

Northminster Multi-Storey Car Park

Structural Review Report

August 2019

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Structural Review Peterborough City Council

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1. Introduction

At the request of Peterborough City Council (PCC), Skanska has been commissioned to undertake an independent review of the findings and recommendations made by the Rolton Group in a recent inspection report (Rolton Group, 2019) regarding the condition of Northminster Multi-Storey Car Park (MSCP) and the implications for its continued use. Due to public safety concerns about the structural integrity of the car park, this review has been undertaken at short notice and is therefore limited within its scope.

Due to the nature of the defects identified in the Rolton Group report (2019), and their subsequent recommendations, PCC has taken the decision to close the car park to vehicles, although the retail units on the ground floor and the CCTV monitoring office on the roof of the car park remain in use. It is understood that a precautionary propping scheme is currently being developed to safeguard the structure from failure in the short term, but also to enable safe remedial works or demolition in the medium to long term.

2. Background

Northminster MSCP, also known as the Market Car Park is situated on Cattle Market Road, Peterborough, PE1 1AY. The structure comprises six reinforced concrete deck slabs (seven levels) supported on reinforced concrete columns on piled foundations. The lateral stability is provided to the structure by the slip formed reinforced concrete lift shafts.

The structure has parking spaces for up to 746 cars and also accommodates retail units on the ground floor, an office and mess room for parking attendants, public toilet accommodation, a switch room, an electrical substation and a CCTV monitoring office on the top floor.

The structure was built in 1978 to 1979 using the 'lift slab' construction technique, which was an innovative and economic method of construction at the time. This form of construction has since been identified to have inherent weaknesses making it susceptible to sudden and unexpected collapse. A detailed description of this construction technique is given in the structural appraisal report prepared for the structure in 1997, (Stirling Maynard & Partners, 1997).

This report was instigated immediately after the 1997 partial collapse of Piper's Row MSCP in Wolverhampton. Northminster MSCP adopts a similar 'lift slab' method of construction to the Piper's Row MSCP and both structures were designed and built by the same company.

The partial collapse of Piper's Row MSCP occurred overnight and without warning, and was thought to have been caused by an overnight drop in temperature resulting in additional stresses in the top floor slab at the connection to the column, causing it to fail under its own self weight.

The unpredictability of this collapse prompted widespread investigation into other multi-story car parks that were built using the "lift slab" construction technique, including Northminster MSCP.

3. Inspection

Within the scope of this review, Skanska carried out a visual, non-intrusive inspection of the car park. Due to the short timescales required for this report, the inspection was restricted to one day on site with no specialist access equipment or access into the retail units, offices or CCTV building. The more structurally significant findings of this inspection are summarised as follows:

- There is radial cracking emanating from all columns and circumference cracking around some columns which appears to reflect patterns similar to that of a punching shear failure. These cracks appears to be a longstanding defects, however there is evidence of more recent deterioration with the appearance of fresh cracking through recent concrete repairs. See **figure 3**.
- This cracking has allowed moisture and de-icing salts to penetrate the concrete, creating an environment in which corrosion can occur to the primary load bearing elements of the structure, including the shear blocks, connecting the slabs to the columns, and the surrounding reinforcement. The depth of corrosion on the shear blocks could not be measured because they remain encased in concrete, however, the depth of corrosion that could be removed from the bottom flange of the shear blocks was indicative of quite a significant depth of section loss.
- There is also widespread spalling and delamination of the concrete, which is indicative of widespread corrosion to the steel reinforcement. The full extent of this corrosion is unknown although recent testing results indicate high levels of chlorides across the whole structure, therefore increasing the risk corrosion over the same areas.

4. Commentary

A review of the inspection and investigation reports since 1997 revealed that the structure has regularly been exposed to de-icing salts on the top deck and ramps. In addition, the structure has not benefitted from the capital investment required to carry out the major maintenance works recommended within the reports, although routine maintenance has been carried out over this period. Despite this, it should be noted the structure has still surpassed all previous life expectancy predictions.

Localised hot spots of corrosion appear to be related to the presence of cracking in the concrete, which has allowed the ingress of moisture and salts into the concrete, making a suitable environment for corrosion to occur. Notably, the cracking and general deterioration in the upper decks was not noted until more recently.

This corrosion is clearly affecting safety critical steel elements including the shear blocks and the highly stressed steel reinforcement adjacent to the connection between the slabs and columns. This corrosion has also led to the delamination of concrete directly beneath. See **figure 1**. It is worth noting that these areas are not easily inspected without carrying out localised concrete breakouts or using specialist surveying equipment. Therefore, the current condition, and potential deterioration to all the columns is currently unquantified.

The inspection and investigations carried out within the scope of this work and within reports prepared for the structure since 1997, have not identified similar concerns to those that caused the Pipers Row car park collapse. Northminster MSCP was built to a higher specification and a number of years later.

The design review carried out in 1997 did however find inconsistencies between the design calculations and the construction drawings which also cast doubt over the adequacy of the original construction.

The main areas of concern identified within this structural review, which could present a risk to public safety are summarised as follows:

Slab to column shear connections

The 1997 design review found the shear connections between the slabs and columns to be “on the limit” yet satisfactory, based on the structure being in good condition. Since this, there has been a notable deterioration in the condition of the concrete and corrosion to the reinforcement and shear block connections. The full extent of this corrosion is unknown, yet significant depths of corrosion have been observed on the bottom flanges of the shear blocks and in the top reinforcement of the slabs.

The chloride levels measured in the concrete means that the concrete may no longer provide a passive layer of corrosion protection to these critical elements, which increases the risk that the steelwork will continue to corrode unless significant remedial works are undertaken.

Progressive collapse

If left untreated, the corrosion will weaken the steel connection between the slab and the column to the extent that it can no longer carry the weight of the slab. There is no alternative load path from the slabs, except through this connection, therefore a localised shear failure may eventually occur. This type of failure may occur suddenly with little to no warning signs.

The connections are currently showing signs of structural distress, and this appears to have progressively worsened over recent years. It is difficult to predict with any degree of certainty about if and when this might happen, but based on its current condition, it is likely that the structure is currently operating outside the scope of its original design, and is therefore at an increased risk of such a failure occurring.

If this happens, then the weight of the slab will be transferred onto the adjacent columns, which is also likely to overload these connections, especially if similar levels of corrosion are present. This may result in a progressive sequence of failures throughout the structure.

General deterioration

The 1997 design review of the slabs showed that very little conservatism was applied within the design. Deflections in the slabs of up to 60mm were also measured.

Since the design review was concluded, concrete testing has revealed notable deterioration in the concrete, including high levels of chlorides, delamination and spalling. This has

resulted in widespread corrosion to the steel reinforcement in the floor slabs. There has also been “black corrosion” observed on the top slab, which may allow corrosion to occur undetected.

The general deterioration of these elements is considered to present a low risk of an unexpected or sudden collapse in the short term, although if left untreated, these defects will continue to worsen and the structure will show more signs of distress.

Given the nature of these defects, it is considered unlikely that the structure would satisfy the original design criteria in its current condition, and even less likely to satisfy current loading standards, therefore making it theoretically unsafe.

The widespread nature of these defects mean that extensive remedial works would be required, including strengthening, and widespread concrete repairs and rehabilitation.

Risks

The main area of concern identified within the scope of this work, is the risk of a sudden and unpredictable failure of the shear connection between the columns and slabs. The extent of the corrosion in these elements is unknown, and the structure is exhibiting increasing signs of structural distress and accelerated rates of deterioration.

In addition, there are inconsistencies noted between the design calculations and the construction drawings which also cast doubt over the adequacy of the original construction.

Since the car park has been closed to the public, the risk of collapse has been reduced, although there remains a risk to the retail units on the ground floor, to the CCTV office and to the public areas surrounding the structure. Whilst the short term probability of failure is considered to be relatively low, the consequences of failure remain high because of the size and location of the structure within a highly populated area.

The brickwork on the parapets and exterior elevations has been identified as having inadequate brick ties, and there is a risk that any sudden movement in the structure could dislodge the brickwork, causing it to fall onto the public areas below.

Options

There are currently considered to be three main options for the structure as summarised with indicative costs and timescales below. In each case, whilst the planning and design of the option is being developed, it is recommended that the structure remains closed to the public, precautionary props are installed to safeguard the structure in the short term, and the CCTV office and retail units are vacated.

Option 1 - Further investigations, analysis and monitoring (estimated £500k to £1m + ongoing annual maintenance and monitoring costs)

It may be possible that further investigations, structural analysis and monitoring may prove (or otherwise disprove) that the structure has some residual life remaining. This will determine the full extent and implications of the deterioration to the structure.

The investigations would need to be intrusive in nature, which would further weaken the structure. Given the signs of structural distress currently being displayed, it is considered highly likely that the analysis will also show a theoretical failure.

This option does not address the issues associated with the ongoing deterioration of the structure, so even if the analysis theoretically proves the structure to be safe to re-open, then it would need to be subjected to an ongoing programme of continuous monitoring, in addition to the normal maintenance costs.

It is assumed that this level of investigations and analysis may take in the region of 12 to 18 months, during which time the structure should not be used.

If this option is successful, then it is unlikely to extend the life of the structure by any more than 2 years, at which point options 2 or 3 would apply.

Option 2 - Strengthening, rehabilitation and refurbishment (estimated costs of £3.5m to £7m + ongoing annual maintenance and monitoring costs)

It may be possible to extend the life of the structure by carrying out strengthening, rehabilitation and refurbishment. Works are likely to include:

- Widespread concrete repairs and crack sealing
- Installation of an impressed current cathodic protection system throughout the structure
- Strengthening to the columns and slabs, possibly using carbon fibre bonded to the concrete
- Replacement of the drainage system
- Installation of brick ties to the parapets
- Re-waterproofing the slabs

A detailed analysis of the structure would be required before this work can be carried out to establish whether the strengthening and rehabilitation measures will resolve the structural deficiencies.

It is assumed that the design and planning for such a scheme will take between 12 and 18 months, with a further 12 months for construction. During this time it would be recommended that the structure is safeguarded with temporary props, and remain closed to the public. In addition, it would also be recommended that the CCTV office and retail units are vacated.

It would not be expected that this option will extend the life of the structure beyond another 10 to 15 years.

Option 3 - Demolition – Estimated costs of between £500k and £1m.

Once options 1 and 2 are no longer considered feasible, then the structure should be considered for demolition. Following demolition, the land may be used for redevelopment or for the construction of a new car park.

5. Recommendations

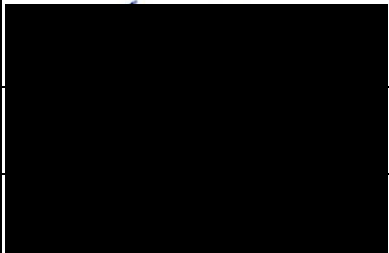
Given the level of uncertainty around the current structural integrity of the car park, the deterioration in the condition of the structure and the nature of the defects identified, it is considered that there is a risk to public safety.

Whilst the probability of the structure failing in the short term is considered to be relatively low, the mode of failure may be sudden, and without warning, and the consequence of such a failure could also be significant due to the size and location of the structure within a highly populated area.

The car park has been closed to vehicles as a precautionary measure. Whilst this reduces the risk of overloading the structure with vehicles, the self-weight of the structure is considerable, and as the structure continues to deteriorate until it becomes susceptible to failure under its own self weight. The following recommendations have therefore been made:

- The structure should remain closed to the public and precautionary propping should be installed at the earliest opportunity.
- The car park should remain closed to vehicles, to eliminate the live loading from moving vehicles. No vehicle loading should be permitted on the structure until precautionary propping measures are in place, at which time, only construction vehicles should be permitted to enter the structure under a safe system of working.
- The CCTV office and retail units should be vacated and relocated within 3 to 6 months under a managed approach to minimise the commercial or operational risk.
- Vibrations should be limited within in the immediate vicinity of the building, including heavy machinery movements.
- Access should be restricted to the public footpaths surrounding the structure in the short term and the brickwork cladding and parapets on the external elevations should be removed to remove the risk of brickwork to falling into public areas if a failure occurs.

It is considered that the structure is beyond economic repair, and it is considered highly likely that any further investigations or analysis will only prove that the life of the structure cannot be extended. It is therefore recommended that the structure is decommissioned and demolished, with the recommendations given above taken as an interim measure to ensure public safety in the short term.

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Appendix A

References

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6. Appendix B



Figure 1: Spalled concrete protection around column exposing corroded steel collar.

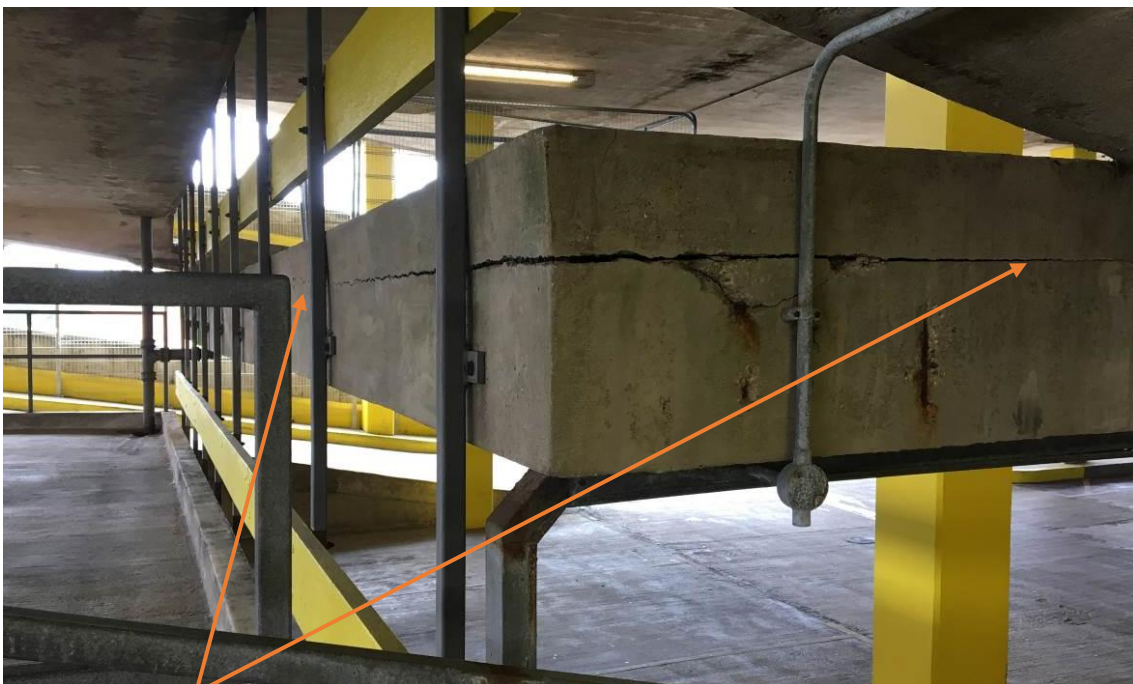


Figure 2: Horizontal cracking (<12mm wide) along the edge of the deck between deck and upstand. Deck has noticeable deflected at the corner.



Figure 3: Fresh cracking through repair material around base of column, crack <2mm wide.

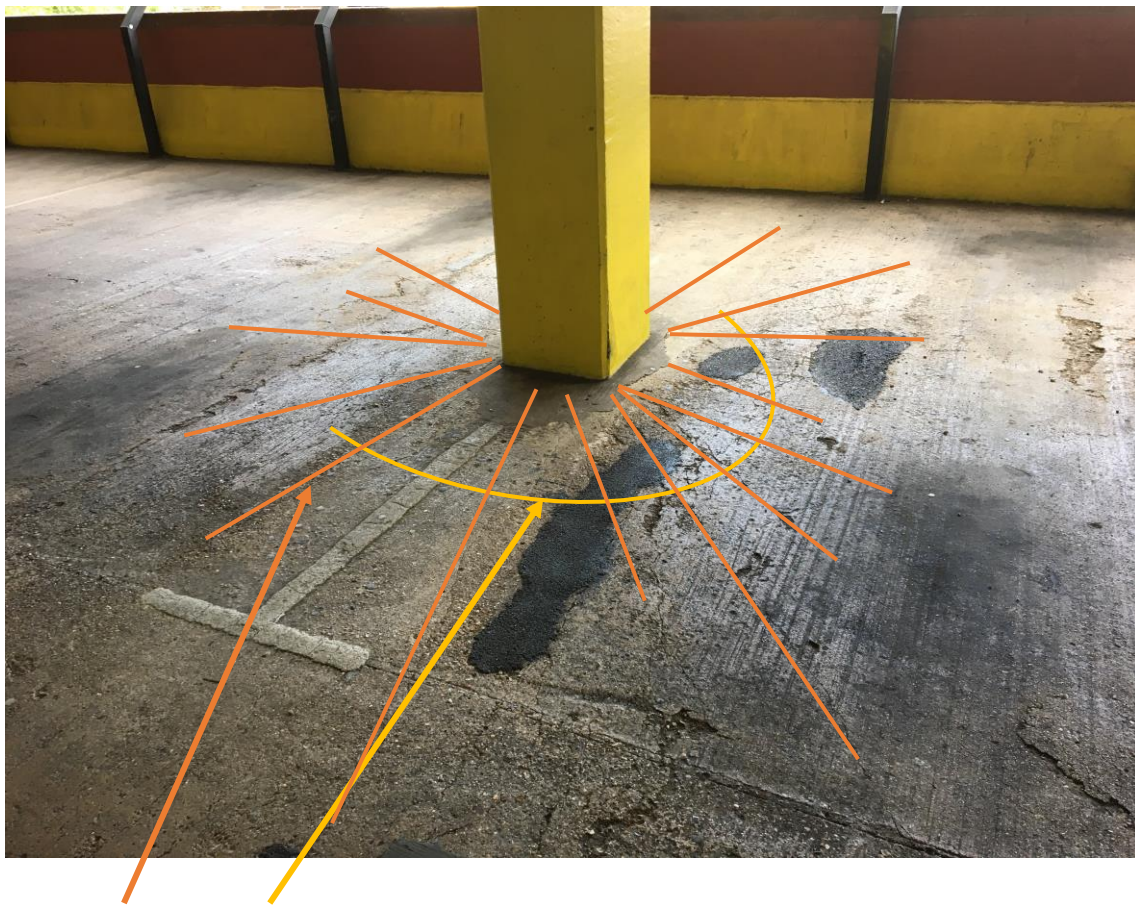


Figure 4: Radial and Circumference cracking around the base of a column on lower level.



Figure 5: Spalling to concrete exposing corroded reinforcement bars at edge of deck.



Figure 6: Multiple areas of spalling to soffit throughout car park, exposing corroded reinforcement bars.

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