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BEESTON BUS STATION CAR PARK, BEESTON

CONCRETE CONDITION SURVEY AND PARAPET LOAD TESTING REPORT

Project Name: *Beeston Car Park, Beeston, Nottinghamshire*
Date: *February 2009*
Reference: *TW/MX/6145*

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1.0 EXECUTIVE SUMMARY

Diagnostic testing and laboratory analysis has determined that Level 1 of the car park (the first suspended slab) is at significant risk from chloride induced corrosion of the embedded steel reinforcement, with half cell potential analysis and the evidence of widespread spalling confirming this. Levels 2 and 3 appear to be at much lower risk.

The existing waterproof membrane throughout has reached the end of its serviceable life and needs to be replaced.

Load testing to 1 No. typical perimeter parapet concluded that the precast units are significantly under strength to accommodate the impact loadings required within a car park. Secondary barriers are required.

2.0 INTRODUCTION:

Matrix were commissioned by Broxtowe Borough Council via order number TWB0001918 to undertake a concrete condition survey of the Bus Station car park in Beeston. The survey was to include a full condition survey and incremental load testing to the perimeter parapets.

This report contains recommendations for repair together with budget costs based upon approximate quantities.

Matrix are an independent contractor providing high quality and innovative solutions for car park repair and refurbishment schemes. Matrix are not restricted by, or indeed tied to, any particular material supplier or manufacturer, enabling bespoke, Best Value proposals to be compiled.

3.0 THIRD PARTIES:

This report is for the sole use and benefit of Broxtowe Borough Council.

It is not intended to be a Structural Survey.

4.0 VISUAL SURVEY

4.1 Upper Parking Level 3

The upper parking deck has been waterproofed with some form of thin layer membrane, which has clearly reached the end if it's serviceable life. Numerous sections of membrane are debonding, worn or cracked exposing the concrete slab beneath.

The precast construction nature of the car park, with thin precast units spanning between beams has also led to cracking in the membrane directly above the beam lines. This may have accelerated the failure of the coating.

Water and salt ingress through to the levels beneath is also evident in some locations.

Parapets

The existing parapet units are extremely thin with many of them suffering from vertical cracking throughout their height. The exact fixing detail to the car park structure is unclear, but the load testing has indicated that they are insufficient in their current form.

A number of the parapets are also spalling on their aggregate exposed external facades.

4.2 Internal Parking Decks (Level G to Level 2)

The internal decks, with the exception of Level G, have been surfaced with some form of lightweight thin film coating, which has reached the end of its serviceable life. The coating has worn in many areas particularly to ramps, turning circles and driving aisles.

The failure of the deck coating has led to the breakdown of the concrete slab in the form of spalling, cracking and deterioration of day joints. Many areas of embedded steel reinforcement are corroding with exposed rebar visible in places. Pot holes are now creating trip hazards throughout the car park.

The ground bearing slab is surfaced with what appears to be a SMA wearing course, and is generally in a sound condition.

The soffits and frame are generally sound with surprisingly little water ingress. Minor spalling was noted to a number of columns, whilst the metal conduit embedded in the soffit is corroding and causing minor spalling.

Parapets

The parapets are in a similar condition to those on the upper deck.

Staircores

The staircores within the car park are in a reasonable condition and appear to be clean and painted. Timber doors are rotten and defective in some locations, whilst the waterproof membrane upstand detail on the car par side has failed.

5.0 DIAGNOSTIC TESTING

To compliment the visual survey, diagnostic testing has also been undertaken to ascertain the condition of the concrete:

Summary of Testing:

- Chloride Dust Sampling
- Indicative Cover and Carbonation Depth Survey
- Half Cell Analysis

5.1 Evidence of Chloride Contamination

Chlorides can penetrate either from external sources (for example coastal environments and/or de-icing salts), or can be present within the concrete at the time of construction as an admixture. Calcium chloride was used extensively in the past as an 'accelerator' particularly in pre-cast concrete until outlawed in 1977 (it is now categorised as a deleterious material).

In terms of corrosion, the chloride ion is one of the major contributing factors affecting even the most highly alkaline uncarbonated concrete. Chloride ions in water form a strong electrolyte. The effect of this is to increase the flow of corrosion current electrochemically, to disrupt the passivating ion oxide film, which exists of the steel surface, which subsequently allows the steel to corrode.

The corrosion products formed are far less expansive then through 'general corrosion', and severe loss of section of the steel reinforcement can occur. Without visible signs, this form of damage can cause serious consequences.

In BRE Digest 444 Part 2, the risk of corrosion of steel embedded in concrete which contains chloride ions is tabulated as follows (assuming a structure in a damp environment):

Chloride Ion %	Corrosion Risk
0-0.45	Low
0.45-0.7	Moderate
0.7-1.0	High
>1.0	Very High

Concrete Dust Samples

Concrete dust samples were extracted using a Hilti TE5 percussion drill fitted with a dust extractor. Each sample was extracted from the car park and placed into sealed containers to avoid contamination. Each dust sample was labelled accordingly to correspond to the location and depth from where it was taken (see drawing in Appendix 3).

Dust samples from decks were taken at incremental depths, 0-25mm and 25-50mm respectively.

Evaluation of Chloride Contamination

A total of 32 No dust samples were extracted and analysed for chloride content by weight of cement. The values ranged from <0.07% to 3.00% by weight of cement.

8 No. of the samples extracted (which represents 25%) fell into the High or Very High category confirming that the concrete decks of the structure are at a high to very high risk of chloride induced corrosion in places. Furthermore 80% of the samples extracted from Level 1 decks indicated a High/Very High risk of chloride induced corrosion.

Level 2 and 3 decks appear to be generally lower risk, with the highest recorded contamination level being 0.57% by weight of cement. All of the samples extracted from the soffits indicated a Low risk.

Due to the nature and pattern of chloride levels recorded, it would appear that de-icing salts are the primary source of contamination. This is perhaps clearly illustrated by the high levels of contamination on Level 1 where de-icing salts have been brought into the car park from the roads.

5.2 Depth of Concrete Cover

Covermeter readings were taken on the decks using a Protovale Covermeter CM5, in areas close to carbonation testing. In general, cover readings were adequate, with isolated low cover depths to both decks and soffits.

When compared to carbonation depths (the depth at which carbon dioxide has penetrated into the concrete and formed carbonic acid), tests indicate that the decks of the car park are not at risk from carbonation induced corrosion due to adequate cover depths.

Covermeter test results for the car park are summarised as follows:

Element	Average Cover (mm)	Range of Cover (mm)
Level G:		
Soffit	35	22-48
Level 1:		
Deck	38	27-53
Soffit	31	21-44
Level 2:		
Deck	44	38-55
Soffit	31	18-51
Level 3:		
Deck	39	31-50

Cover to reinforcement is generally good, reducing the risk of carbonation induced corrosion

5.3 Depth of Carbonation

Good reinforced concrete consists of suitably spaced reinforcement bars surrounded by cement/sand/aggregate matrix normally with a pH greater than 11. It is this level of alkalinity that protects the steel reinforcement against corrosion.

The most common cause of alkalinity is carbonation (the formation of acidic carbonic acid). If the pH of the concrete drops to 9 or below then protection is lost and the steel is free to corrode (when sufficient water and oxygen are present). Once the carbonation front reaches the reinforcement, corrosion occurs, which enlarges the bar size with rust scale. This in turn exerts pressure on the concrete cover causing it to crack and eventually spall.

Carbonation depth measures were taken near to the test sites for dust extraction. The broken surface was cleaned and sprayed with the indicator Phenolphthalein. The mean depth of carbonation was measured as the distance from the concrete surface to the boundary of the uncoloured zone.

Carbonation analysis was undertaken at locations throughout the car park to decks only. The values ranged from 3mm to20mm. The results recorded for the decks of the structure are summarised in the following table (in mm):

Element	Average Carbonation (mm)	Range of Carbonation (mm)
Level G:		
Soffit	5	3-10
Level 1:		
Deck	14	12-20
Soffit	6	4-8
Level 2:		
Deck	12	8-16
Soffit	6	3-12
Level 3:		
Deck	4	3-6

Concrete carbonation levels were low/average, indicating that the embedded reinforcement is generally at a low risk from carbonation induced corrosion. There may however be very isolated areas where the depth of carbonation has exceeded the depth of cover.

5.4 Half Cell Analysis

Testing Procedure:

Testing within the car park was undertaken on an orthogonal grid over the test area at centres of 500mm. A reference connection was made for the Half Cell testing on each individual element of the structure.

The testing was undertaken using a Rate of Corrosion monitor, manufactured by BGB Projects Ltd, which is fitted with a copper/copper sulphate reference electrode. The instrument was checked prior to use in accordance with a documented in-house procedure. The concrete was pre-wetted and once the meter reading had stabilised the value was recorded. One reading per panel, or one in twenty, whichever is the minimum was retaken as a check and logged on the site data sheets.

Reinstatement:

All sampling holes and reinforcement exposures were reinstated as soon as practical after completion of the testing with a low shrinkage high-build polymer modified cementitious repair material.

Half Cell Potential Survey:

The results of the survey can be compared to the guidance contained within ASTM C876-91. The absolute values of the individual readings can be compared with the following table:

Potential Levels (mV):	% Chance of the steel being corrosively active:
Less negative than -200	10
-200 to – 350	50
More negative than -350	90

It should be noted that the results to the Half Cell potential survey are affected by site conditions, particularly the moisture content and temperature of the concrete.

Alternatively the relative values between the adjacent nodes can be compared. Any significant difference in readings may be indicative of the increased electrochemical activity that is associated with the corrosion process.

When steel reinforcement is affected by two different environments, caused by either different concentrations of chloride ions or the difference in porosity between one area of concrete and another, one area of the steel will begin to release ferrous ions, thus forming an anode and electrons. The electrons flow through the concrete pore fluid eventually reacting with water to form hydroxyl ions, a cathodic reaction. The electrical potential of the steel now varies and these differences are measured during the Half Cell potential survey.

Half Cell Potential Survey Results:

The results can also be considered by comparing both the absolute values of each node and the relative value of the Half Cell readings on adjacent nodes. Large gradients between adjacent nodes are indicative of increased electrochemical activity, which suggests a higher probability of the corrosion being active

The readings ranged from –511mV to +46mV, with a mean value of -267mV.

From the data collected, the three lowest Half Cell values were identified. They are presented within the following table.

Position	Value (Mv)	Location
1st	-511	Level 1 Area C
2nd	-508	Level 1 Area B
3rd	-501	Level 1 Area C

In total, 225 No. Half Cell readings were taken during the survey. The readings were analysed to determine the distribution. The analysis is shown below.

Half Cell Categories	Number of Readings	Percentage
Greater than 0mV	46	21%
Less negative than –200mV	43	19%
Between –200mV and –350mV	96	43%
More negative than –350mV	40	17%

The Half Cell results were varied with over 28% of the readings taken on Level 1 indicating a 90% probability of corrosion. Generally the trend of the results taken from Levels 2 and 3 indicates localised hot spots with 50-90% probability of corrosion (turning circles/worn coating areas), with the remainder of the areas 10-50% probability.

The results of the half cell survey indicate that corrosion is highly likely (almost certain) to Level 1 decks. This is not surprising based on the very high chloride contamination levels. Half cell results from Level 2 also indicate that corrosion is highly likely, albeit not so widespread.

5.5 Incremental Load Testing to Perimeter Parapets

Please see Appendix 5 for full report.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The results of the diagnostic testing have indicated that Level 1 is at a high risk from chloride ion induced corrosion. Half cell analysis also confirms that the likelihood of corrosion is very high in many areas.

Whilst all decks have been coated with a waterproof membrane, this has reached the end of its serviceable life and is allowing water/salts to penetrate into the concrete. Whilst some areas of the membrane remain intact this is in fact exacerbating the problem, with water (and salts insitu) being concentrated on open day joints, cracks and exposed section of concrete. Spalling and cracking of the deck to Level 1 is common.

The perimeter parapets have been found to be insufficient in terms of loading, and do not comply with the requirements as stated within Edge Protection in Multi-Storey Car Parks – Design Specification and Compliance testing", Oct 2001. Secondary barriers should be installed at the earliest opportunity.

Minimal Requirements:

Level 1:

We recommend that the existing membrane is removed from the decks to expose the concrete slab.

Repairs should then be carried out to all spalled and defective areas of deck including the installation of Rebaguard sacrificial anodes within all repairs. This will combat the onset of the incipient anode affect which is common in chloride ion contaminated concrete.

We would then recommend that some form of migrating corrosion inhibitor (Sika Ferroguard) or hygroscopic/hydrophilic clear treatment (Pavix CCC100) is applied to the decks of Level 1 to prevent the onset of further reinforcement corrosion. A new waterproof deck coating should then be installed to provide a trafficable, durable and anti-slip surface.

Level 2:

Repairs should be carried out as a minimum including the installation of Rebaguard sacrificial anodes where required.

Level 3:

The existing membrane has reached the end of its serviceable life and needs to be replaced with a durable trafficable coating.

All Levels (1 to 3):

In line with proactive Life Care Plan initiatives, we would recommend installing a number of buried reference electrodes within the decks of the car park. This will enable the client/clients Engineer to monitor corrosion activity within the structure, targeting any future maintenance spend on areas shown to be at risk from corrosion.

Secondary impact barriers need to be installed in front of parapets to all levels. These could incorporate an additional handrail if required.

Additional Recommendations:

The existing deck coating to level 2 should also be removed and replaced in conjunction with works to the other levels. This could be incorporated into a later phase.

The external elevations are showing initial signs of spalling and could be treated with Pavix CCC100 to prevent further water ingress, freeze thaw and reinforcement corrosion.

7.0 REFURBISHMENT BUDGET COSTS – MINIMAL REQUIREMENTS

7.1 Level 1:

Remove existing membrane from Level 1 deck and install new fast cure, durable and trafficable system - £120,000.00

Apply corrosion inhibitor or hygroscopic/hydrophilic treatment to Level 1 deck prior to application of new membrane to prevent further corrosion - £45,000.00

Carry out patch repairs to all Level 1 hollow, spalled and defective areas of concrete, incorporating Rebaguard anodes into repairs – £30,000.00

7.2 Level 2:

Carry out patch repairs to all Level 2 hollow, spalled and defective areas of concrete, incorporating Rebaguard anodes into repairs – £20,000.00

7.3 Level 3:

Remove existing membrane from Level 3, prepare and repair deck followed by the installation of a new waterproof, flexible and durable coating - £135,000.00

7.4 Levels 1, 2 and 3:

In line with Life Care Plan initiatives install 12 No. embedded reference electrodes (4 No. to each suspended level) to monitor corrosion activity on a 'regular' basis (includes 12 No. channel control box) - £30,000.00

Install secondary crash barriers in front of existing parapets (assuming base plates can be fixed into deck slab without the need for retaining plates on underside of soffit - £125,000.00