would not expect to find PT cables suspended in the air across the full width of a building in isolation from a concrete beam or slab.

This was what you would have seen during the recent redevelopment of an historic building in the US city of Washington, where PT cables were used to counteract the thrust forces generated during demolition – thought to be the first time this has been done anywhere in the world.

The Uline Arena has been a Washington landmark since it was built in 1941. During its 50-year history it was home to ice hockey and basketball teams, and hosted tennis matches, circuses, rodeos, car races, ballet and music concerts – including the Beatles' first appearance in the US in 1964.

The building also has architectural and engineering significance, as it was built using the 'thin shell' technique. This engineering method, originally developed in Germany, uses the inherent action of arches to enable huge unsupported spans to be built using very thin concrete.

The Uline Arena has brick walls and a barrel-shell roof that spans 48m with no intermediate supports, creating a huge cavernous space that was ideal for housing an ice rink – its original use. The roof was

formed of thin sprayed concrete panels supported by external concrete arches that sit on concrete columns.

Despite its engineering significance, the arena fell into disrepair in the 1980s. Now it has been given a new life as an office/retail development in the city's hip NoMa neighbourhood. Douglas Development has combined the old Arena, the adjacent Ice House and two other commercial buildings to form a one-hectare mixed-use site designed to attract tech start-ups and lifestyle stores.

The Arena itself has been converted from a single-storey hangar of a building into one level of retail beneath three levels of office space. The developer's aim was to create interesting, modern spaces while preserving and embracing as much of the existing structures as it could. This includes keeping much of the Arena's ribbed, barrel arched roof but punching sections out to form roof-level terraces.

The roof openings were created by demolishing sections of the original thin concrete shell panels. But, as the panels and arched ribs were designed to act together structurally, removing any portion of the structure has an impact on the stability of the entire building. If roof panels were removed without any support, the loads in the arched beams would deflect and push outwards on the columns, which could buckle under self-weight.

In the permanent condition, new intermediate post-tensioned floors prevent the columns from buckling and resist thrust forces. But until those floors were built, a temporary solution was needed to prevent the entire roof collapsing.

The traditional option would have been to build a temporary support structure in steel. However, this would have required very large, heavy frames or trusses – an expensive option that would have made it difficult to build the new intermediate floors.

Instead, the design team came up with the idea of putting an equivalent counteracting force through internal ties within the structure – something that could be done using (PT) cables. The team called on specialist company CCL to help devise a PT solution in which the cables could act as thrust restraints; the answer was to install groups of cables at each column-beam location and then stress them in a carefully controlled sequence.

Each cable was fixed onto an anchor block on the column, then slung across the full 48m span of the Arena before being fixed to an equivalent anchor block on the other side. The cables were supported by hangers until they were ready to be tensioned.

Eight cables were installed at each beam location, each stressed to 147kN from both ends of the cables simultaneously. 'The cables had to be tensioned in a very specific sequence,' explains CCL engineering manager Srinivasan Neelamegam. 'Once the first beam location had been stressed, the next group of cables had to be stressed within 12 hours to prevent differential stresses building up.

All the cables had to be installed, fixed to the anchorages and supported by their hangers before stressing could start at the first location,' he adds. 'Then the cables had to be stressed from both sides, so there were two crews working together.'

As soon as all cables were in place and fully stressed, the contractor was able to start taking out sections of the roof slab. Throughout the demolition, the building was monitored using a deformation monitoring system that utilised multi-station robotic surveying instruments to collect data every 15 minutes.

The PT cables did their job, and the demolition went very well. As a result, the redevelopment has now been completed, and the building is occupied by shops and offices.

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