MOMENTUM
structural engineers

Design note

Project	Date	By	Reference
Ambassadors Theatre, London	2 Mar 2023	RR	5208_DN_001

Title

Structural design philosophy, remedial works overhead pavement support

Introduction

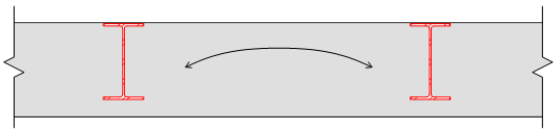
This design note discusses the overhead pavement support at basement level and the structural design philosophy adopted for the Ambassadors Theatre in West Street, London. The existing structure has been found to be in a poor condition and remedial works are proposed to ensure the longevity of the building.

This note refers to the areas at the stalls level (basement) in red below.

Stalls level (basement) survey drawing showing the areas considered in red.

Existing Structure

The existing overhead structure - supporting the pavement and skylights - is of a filler-joist construction, which was typically used in the era when the Ambassadors Theatre was constructed (1913). A filler-joist floor consists of steel beams, at relatively close centres (~600mm in this case), with an unreinforced concrete slab spanning between them and taking support of the bottom flanges. The bottom flange of the steel beams was fully encased in concrete as this provided a certain degree of fire protection.



Cross section of a filler joist floor with the steel beams shown in red and the unreinforced concrete spanning in between.

Additionally, steel trimmer beams are present around the skylight openings: these form the ‘opening’ to let the light in as this is where the structure steps up typically. These steel beams were originally encased in concrete as well, for reasons of fire protection.

Condition of Existing Structure

The existing structure has been inspected from below - the top is covered by the pavement and its build-up and this was not dug up - to understand it’s current condition. What became apparent was that the concrete cover on the bottom flange had completely spalled, which was due to the corrosion expansion of the steel beams: when steel corrodes its volume increases up to a factor of ten. The steel beams had suffered from various levels of corrosion: certain areas only had surface corrosion, whereas other areas (typically near the supports) had completely delaminated and could be removed by hand. Hence, the structural integrity of the steel beams - and thereby the floor as a whole - had been compromised and can’t be relied on anymore.

Left photo: the concrete encasing around the bottom flange had spalled, due to corrosion expansion.
Right photo: the corrosion was quite severe in certain locations, with delamination of the steel.

The cause of the corrosion is water ingress, in combination with the lack of ventilation (as the steel is encased in concrete). This might have been further exacerbated by the the clinker concrete typically used in those days: when the clinker concrete gets wet it creates a strong acidity which affects the steel.

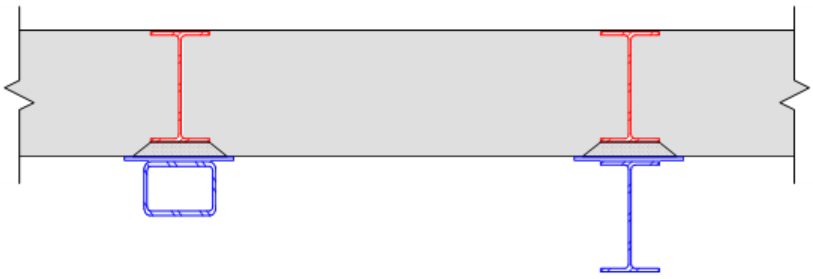
With regards to the steel trimmer beams around the skylights, similar deterioration was found: the concrete originally encasing the steel had spalled nearly completely, due to the corrosion expansion, and had exposed the soffit and sides of the beams. The steel was in an equally poor condition: serious delamination was visible at the top and bottom flanges and the web had been affected too. As a consequence, the steel trimmer beams need remedial works as well.

Left photo: the concrete encasing around the trimming steel beams had spalled, due to corrosion expansion. Right photo: delamination was severe in certain locations, in particular on the top and bottom flange.

Remedial Works

The structural design philosophy for the remedial works sets out to make the structure safe again whilst balancing this with practical restraints. Removing the existing steel beams would result in digging up the pavement and extensive temporary works as the slabs also prop the external retaining walls. As a consequence, new steel beams are proposed which sit below the existing ones, taking over their support function. Putting these beams in place with a significant level of corrosion protection (by galvanising) will ensure the correct level of support is achieved again. Also, the insertion of the steel beams could be reversed at a later date if it is ever decided to replace the full slab overhead.

The new steel beams will be as shallow as possible, not to affect the headroom too much. Depending on the extent of the spalled concrete, steel top plates will be introduced to provide sufficient support width. The area where the concrete is lost will be infilled with grout.



Principle of remedial works: providing new steel beams below the existing ones to take over the support function: new steel sections can be UB-sections (shown right) or reduced depth sections (shown left) where headroom is an issue.

With regards to the boiler room, a small portion of the existing filler-joist floor is removed completely: the structure for this is also in a really poor condition - both the steel and the concrete - and its removal is simplified as this is a suspended floor without anything above. Adding remedial works would lead to a reduced headroom in an already confined space and it would be difficult to deal with the safety risk of the spalling concrete (falling on people working below).

Left photo: small portion of the boiler room floor seen from stalls level. Right photo: existing structure seen from below, showing the significant corrosion and subsequent spalling of the concrete.