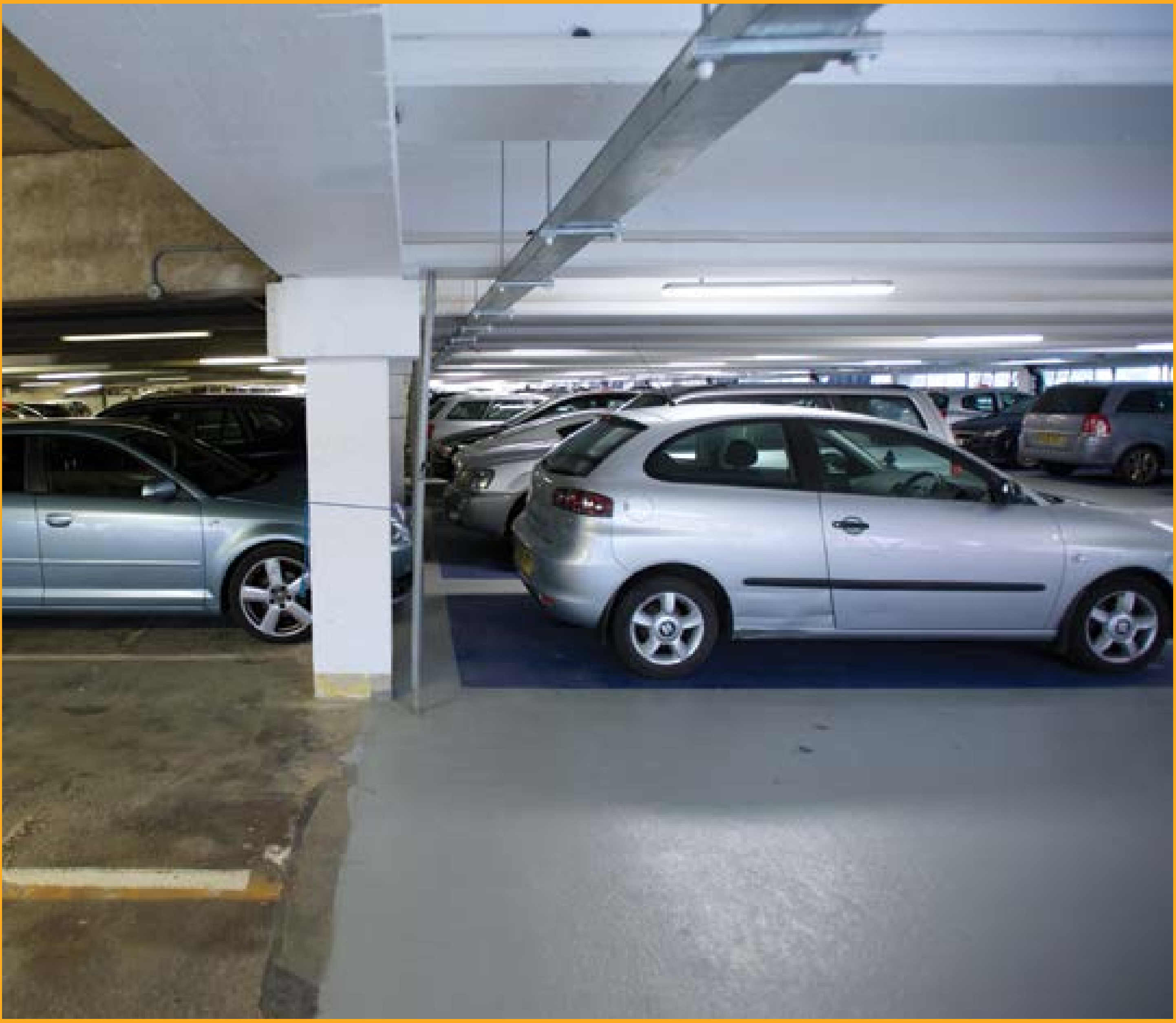


REFURBISHMENT
MERRION CENTRE MSCP

BUILDING TRUST

INTRODUCTION

The Merrion Centre is a prime Leeds shopping location with over 100 retailers within it. One of the longest established Leeds shopping centres it includes a range of shops, cafés, bars and clubs and is located near to the First Direct Arena Leeds and associated Arena Quarter Development. Opened in 1964 it has been owned and managed, from construction to the present day, by TCS Holdings Limited. Originally open air, the centre had a roof installed during the 1970s and is an early example of a mixed-use development.

As the structure approached its 50th anniversary, Curtins Consulting was employed to develop and deliver a refurbishment strategy for the multi storey car park at the Merrion Centre. Curtins have been involved in refurbishment projects for over 50 years. They have experience of large and small, straightforward and complex projects which enables them to develop an approach to give the best value to the client and the team.

Using there RAPID approach they quickly highlight areas of uncertainty within the proposed works so costs could be adequately assessed during the feasibility stages. Their experience of similar challenges and extensive knowledge of construction materials, both historic and cutting edge, enabled them to advise quickly and confidently on an appropriate solution for the Client. Early involvement of the specialist material supplier, Sika Limited, to provide technical information and input to support the design process, ensured a practical solution, following the current best demonstrated practice laid out in current standards and other relevant documents, to many of the technically challenging issues of the project, whilst allowing the design brief and financial constraints to be considered.

MERRION CENTRE – BEFORE REFURBISHMENT

This helped to manage the risks associated with budget assessment and pre-planning design development.

The Structural Engineering design brief for the project was to carry out refurbishment of the existing multi-storey car park, including construction of new vertical circulation cores and change of use for retail units where necessary with a proposed design life of 20 years.

The 110m long by 48m wide car park is of split level deck (SLD) design and one-way flow configuration, providing parking for 1050 vehicles over eight separate decks. Even numbered decks are 110m long and 32m wide and feature four lines of parking bays with two driving aisles, whilst the odd numbered decks are 110m long by 16m wide featuring one driving and two lines of parking bays.

The decks are constructed from precast, pre-stressed concrete planks, spanning between precast, pre-stressed inverted T bridge beams, with an insitu concrete topping providing the wearing surface for the car park. The bridge beams are supported simply on corbels on columns or primary beams running between columns. Car park level decks were originally designed for 1.9kN/m2 (40 lbs/ft2).

Based on an article from the Concrete Magazine dated September 1964, it was understood that the deck slabs were 110mm thick; consisting of a 60mm deep precast concrete (PCC) pre-stressed Bison plank unit overlaid with 50mm of insitu, part reinforced, concrete wearing screed.

The partial reinforcement consisted of transverse reinforcing bars positioned within the concrete wearing screed but only placed perpendicular to the line of the inverted T-beams beneath, which were situated at 2.7m spacing and span 16m, either to a perimeter corbel or an internal spine beam.

TYPICAL PRECAST BRIDGE BEAM WITH INSITU SLAB

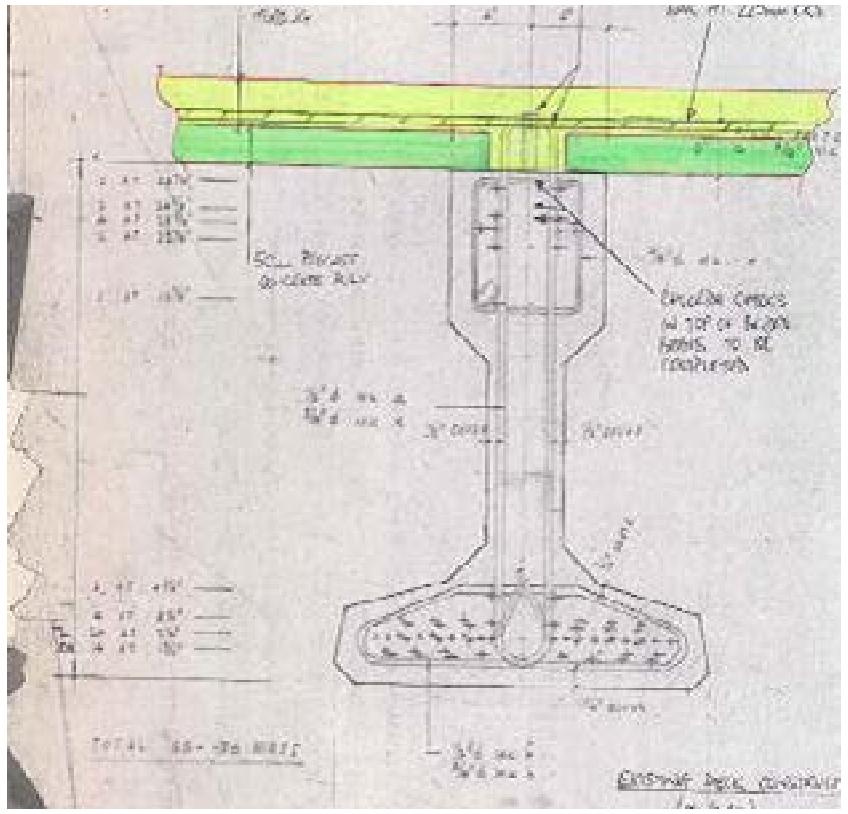
The original drawings referred to these bars as 3/8th inch diameter (approximately 10mm) positioned at 9 inch centres (approximately 250mm) perpendicular to the line of the T- beams. Each bar is shown as approximately 4 feet long (approximately 1220mm). Additional ¼ inch diameter bars (approximately 7mm) were also specified at 4 No. per bay.

Construction trials and investigations carried out in 2011 witnessed severe pitting corrosion to steel reinforcement in the insitu concrete section of the existing floor slab. Transverse steel bars, composite shear studs and reinforcement links projecting from precast, pre-stressed bridge beams were all observed to be suffering from severe corrosion where de-icing salts had penetrated the concrete matrix from the surface and through surface cracks. Delamination between the precast pre-stressed planks and the insitu topping had been recorded prior to these construction trials.

Curtins assessment was that the original structure had been designed such that the down stand bridge beams were acting compositely with the floor slab; the floor slab was spanning between the bridge beams and gaining the benefit of fixity by the provision of projecting dowel bars and shear links and inclusion of transverse steel reinforcement.

Prior to the refurbishment the car park, floor slabs acted more as a series of simply supported elements which were not positively tied together. The bridge beams were receiving benefit from the projecting dowel bars and shear links but not the full benefit that appeared to have been designed from the drawn details.
Cracks had developed in the insitu concrete topping and corrosion of steel reinforcement has taken place. It was concluded that corrosion and deterioration will continue to take place unless remedial action was taken.

The corrosion had led to the bridge beams no longer acting compositely over their length. This did not appear to be affecting their strength, which would be evidenced by vertical stress cracks forming in the middle of them.



The lack of composite action and reduced effective depth from delamination may have been affecting deflection which was a perceived problem around the car park generally.

Corrosion has led to fixity of the slab support being reduced; this in turn increased the mid span bending moment and hence the potential of overstressing in the pre-stressed tendons in the slabs. Exposure of the slab support during the construction trials showed that support of the slabs was less than 50mm to some planks, in some places less than 10mm. Originally, the transverse steel reinforcement would also have provided support; this benefit has been reduced or removed following corrosion of those bars.

Delamination between the pre-stressed planks and in-situ topping has led to reduction of bending and shear capacity of both the floor slab and bridge beams due to the reduction in overall structural depth of each element.

To achieve the 20 year life extension brief, a design incorporating the management of the existing corrosion within the structure by an agreed method of corrosion protection, repair to all observed deficiencies in the concrete structure, application of carbon fibre strengthening where it is believed that corrosion of the steel had resulted in a reduced capacity of the structure, either directly or through changes in articulation and finally seal the concrete structure from ingress by water, was required.

The refurbishment proposed that:

1. Delaminated insitu concrete topping shall be removed from the existing concrete floor slabs.

2. Where exposed, corroded transverse reinforcing bars (10mm dia) shall be replaced along their full length (1200mm) or lapped minimum 400mm with existing uncorroded bars.

3. Remaining mild steel reinforcement should be protected by either the use of a corrosion inhibitor or galvanic anodes; the concentration or frequency depending upon chloride content of the original remaining concrete substrate shall be determined by a concrete repair specialist.

4. Migrating Corrosion Inhibitor (MCI) or Galvanic anodes should be used to provide corrosion control to the entire intact (sound) concrete deck surface including top and soffits, surfaces and downstand bridge beams. A decorative protective anti-carbonation paint should also be spray applied onto the downstand bridge beams.

5. Areas where concrete had been removed should be replaced with new pre-bagged concrete repair mortar of equal or higher compressive strength and all concrete repairs should be allowed to reach their design strength.

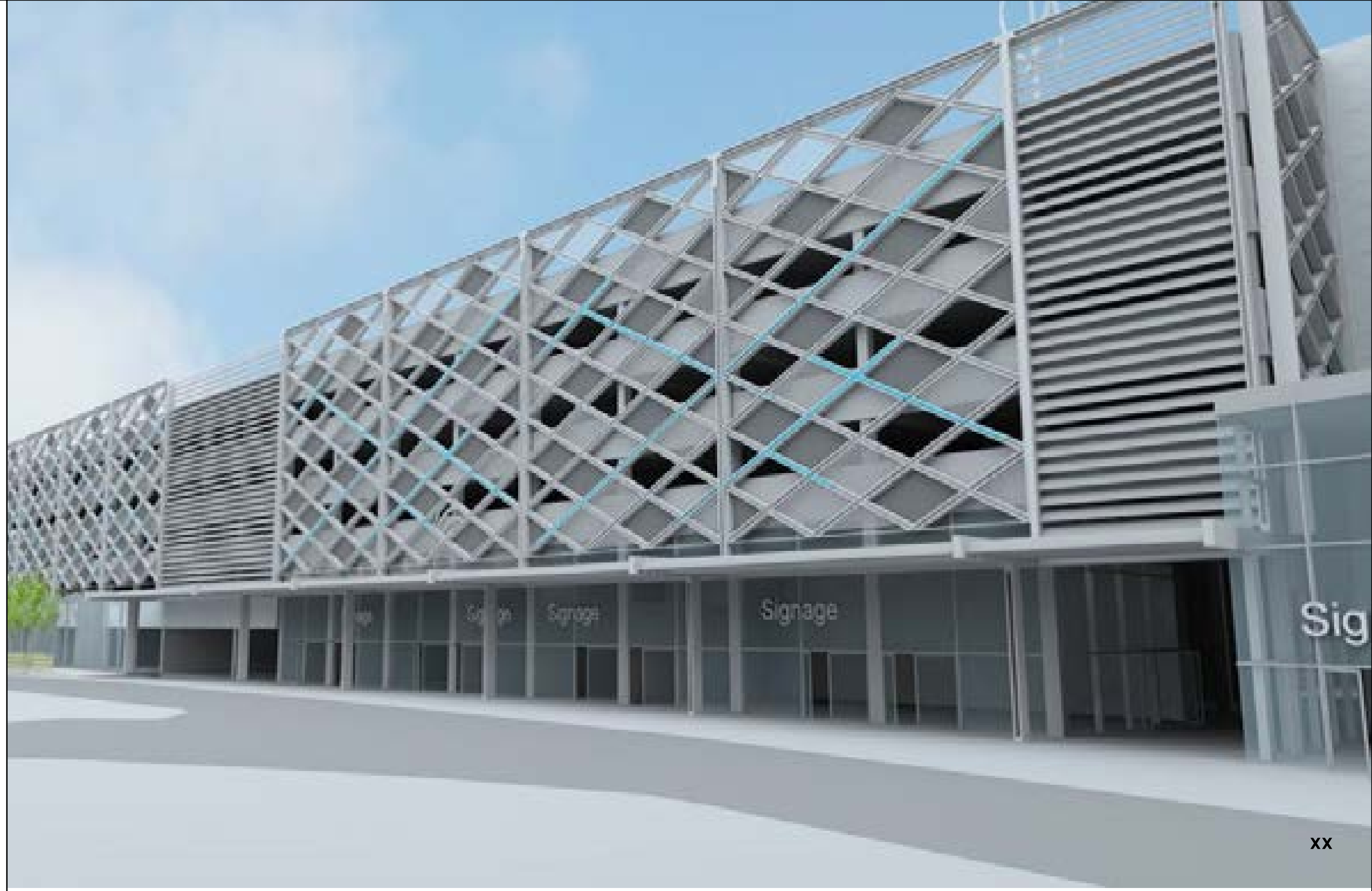
6. Carbon fibre anchorage points should be drilled into the existing or repaired concrete slab above the pre-stressed bridge beams.

7. Carbon fibre wrap should be installed using the dry method to the entire soffit of the existing car park planks and vertically down the vertical face of the downstand bridge beams, a minimum length of 200mm.

8. Carbon fibre anchors should be installed into the existing or repaired concrete slab or perimeter edge beams, to a suitable depth depending on installation. The existing slab was approximately 110mm thick, or 220mm at an inclination of 30 degrees above the horizontal.

9. Carbon fibre plate bonding to strengthen long span traditionally reinforced beams.

10. Elastomeric waterproof decking should be applied to the entire top surface of each car park deck.



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Prior to finalisation of the scheme a full scale trial installation and load test was carried out to confirm that the proposed strengthening works would satisfy the requirement of the design and identify any practical installation issues. This trial was carried out on an area of good condition slab, and any areas with structurally damaged concrete due to spalling were avoided, for the purposes of the trial.

The installation included application of the required thickness of fabric to the soffit of the slab, including the anchoring and lap details onto the down stand inverted T beams. A 20mm radius fillet was cast in the angle between beam and slab along with holes drilled to allow the installation of the composite spike anchors, prior to the installation of the fabric.

Following the full cure of the strengthening system the slab was then loaded and monitored, to demonstrate its performance.

The project was tendered at the end of 2012 and the specialist car park refurbishment contractor, Makers Construction Ltd, was awarded the project and started on site in autumn 2013. They started with an initial external façade phase, which was designed to increase the level of occupation of the retail units by improving the aesthetics of the centre and resolve some water penetration issues to the retail units from the car park above.

The full range of technical specialist refurbishment materials were supplied by Sika Limited, which included strengthening, repair and protection, corrosion control and car park deck waterproofing systems.

Makers Construction Ltd continued onto the main phase of the works, pulling off site only during the Christmas periods to maximise parking spaces available during the busy period for the centre.

2 COMPOSITE STRUCTURAL STRENGTHENING

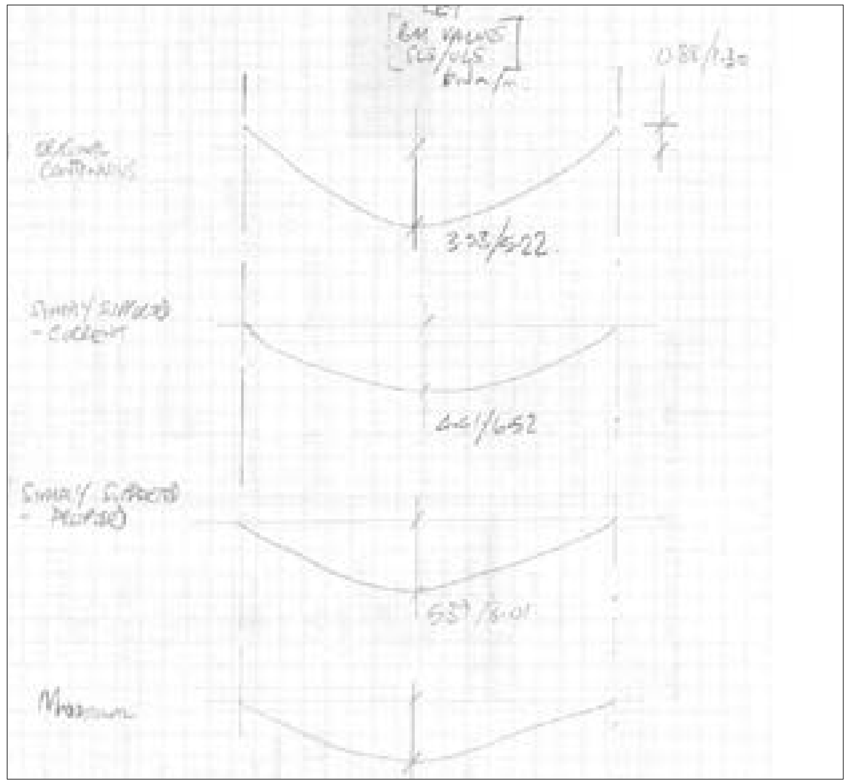
Carbon fibre strengthening was required to areas of the existing primary structure that had or was showing signs of structural distress. There were two proposed areas of application. The first was to strengthen isolated reinforced concrete beams which were showing signs of excessive deflection or where additional load was being applied to them as part of the re-development. It was proposed that carbon plates would be applied to these beams subject to detailed design. The second area is the wholesale strengthening of the existing floor decks whose support conditions have been relaxed over the life span of the car park. This strengthening would satisfy the original design loading in non-continuous (more onerous) conditions.

The design of the strengthening was carried out using guidance from the Concrete Society Technical Report TR55 'Design Guidance for Strengthening Concrete Structures using Fibre Composite Materials'. The guidance recommends for members strengthened in flexure the following points need to be considered:

- The maximum moment.
- Risk of peeling of the ends of the composite material needs to be investigated.
- Potential debonding of the composite material and the concrete substrate should be checked.
- Shear capacity of the structure determined.
- The ductility of the strengthened member needs to be verified.

Serviceability Limit states needs to be complied with e.g. cracking, deflection, fatigue, creep and rupture.

EXISTING FLOOR SLAB - BENDING MOMENT DIAGRAM



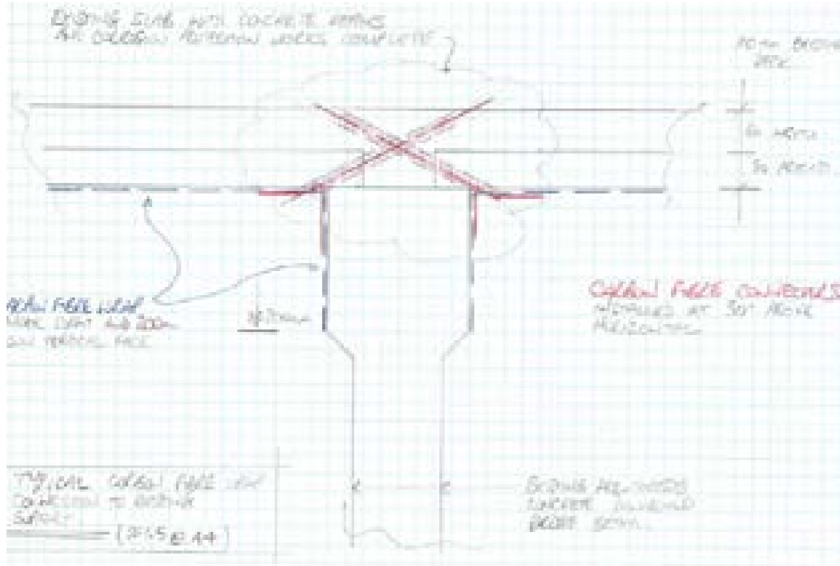
Strengthening was to be applied to the soffit of the existing concrete floor slab. Curtins had completed calculations which indicated the structural requirements for the carbon fibre wrap and its restraint at support locations.

A single layer of bi-directional carbon fibre fabric applied using the dry application process was found to meet the additional moment capacity requirement. The design considered the increase in capacity between supports obtained from the carbon fibre application. The product used in the calculations was a bi-directional carbon fibre wrap system which provided the benefit of increasing the capacity across the lateral joint of existing precast planks.

The calculations assumed that the existing concrete floor slab was intact and solid throughout its full 110mm depth and a full bond of the strengthening could be achieved with the soffit of the existing precast concrete planks. The fabric selected contained 150g/m2 in each direction of carbon fibre with a characteristic tensile strength of 4000MPa and Modulus of Elasticity of 240GPa. This fabric gave a design thickness of 0.083mm in both directions. With the strengthening installed this would give the slabs enough capacity to satisfy the maximum moment requirements and ensure the serviceability requirements, particularly deflection were also satisfied.

SPIKE ANCHORAGE DETAIL SKETCH

However, the design showed that there was a potential peeling issue where the fabric applied to the soffit of the slab met the beams. This issue was resolved by the inclusion of unidirectional carbon fibre spike anchors. Laboratory sample testing carried out and reported by Eshwar, Nanni and Ibell in ACI Materials Journal had shown that the use of spike anchors could significantly improve the performance of externally bonded CFRP. This conclusion was also confirmed by a Test Report carried out by Sika Services AG 'SikaWrap with and without anchor: Lap shear tests on L Shape substrates'.



Drilled into the concrete slab at 30 degrees above horizontal, for the Merrion Centre, these anchors would need to be installed at 350mm centres and be able to withstand an ULS force of 26.7kN each to meet the performance requirements of this project. The 10mm diameter and 300mm long spike anchors were bonded into 20mm diameter holes drilled into the concrete slab to give an embedded depth of 150mm. The edges of the holes were smoothed off with a radius to remove a sharp arris.

Spike Anchor

A schedule of beam length and carbon fibre wrap or plate thickness was provided in tender documents, although full detailed design was developed subsequent to the tender process, for the isolated beams.

The client expressed a desire to have the proposed carbon fibre strengthening works tested to confirm that the expected increase in load capacity was achievable.
The ideal location for this trial meant that the access road would need to be closed off whilst the works were ongoing, so part of the car park needed to be closed a traffic diverted as necessary for the duration of the trial.

Following the 3m by 2.7m application of the strengthening trial, it was loaded using dense blocks to apply a maximum load of 4.0kN/m2. Prior to application of the blocks a 25mm maximum thickness layer of sand blinding was applied to the top of the slab. This blinding was then covered with 1 layer of blocks laid flat (100mm high) to provide an applied load of approximately 2.0kN/m2. Deflection readings were taken after 5 minutes and again after 30 minutes had elapsed. A further layer of blocks was added providing an applied load of 4kN/m2. Deflection readings were taken again after 60 minutes and again the following morning.

As a precaution a crash deck was provided for the duration of the testing, with the design requirement that it should be able to transfer 8kN/m2 directly to the bridge beams below with no load being transferred to the existing car park.

A sample application of the waterproofing system was also applied to the deck in the strengthening trial area.

The monitoring of the various stages of application of the load concluded that there was very little deflection of the trial area, and what movement was recorded was likely to be influenced by the dynamic load applied by vehicle movements elsewhere on the structure.

3 CONCRETE REPAIR AND CORROSION PROTECTION

The primary objective of the repair and corrosion protection strategy was to replace all structurally damaged or delaminated concrete and manage the future corrosion of the mild steel reinforcement within the in-situ concrete topping and precast concrete planks, beams, cladding panels and columns, in line with the 20 year design life of the project.

The principles and project phases outlined within BS EN1504 for the assessment, management and design of the repair work were adopted by Curtins at an early stage in the project.

A study was carried out at the beginning of the design phase of the project to collect information about the structure. This included general condition and history, documentation e.g. calculations, drawings and specifications and repair and maintenance history. This information provided valuable data to understand the existing condition of the structure.
A process of assessment was undertaken which included an in-depth condition survey identifying visible and not readily visible defects of the structure to access and address the root causes of the damage. This was then used to assess the ability of the structure to perform its function.
The aim of a concrete survey is to identify defects to the concrete, such as mechanical, chemical or physical including defects in the concrete due to reinforcement corrosion.

Based on the assessment and survey, the owner was presented with a number of options to be selected while deciding the relevant actions to meet the future requirements of the structure.

Typical examples of repair options were:

- Do nothing or downgrade the capacity.
- Prevent or reduce further damage without repair.
- Repair all or part of the structure.
- Reconstruction of all or part of the structure.
- Demolition.

The final design of the refurbishment solution considered important options including:

- Intended design life following repair and protection.
- Required durability or performance.
- Safety issues during repair works.
- Possibility of further repair works in the future including access and maintenance.
- Consequences and likelihood of structural failure.
- Consequences and likelihood of partial failure.

The relevant protection and repair principles were defined and the repair options developed from management strategy as outlined in BS EN1504-9. The design philosophy for repair took into consideration the type, causes and extent of defects and future service conditions and maintenance program.

Following the selection of the relevant principles from BS EN 1504-9, Curtins also considered the intended use of the structure. In the case of concrete refurbishment the specifications were to be drawn up based on the requirements of the relevant parts 2 to 7 of BS EN 1504.
It is important strategy work considers not only the long term performance of the structure, but also the effect of the selected materials on the rest of the structure and ensures there is no adverse effect on the structure.

As part of the in-depth condition survey, a deck delamination inspection and schedule of repairs was carried out and provided as part of the tender documents to allow contractors to estimate repair areas and propose efficient methods of removal and repair.

Where the in-situ concrete was delaminated from the deck, this structurally damaged concrete was removed, taking care to avoid damage to the existing precast pre-stressed planks below and replaced with a new concrete repair material. As a high level of alkalinity would be provided by the repair system, additional corrosion management for bars in the main volume of the repair area was unnecessary. However, around the perimeter of the repair there was a risk that new incipient anodes may be created by the installation of the new more alkaline repair mortar. Corrosion inhibitor or galvanic anodes were to be used to provide protection to reinforcement around the perimeter of all areas of new concrete repair mortar. Where mild steel reinforcement lacer bars were exposed and observed to have been detrimentally affected by corrosion they were replaced or spliced with new 10mm diameter high tensile ribbed reinforcing bars over the full length of their exposure.

The compressive strength of the new concrete was specified to be a minimum of 40N/mm² or a grade R4 material, as a structural repair material was required as specified in BS EN1504-3 and providing a repair methodology as per Principle 3 of BS EN1504-9: Concrete Restoration, the full strength needed to be achieved prior to any carbon fibre strengthening works commencing. The concrete repair material had to be suitable for installation around existing and new reinforcement which was of particular importance above the bridge beams.

In areas of deck where the in-situ concrete was structurally sound, the contractor was given the choice of installing sacrificial galvanic anode or migrating corrosion inhibitor, at a frequency or concentration to suit the corrosion potential and the density of reinforcing bars. Systems which would provide protection as outlined in Principle 9 of BS EN1504-9 Cathodic Control - Method 9.1 were defined as acceptable.

In accordance with the BRE Digest 444 Pt2:2000 the risks associated to potential steel reinforcement corrosion occurring due to chloride contamination within the concrete are variable depending on the source and age of the structure. For ease of ingressed chloride classification, the following criterion was defined:

% Chloride by weight of cement	Risk
<0.30%	Negligible to low risk
<0.30 – 0.69%	Moderate risk
<0.70 – 1.0%	High Risk
>1.0%	Extremely High Risk

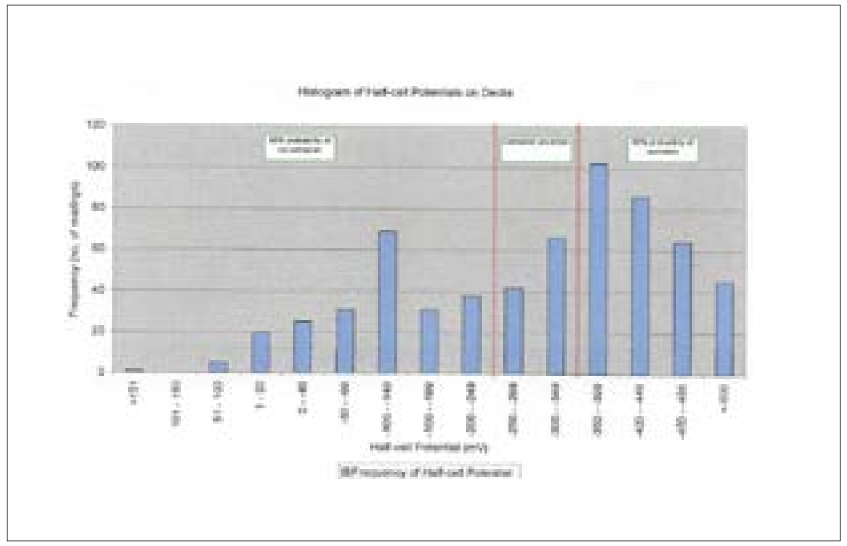
Half-cell potential mapping of the whole floor decks was not completed as part of the investigations prior to tender as there is limited continuity of reinforcement in the in-situ concrete topping to the floor slabs. In areas where continuity existed, test panels were created. The contractor could undertake any additional testing to prove the suitability of the corrosion protection system that he proposes to the satisfaction of the Engineer.

Half-cell potential testing was used to measure the probability of a corrosion condition existing within the reinforced concrete structure. Results can vary from day to day and can generally vary by season due to the prevailing moisture condition of the concrete. Interpretation of results should be carried out in accordance with ASTM C-876 as follows:

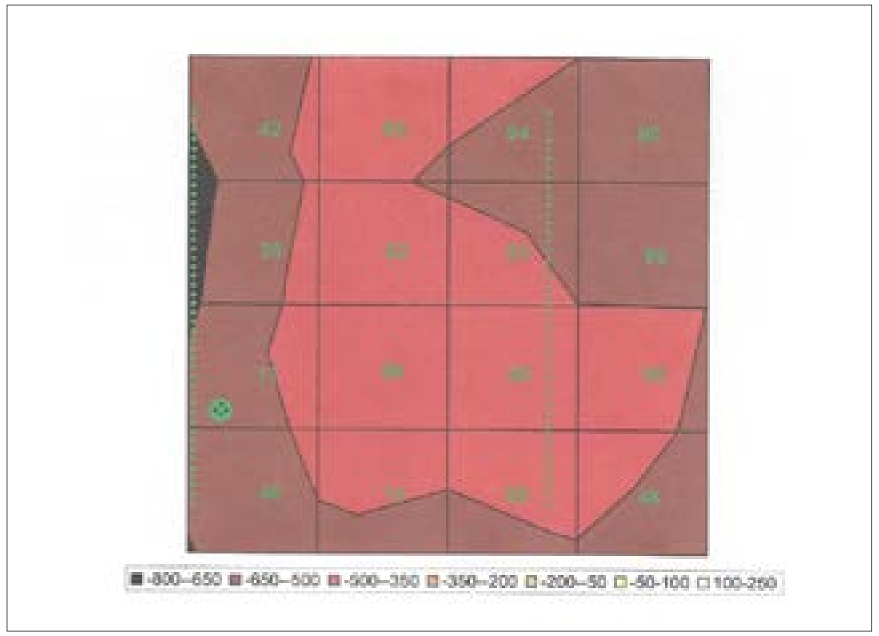
Half Cell Readings	Risk
More negative than -200mv	Less than 10% probably of corrosion
-200 to -350mv	Uncertain, 50% Probability of corrosion
More negative than -350mv	More than 90% probability of corrosion

With the above points considered and the available testing results on the car park showing many chloride readings in the extremely high risk category and many half-cell results in the more than 90% probability of corrosion category, it was anticipated that the specialist contractor could propose different regimes of corrosion protection frequency or concentration depending upon measured results on site using his experience.

HALF CELL POTENTIAL DISTRIBUTION OF DECKS



HALF CELL MAP FOR TEST PANEL 14- DECK LEVEL 6



The areas which consistently showed the highest chloride concentrations and corrosion potential were over the precast concrete bridge beams. Areas of lower risk were typically the floor slab areas be Areas of lower risk were typically the floor slab areas between bridge beams.

Test Panel 14 showed one of the highest levels of corrosion potential. In the results diagram below, 2 cracks were present shown by the dotted line and in the broken out area, shown by the circle, surface corrosion was observed.

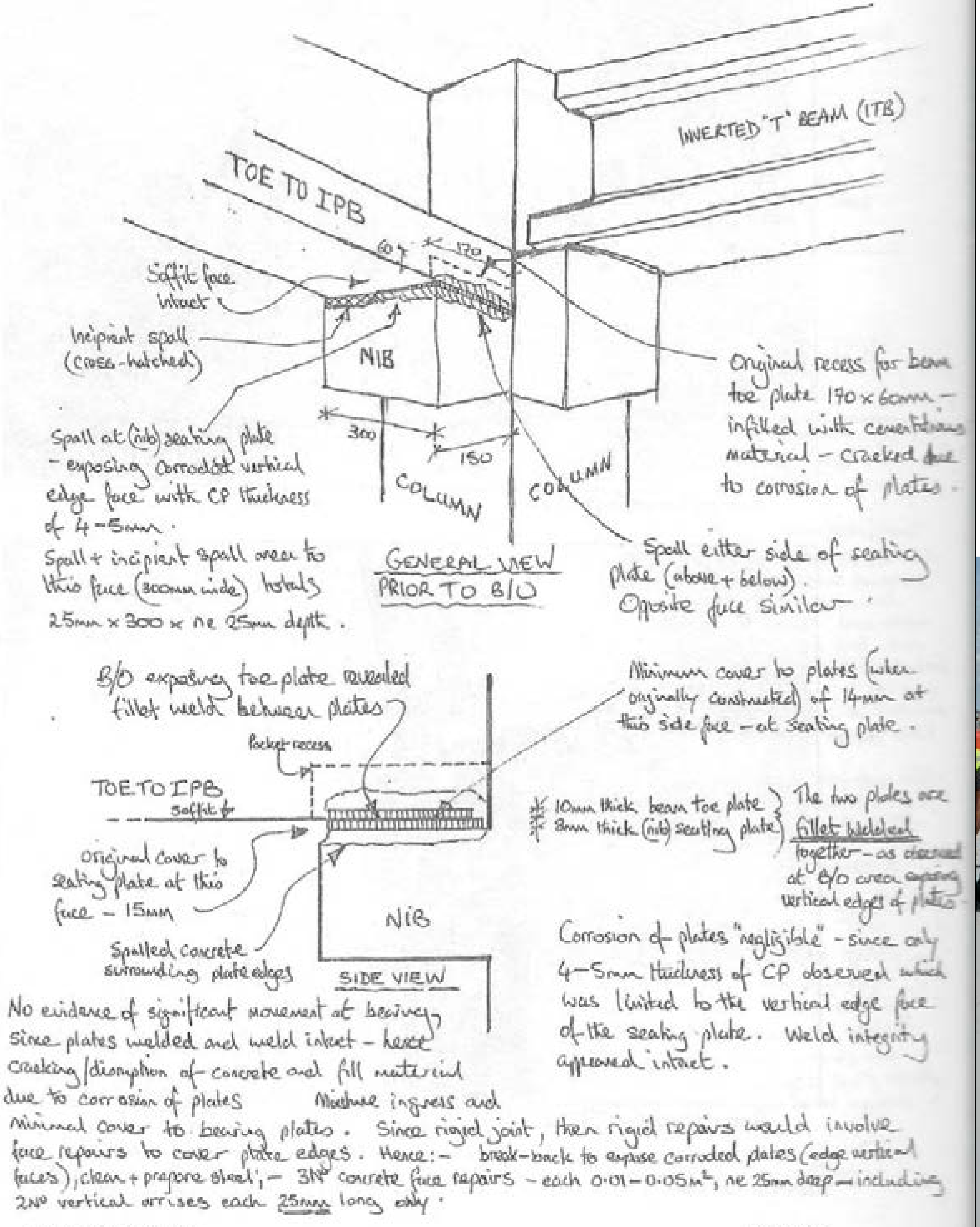
Direction was given in the tender documents that where galvanic anodes were proposed they may be fixed to the stirrups or dowel bars of the main bridge beams and continuity through the reinforcement in the bridge beams may be assumed. All other reinforcing bars could not be assumed to be electrically continuous. Where migrating corrosion inhibitors were proposed qualitative test results and evidence that the migrating corrosion inhibitor had reached the reinforcement to reform the passivating layer needed to be provided.

Chloride concentrations and corrosion potential rates within precast pre-stressed concrete floor planks, precast concrete cladding panels, down stand beams and columns were significantly lower than the existing in-situ concrete floor topping.
To provide long term protection once again a system that would provide protection as outlined in Principle 9 of BS EN1504-9 Cathodic Control - Method 9.1 was called for, such as a migrating corrosion inhibitor applied to the remainder of the structural elements on the face which is closest to the reinforcement:

- Soffit of precast concrete pre-stressed planks.
- Internal face of precast cladding panels.
- Full exposed perimeter of all downstand beams and columns.

In addition to the repairs to the in-situ concrete floor slab, there were many other repairs required to the various other elements of the structure. Each defect was carefully documented within the tender information, including the proposed method of repair. Once again the principles and materials were defined in accordance with BS EN1504, for these smaller but much more complex repairs.

Typical Complex Repair Detail



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After concrete repairs were completed, the exposed concrete building façade was coated with a flexible anti-carbonation paint which fully conforms to the requirements of BS EN1504 – 2 as a protective coating and had to be:

- Suitable for protection against ingress (Principle 1, method 1.3 of EN 1504-9).
- Suitable for moisture control (Principle 2, method 2.3 of EN 1504-9).
- Suitable for increasing the resistivity (Principle 8, method 8.3 of EN 1504-9).

Whilst a variety of colours are available the anti-carbonation coating on the Merrion Centre was generally white to suit the aesthetic finish of the building.

4 CAR PARK DECKING SYSTEMS

The purpose of installing car park decking systems at the Merrion Centre was to stop water ingress into the existing concrete structure and to halt corrosion of the existing steel reinforcement. The existing concrete frame was known to move and deflect and was of an overall physical size that meant that thermal expansion and contraction would continue in future years.
As with the concrete repair specification, the principles and project phases outlined within BS EN1504 for the assessment, management and design of the waterproofing membranes were adopted by Curtins at an early stage in the project.

In selecting a waterproof decking system or systems for car parks, consideration to the following factors needs to be given in order to select the most appropriate system to meet the requirements of the project:

The Construction of the Structure
- in-situ concrete.
- steel framed.
- composite decks.
- precast units.

Movement
- Ground movement or movement of the structure or of individual components, eg at construction joints, expansion joints, is usually visible. Parking structures in use are always subject to dynamic loading.

Thermal Variations
- Sunlight causes thermal expansion and stress cracking.
- Frost causes thermal contraction and freeze/thaw damage.
- Ultraviolet light causes degradation of organic materials, ie waterproofing membranes, resin and coatings.

Atmospheric Carbonation
- Atmospheric carbon dioxide gradually and progressively reduces the protective alkaline layer around the reinforcement, which will allow the steel to corrode.

Rainwater
- With water filling the pores and capillaries, concrete becomes susceptible to freeze/thaw damage.
- In carbonated concrete water ingress will allow steel reinforcement to corrode.

De-icing Salts
- De-icing salts are based on chlorides. The penetration of water contaminated by de-icing salt into concrete cause corrosion of embedded steel reinforcement and often cracking, spalling and delamination of concrete cover.

Aggressive Pollutants
- Acidic oxide gases of sulphur and nitrogen from exhausts diffuse into the condensation and attack and corrode the concrete surface, which reduces the strength and increases the porosity.

Automotive Fluids
- Some liquids, such as hydraulic brake fluids, are very aggressive and will attack concrete and steel surfaces.

Mechanical Exposure
- The decks of parking structures are exposed to different levels of mechanical stress, according to their location and function, ie:

- Pedestrian levels: walkways.
- Standard levels: in primary parking bays.
- Heavy levels: entrance and exit areas, ramps and turning cycles.

When these considerations were taking into account, the Engineer for the project developed a specification which requires several different types of system for different areas.

An elastomeric waterproof coating was required to be applied to all levels of the car park. The system supplier needed to include any conditions such as cleaning and maintenance regime and use of de-icing products as relevant for the proposed system, to maximise durability and provide a design life of 10 years for the applied system.
The elastomeric coatings were required to have dynamic and static crack bridging properties to the maximum crack width of 0.3mm when the structure is accessed in accordance with BS8110 at -20oC.

The specification called for the roof level waterproof system to meet classification OS11a according to German Standard DIN EN 1504-2 and DIN V 18026, being resistant to UV light and have greater flexibility to accommodate daily thermal changes.
Intermediate decks were required to receive a waterproof system meeting classification OS13 according to German Standard DIN EN 1504-2 and DIN V 18026. Both of the above were to be applied to the existing concrete surface which will have concrete repairs recently completed, so repair and waterproofing programming needed to be considered.
The existing concrete surface had to be prepared in accordance with the approved system product installation instructions.
On car park levels 0, 1 and 2 from grid A to L, asphalt had been used previously to try and prevent water ingress to shops below; a system suitable for the application over asphalt was required.
The existing asphalt surface shall be prepared in accordance with the approved system product installation instructions.

The specification also required the coating to the exposed Level 0 external roof and internally to grid line W had to be a waterproof system meeting classification OS11a according to German Standard DIN EN 1504-2 and DIN V 18026 and be resistant to UV light and have greater flexibility to accommodate daily thermal changes and suitable for over occupied areas. The remainder of the asphalt covered decks were to receive a waterproof system meeting classification OS13 according to German Standard DIN EN 1504-2 and DIN V 18026.

The relevant elastomeric coating shall cover the whole of the horizontal surface of each deck level and lap up a minimum of 100mm vertically up vertical faces of concrete walls, plinths and columns. All elastomeric waterproof decking systems shall have a minimum thickness of 4mm.
The European Standard for repair mortars, protective coatings and waterproofing membranes is BS EN 1504. This standard is based on the German equivalent Rili-DAfStb. The reason for following the German standard was that it was the most complete and complex standard for such applications; in fact it was the only standard that tested and categorised car park decking membranes. Therefore, this standard has had a significant influence on the development of the European standard (most of the test procedures within the German Standard have an EN number already).

This German Standard is an important guide to system selection and categorisation as:

- It defines surface preparation for all concrete repair systems, injection resins and protective coatings – therefore, it is easy to compare different systems and their capabilities in order to choose the best and most appropriate ones.
- It is the only standard that includes decking membranes especially for car parks – therefore, the tested systems will provide a high level of certainty for the end user.
- It is approved by the German government (independent non-profitable organisation) – independent results to make an objective decision.
- It defines standardised testing methods – comparison of different systems and materials is easily possible.
- The tests within it reflect every possible exposure – to guarantee the applicability of systems.

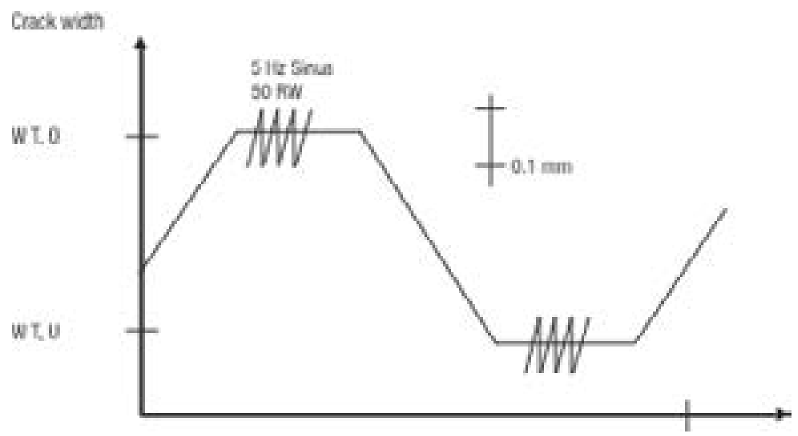
For example, the test method for the resin based decking systems reflects every possible exposure on car parks, such as:

- Artificial weathering (DIN 53384 – EN 1062-11).
- Pull off tests in line with EN 13687.
- Abrasion/wear resistance test SRT (61) to DIN 51 963.
- Slip resistance test to (DIN 51130 or EN 660).
- Skid resistance test SRT (62) to BS 812.
- Artificial ageing for 7 days @ 70°C (EN 660).
- Chemical resistance test (EN 660).
- Impact resistance test (EN ISO 6272).
- Test to determine crack bridging properties of decking system (EN1062- 7) - Dynamic and static of 0.3mm @ - 20°C and Static of 0.1mm @ -10°C.

An example of a test method used to determine crack bridging properties (EN 1062) is outlined below for an OS11 System and demonstrates the dynamic loading carried out at both upper and lower crack width boundaries of an applied system:

System: OS-11.
Classification: II T+V, dynamic.

W T, O = 0.30mm	upper crack width.
W T, U = 0.10mm	lower crack width.
D W V = 0.10mm	change of crack with through traffic.



Note: the graph is showing 1 cycle, the test involves a total of 1000 cycles.
The standard categorises systems in the following way:

- OS 8: Rigid, broadcasted, coloured, high wear resistant surface protection system for concrete according to DIN EN 1504-2 in consideration of DIN V 18026 for OS 8.

- OS 11 a/b: Flexible, broadcasted, dynamic crack-bridging, coloured, wear resistant surface protection system for concrete according to DIN EN 1504-2 in consideration of DIN V 18026 for OS 11 a/b.

- OS 13: Flexible, broadcasted, static crack-bridging, coloured, wear resistant surface protection system for concrete according to DIN EN 1504-2 in consideration of DIN V 18026 for OS 13.

The global experience and presence of Sika Limited meant they were ideally suited to assist with the correct selection of the protective systems needed at the Merrion Centre.

MERRION CENTRE MSCP, LEEDS

For further information on any of the products detailed in this paper, please contact us on:
0800 112 3863

Our most current General Sales Conditions shall apply.
Please consult the Data Sheet prior to any use and processing.

bsi. ISO 9001 Quality Management

bsi. ISO 14001 Environmental Management

bsi. OHSAS 18001 Occupational Health and Safety Management

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