



# Sutton-on-sea

## Structural Condition Report on Concrete Colonnade

For East Lindsey District Council

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Photo no 01: North West Elevation of Colonnade

## Executive Summary

AECOM was commissioned by East Lindsey District Council, on 9th May 2018, to undertake a condition inspection of the historic concrete structure to the Colonnade Pleasure Gardens, at Sutton-on-sea. The assets required to be inspected comprised a single-storey, reinforced-concrete (RC) structure whose east rear spine wall was built abutting the (landside) side of the North Sea defence structure. The first floor of the structure is at the raised promenade level and currently supports 38 traditional timber-framed, beach huts accessed by two built in staircases. The west side of the structure faces the Pleasure Gardens and the bowling green at a lower ground level. The colonnade structure forms a covered area for residents and visitors to sit and enjoy the facilities. The brief to AECOM excluded inspection of timber members, beach huts, ancillary equipment and services.

The aim of the condition report is to visually inspect the RC structure, and take intrusive tests of the concrete to understand the cause, confirm the findings of the inspection of the RC Structure and to recommend remedial options which are considered necessary to preserve the structure for a further 40 to 50 years use by the public.

After completing our condition inspection of the Concrete Colonnade in May 2018, and analysing the intrusive and non-destructive concrete testing results, the following recommendations were concluded. The ageing structure is exhibiting common defects for a reinforced concrete design constructed in the 1950s and 1960s and exposed to an aggressive marine environment. For the structure to be continued to be used for the benefit of the public a number of defects will need to be remediated. Some of these defects are serious and are currently affecting the safe use of the structure as there is a high risk of small sections of concrete cover to the I reinforcement being jacked off, by ferrous oxide expansion, from the high sections of the structure and falling and potentially injuring persons moving close to and/or within the structure. This safety risk is expected to increase with time unless robust remedial measures are undertaken or parts of the structure decommissioned from its present usage. The temporary safety provisions that have already been implemented on site in the form of a barrier fence and structural props to the enclosed area under the first floor, thereby separating sections of the structure from public access. These works will need to be enhanced for robustness and maintained until a remedial proposal is implemented.

Since the fascia and transfer beams which span over the public access to the North stairs to the promenade are not currently closed off to the public are showing advanced signs of degradation, we would recommend that these are inspected for safety by an engineer with appropriate structural experience, at least every 10 weeks starting from 1<sup>st</sup> June 2018.

The defects have reached an advanced stage of deterioration so that local patch repairs are insufficient to safeguard all the structure for an extended life, and wholesale reconstruction of certain members is considered necessary. Within the report we have outlined a number of remedial options that can be considered depending on the degree of disruption and the budget that is available to finance the works and its future commercial viability. The confidence level in the results could be improved with future testing but given the visual observations made it is unlikely to improve significantly but it would be prudent to undertake further local tests during any delayed remedial measures proposed to ensure compatibility.

A supplementary section to this report, being prepared by Gleeds, will help focus the route for remedial strategies.

## 1. Introduction

AECOM was commissioned by East Lindsey District Council, under the SCAPE consultancy framework agreement, on 9th May 2018, to undertake a condition inspection of the historic concrete structure to the Colonnade Pleasure Gardens, at Sutton-on-sea, Lincolnshire. The assets required to be inspected comprised a single-storey, reinforced-concrete (RC) structure whose east rear (spine) wall was built abutting the (landside) side of the North Sea defence structure, which is owned by the Environment Agency. The first floor of the structure is at the raised promenade level to the North Sea and currently supports 38 traditional timber-framed, beach huts. The west side of the structure faces the Pleasure Gardens and the bowling green at a lower ground level. The colonnade structure forms a covered area for residents and visitors to sit and enjoy the facilities in the various built-in kiosks. In addition, two reinforced concrete staircases (North and central) are built into the structure to allow access from the lower ground level up onto the raised promenade. It is understood that the concrete colonnade structure was built in the 1950 and 1960s. The brief to AECOM excluded inspection of timber members, beach huts, ancillary equipment and services.

The aim of the condition report is to visually inspect the RC structure, and take intrusive tests of the concrete to understand the cause, confirm the findings of the visual inspection of the RC Structure and to recommend remedial options which are considered necessary to preserve the structure for a further 40 to 50 years use by the public.

## 2. Inspections

The site inspection of the elements of the structure that were made accessible during the visit, was undertaken between 23 and 24th May 2018. Detailed records, material samples and photographs were obtained from site and have been incorporated in the Report. Concrete core and dust samples for strength and chemical testing respectively, were recovered from site for testing at UKAS approved testing laboratories. For ease of reference, a GL arrangement has been included on the sketch plan of the colonnade provided in Appendix B.

The existing structure is sub-divided into sections by movement joints which broadly divided the structure up into a Northern section, supporting rented beach huts, numbered 2 to 15 (GL B to N), Central section (GL N to Y-Z), supporting empty beach huts numbered 16 to 29, and the Southern section supporting (GL Y-Z to MM), supporting privately owned beach huts, numbered 30 to 39. A three flight public access staircase to the promenade, is incorporated into the Northern and Central sections of the structure.

A typical cross-section sketch has been developed for the Northern section, and a second typical section for the central and southern sections has been developed and included in Appendix A.

A summary of the degree and amount of visible damage to the various elements in the three different sections has been included in a Schedule of Visible Concrete Defects and two sketches included in Appendix A.

Detailed intrusive tests undertaken on six specific areas of the concrete structure included:

- o Concrete cores of a column, slabs and walls.
- o Hammer acoustic tests on concrete.
- o Carbonation depth tests to assess the alkalinity of the existing concrete.
- o Concrete dust samples for chloride content tests.
- o Electrical resistivity tests on steel reinforcement continuity.
- o Half-cell potential monitoring of concrete to help assess level of corrosion of reinforcement and feasibility of potential remedial options.

The safety of the structure during and post inspection was a prime concern given the advanced degree of degradation that the RC structure had suffered, over its 60 to 70 year life in the aggressive coastal marine environment. The safety precautions adopted during the works was to prop the more severely degraded concrete beams and slabs with steel adjustable props. The critical beams propped during the inspection included fascia beam GL 1, G to H, either side of a half lap joint; the beam across the stair access GL 2, Z-AA and longitudinal beam 1 / 2, LL-MM. Owing to the risk of smaller sections of concrete being jacked from the surface due to rust formation on the steel reinforcement and falling onto the public, it is recommended that the 'Heras'

barrier fencing at garden level, along GL 1 is maintained to separate the structure from the public until the structure is remediated or sections taken out of service. Whether any further safety precautions like closing certain beach huts to use, is still under review as material data is obtained.

We recommend that the 11 props temporarily erected to support weakened beams and slabs should be fixed in place by screw fixing, to the bases and heads respectively, to the floor slab and beam/slab soffit by your Maintenance contractor. This is to ensure they are not interfered with by unauthorized persons.

During our inspection, we have removed all the currently loose concrete that could readily fall on the public or inspectors. The fascia beams at the Northern end of the colonnade, which are currently not separated from the public accessing the stairs and cafes, are showing signs of advanced degradation and will need to have a safety inspection. This inspection should be done by an appropriately qualified person, on a regular 10 weekly basis from the 1<sup>st</sup> June 2018, (to ensure they will not require temporary support and separation from the public) until remedial measures implemented.

The inside faces of six bays (GL 1 to 2, B-C, D-E, E-F, S-T, JJ-KK and KK-LL), could not be inspected as the kiosks were locked on the days of the site visit.

### 3. Visual Observations of Concrete Defects

The defects observed were generally typical of an old RC structure built 50 years ago where the significance of the shallow concrete cover thicknesses specified to the embedded unprotected steel reinforcement were not generally appreciated in an aggressive marine environment. In addition, a number of different types and quality concrete patch repairs had been undertaken to earlier defects at various different times and a number of these had started to fail by becoming detached. The observed loose concrete was removed during the inspection to protect our survey team and later inspectors whilst on site.

The RC elements inspected comprised circular and rectangular cross section columns supporting continuous spanning rectangular fascia beams on GL 1, simple supported cross beams spanning between columns and the vertical spine wall on GL 2, one and two-way spanning slabs spanning between fascia beams, cross beams, spine walls, and six movement joints between various concrete elements. Structural movement joints were observed between GL 1-2, G & H, at GL 1-3, N, at GL 1-2, Q-R, GL 1-2, Y-Z, GL 1-2, AA-BB at GL 1-3, MM.

Visual inspection of the circular concrete columns showed no significant visible damage or distress. Similar inspections of the rectangular columns on the Northern section showed localised defects to corners and faces of six columns. Most of the defects had resulted from previous concrete repairs failing by detaching themselves, due to carbonation and ferrous rust oxide jacking, and others were showing hollow sounding concrete due to similar reasons.

#### i) Northern Section

Visual inspection of the rectangular and arch profiled fascia beams on the Northern section revealed hollow sounding concrete to sides and soffits, rust staining to outside faces, structural cracking over heads of columns 1J and 1L and tops of beams. A number of vertical hairline historic shrinkage cracks were observed on the front face of three beam spans. The fascia beam over the access to the North staircase and seating area of the ice cream kiosk (GL 1, C-D) was exhibiting extensive hollow sounding concrete and will need regular structural inspections so the access to the stairs and kiosks could be kept open to the public. Some of the damage to the top face and edges of the beams can have resulted from previous (rusting) and current fixings to balustrade standards. At spalled concrete locations the reinforcement has suffered advanced laminated corrosion with significant loss of cross section.





Photo no 02: Showing spalling to fascia beam on GL 1, C-D near Ice Cream Kiosk.



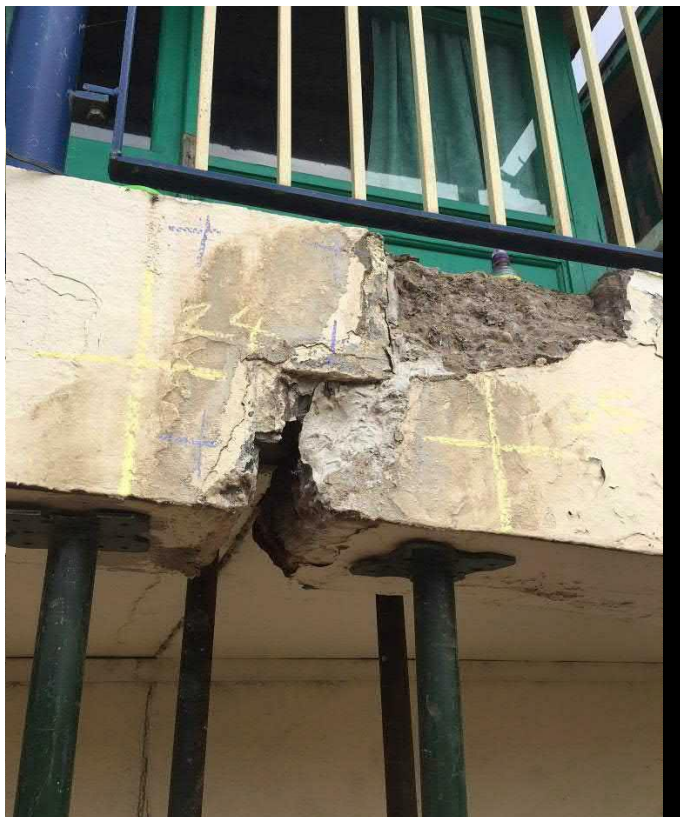
Photo no 03: Showing spalling to fascia beam on GL 1, D near Café.





**Photo no 04: Colonnade to Northern section showing curved profile to fascia beams.**

The half lap joint within the fascia beam spanning between columns 1G and 1H had suffered significant structural cracking to the top part of the half lap detail, along with concrete spalling and loss of reinforcement section due to corrosion that it was considered structurally at risk so was left propped for safety. The corresponding transverse movement joint from GL 1 to 2 across the slab exhibiting extensive hollow sounding concrete will require patch repairs and resealing. The corresponding vertical joint in the spine wall is showing only minor defects requiring patch repairs and resealing.



**Photo No 05. Half-lap Joint Fascia Beam GL 1, G-H**



**Photo No 06. Debris from previous repair to Half-lap Joint Fascia Beam GL 1, G-H**

Only three first floor slab down stand, cross-beams existed on this section and no significant defects were observed on the day of the inspection.

Inspection of the rectangular columns on the Northern section showed localised defects to corners and faces of six columns.

A bay of the spine wall at GL 2, M-N was exhibiting a hairline crack over its full height at an inclined angle to the vertical. The cause of the crack was not readily identified but believed to be shrinkage. A large number of the weep holes on the spine wall were blocked with weak concrete on the far face, as proved by a concrete core.



**Photo no 07: Shrinkage crack in spine wall near GL N 2.**

The first-floor slab soffits were exhibiting a number of hairline and narrow cracks and patches of hollow sounding concrete, but only a few areas of spalled concrete. Only three of the eleven bay slabs were able to be observed on the soffit owing to locked kiosks restricting access. The transverse end wall on GL N1 to 2 near the MJt was revealing hollow concrete suggesting some internal ferrous oxide jacking.





**Photo no 08: Floor slab at promenade level GL B-D, 1-3 North end showing shrinkage cracks and mastic asphalt remedials to kiosk roof in distance.**



**Photo no XX: Slab at promenade level showing shrinkage cracks GL 1-2, M-N.**

One core was taken from a rectangular column on GL 1M and the north flanking wall (GL C-D, 2-3) to the north staircase.

Three bays were not inspected fully due to locked kiosks to the café and ice cream shop.

## **ii) Central Section**

Visual inspection of the rectangular fascia beams on the Central section revealed hollow sounding concrete to sides and soffits on five beam spans and spalled concrete to one span. A number of vertical hairline historic shrinkage cracks were observed up the front face of four beam spans. The cross beam over the central staircase, GL 2, Z - AA, was exhibiting extensive cracking, and hollow sounding concrete and was considered a

risk to the public and has been propped and barriered off from public use until a remedial proposal has been implemented. On this section, and part of the southern section, face fixed balustrade standards have not been fixed to the RC fascia beams but the rendered brick wall above, which has been built off the top of the RC fascia beams.

Inspection of the first floor slab down stand, cross-beams revealed spalling, hollow beam soffits to six spans. At spalled concrete locations the reinforcement had suffered advanced laminated corrosion with significant loss of cross section in four locations.



**Photo no 09: Cross beam GL P1-2 showing spalled concrete and loss of section to rebar and electrical meter boxes**

In the tank room, the down stand beam on GL 1-2, N had had a recent rebate cut out up the side face of the beam, for an electrical conduit, leaving the beam steel reinforcement poorly protected and subject to increased corrosion.



**Photo no 10: Slab soffit inside tank room showing spalling, cracks and rust stains. Also a detached electrical services (far wall) [Safety Hazard].**



Only one minor defect of spalled concrete was observed on the circular column (GL 1, BB) within the section.

A bay of the spine wall at GL 2, N-O was exhibiting a hairline crack over part of its height. The first-floor slab soffits were exhibiting large areas of hollow sounding concrete, a large number of narrow cracks (generally tracking slab reinforcement bars) and numerous areas of spalled concrete exposing rusty reinforcement, on nine bays. At spalled concrete locations the reinforcement had suffered advanced laminated corrosion with significant loss of cross section in eight bays. The exposed top surface, at promenade level, was protected with a mastic asphalt layer which was exhibiting early signs of degradations and potential water leaks on to the timber substructure and colonnade slabs below. The first floor slab and beams around the central stairs were intensively tested and are reported on in detail in section 4 of the report.

The four structural movement joints (MJ) within this section were displaying defects. The MJ at GL 1-2, N required resealing on the soffit and vertical face of the wall. The transverse MJ in the first floor slab on GL 1-2, Q -R and AA-BB were revealing extensive hollow concrete and cracking in the flanking sections of slab.

The transverse movement joint from GL 1-2, R-Q across the slab exhibited extensive hollow sounding concrete so would require rebuild repairs and resealing. The corresponding vertical joint in the spine wall was showing only minor narrow cracking defects requiring patch repairs and resealing. The vertical section of the movement joints in the spine wall at GL 2, Y-Z and AA-BB revealed extensive hollow sounding concrete, narrow cracks and rust stains.

Large areas of the soffit to the first floor slab were found to have rust staining and hollow sounding concrete indicating extensive ferrous oxide corrosion jacking presence.



**Photo no 11: Slab soffit rust stains, cracks and spalled concrete GL 1-2, U-V.**

Two diamond drilled concrete cores were recovered from each of two different first floor slabs and one through the spine wall. The slabs were 125 to 130mm thick and the spine wall was approximately 200mm thick.

One bay was not inspected due to a locked kiosk restricting access.

### iii) Southern Section

Visual inspection of the rectangular fascia beams on the southern section revealed extensive hollow sounding concrete to soffits on eight beam spans and spalled concrete to three spans. A few vertical hairline historic shrinkage cracks were observed up the front face of three beam spans.

On this section balustrade standards have not been fixed to the RC fascia beams but have been fixed to the rendered brick wall built off the top of the RC fascia beam.

Inspection of the first floor slab down-stand cross-beams revealed spalling, hollow beam soffits to two spans. At spalled concrete locations, the reinforcement had suffered advanced laminated corrosion with significant loss of cross section in two locations. The down stand beam on GL BB, 1-2 had hollow concrete and extensive cracks on the side faces of the beam with one area of spalling.



**Photo no 12: Down stand transverse beams and movement joint GL 1-2, AA-BB showing spalled and hollow concrete, along with NDT testing chalk notes.**

Exposed aggregate was evident on cross beam at GL 1-2, CC and extensive deposits of a white salt was present in the peeling edges of the various coatings of decorative finishes on the beam.



**Photo no 13: Transverse beam GL CC, 1-2 with exposed aggregate on side of beam**

Two bays of the spine wall at GL 2, GG HH & HH to JJ were exhibiting three hairline vertical, shrinkage cracks over its full height at an inclined angle to the vertical, the cause of which is not readily obvious.



The first-floor slab soffits were exhibiting large areas of hollow sounding concrete, a large number of narrow cracks (generally tracking slab reinforcement bars) and numerous areas of spalled concrete exposing rusty reinforcement affecting seven bays. At spalled concrete locations the reinforcement had suffered advanced laminated corrosion with significant loss of cross section in all locations. The exposed top surface, at promenade level, was protected with a mastic asphalt layer which was exhibiting early signs of degradations and potential water leaks on to the timber substructure and colonnade slabs below. At bay GL 1–2, KK–LL a hairline horizontal crack extended across the full width of the slab GL 1 to 2.



**Photo no 14: Slab soffit GL 1-2, CC-MM showing cracks, spalling and rust staining.**

One diamond drilled concrete core was recovered from a first floor slabs in bay GL DD to EE where the RC slab was 125 to 130mm thick.

The transverse movement joint from GL 1-2, MM across the slab exhibited extensive hollow sounding concrete so will require patch repairs and resealing. The front corner of the joint near GL 1 had a wide diagonal crack where a balustrade had been fixed. This detail will require reconstruction as section too small to repair. The corresponding vertical joint in the spine wall was showing only minor defects requiring patch repairs and resealing.



**Photo no 15: Spalling at head of column GL 1BB, and exposed aggregate to transverse beam GL BB and movement joint to central stairs**



**Photo no 16: Movement Joint in slab soffit GL KK, 1-2 showing rust stains and cracking.**

The bay GL 1-2, LL-MM was of a different construction arrangement at first floor level to the rest, as the first floor slab and fascia was set back approximately 1200mm. In the recessed area, the free spanning feature open grid of small cross section RC beams (no slab) had suffered extensive cracking, rust stains, hollow sounding concrete and some spalling. The recessed fascia beam had extensive spalling with advanced laminated corrosion and significant loss of cross section of the reinforcement steel to both the main tension steel and shear stirrups. The damage was so extensive to the small sections it was considered that grid of beams and the adjacent recessed fascia beam (supporting first floor slab) was a structural risk from falling concrete, and should be barriered off to the public until remedial measures implemented. The cross beams in Bay GL 1-2, LL-MM have suffered severe corrosion spalling and cracking and require replacement insitu, to a new structural design, if section retained for public use.



Photo no 17 Cross beams GL 1-2, LL-MM showing severe cracking and spalling necessitating temporary structural support.



Photo no 18 Cross beams GL 1-2, LL-MM showing severe cracking and spalling and temporary structural support.





**Photo no 19 Small cross beams to fascia beam GL 1, LL-MM showing severe cracking and spalling.**



**Photo no 20: Promenade slab at GL 2-3, LL-MM showing shrinkage cracks.**

One bay (GL KK-LL, 1-2) was not inspected due to a locked kiosk restricting access.

No evidence of differential settlement observed in any of the sections

## 4. Summary of Concrete Testing Results

Detailed intrusive tests undertaken on seven specific areas of the concrete colonnade included:

- Concrete cores of a column, slabs and walls.
- Concrete core compression tests.
- Concrete core cement contents for durability and strength.
- Light hammer acoustic tests for location of hollow sections of concrete as a result of delamination from oxide jacking.
- Intrusive test for carbonation depth tests to assess the alkalinity of the existing concrete to passivate corrosion of steel reinforcement. Refer also to AECOM Testing Report in Appendix F.
- Intrusive concrete dust samples for chloride Ion content tests. Refer also to AECOM Testing Report in Appendix F.
- Non-destructive test (NDT) for electrical resistivity on concrete to give an indication of the rate of reinforcement corrosion. Refer also to AECOM Testing Report in Appendix F.
- NDT Half-cell corrosion potential monitoring of concrete to help assess reinforcement being corrosively active and the feasibility of potential remedial options. Refer also to AECOM Testing Report in Appendix F.

There were three test areas (Areas 5, 6 & 7) within the North section, one (Area 4) on the Central section, one (Area 2) on the Central stairs and two (Areas 1 & 3) within the South section. Test areas 2, 3, 6 and 7 were chosen as these areas are in poor condition with exposed reinforcement and rust staining noted. Test areas 1, 4 and 5 were in areas in good condition, with no rust staining, spalling or obvious defects noted, and were chosen to determine a base reading of the structure. The location of the Intrusive and NDT test areas are shown on Figures 01 and 02 in the Concrete Testing Report by AECOM in Appendix F.

### i) Concrete Cores

Concrete cores were taken from 10 different areas and a summary table of their test results follows:

Location Concrete Cores	Initial Visual Assessment	Structural Element	Concrete Cores  N/mm <sup>2</sup>	Cement Content (maximum values +/- 25kg) Kg/m <sup>3</sup>
South Section GL DD, 1-2 GL DD-EE, 2	Reasonable	Soffit slab Back Wall	No test 48.5	477 447
Central Stairs GL Z, 2-3	Poor	Stair Side wall	47.1	577
Central Section GL P2 GL R, 1-2 GL X, 1 - 2	Reasonable	Back Wall P2 Soffit GL R, 1-2 Soffit X, 1-2.	62.8 54.0 32.8	483 563 474
North Section GL K 2, GL KW, 2 GL M1 N Stairs GL D, 2-3	Reasonable	Back Wall Back Wall Column M1 Stair side wall	60.0 59.7 44.9 26.0	451 458 474 381

The concrete core test results confirm that a relatively high content of ordinary Portland cement was probably used in the mixes at the ten areas tested, so give a good positive measure of the potential future durability of the concrete. A closer assessment of the test results shows there were a few inconsistencies such as the



compression strength varying by 50% with the same assessed cement content in three cores, and not all the high cement contents cores achieved the highest compressive strength. The cement content tests results were the maximum value that could be achieved from the test used and the lime content being the dominate factor. Since we do not have the benefit of samples of the original aggregates from 60 years ago, this is the best estimate that can be made by a back analysis chemical test. The variation in the cement content results could be explained by the concrete mix containing a higher content of calcium lime from some other sources, such as limestone coarse or fines aggregates, which exist locally near Lincoln and have been mined for more than fifty years. Examination of the concrete samples show rounded silica aggregate, and not limestone, for the coarse aggregate. There is a slight chance of a proportion of crushed calcareous fine aggregate in the sands as this has been available for agriculture use for decades, but no so much in concrete fifty years ago, as it would have been generally more expensive than silica sand and too fine in size (hungry), requiring a higher proportion of costly cement.

All bar one of the compression strength test results are good or very good for structural concrete and probably accounts for how well the reinforced concrete structure has generally performed to date. The one test that is marginal, as far as strength is concerned for reinforced concrete, is the one from the side wall of the North stairs which only reached 26 N/mm<sup>2</sup> with a tolerance of +/-5 N/mm<sup>2</sup>. The generally accepted minimum is 25 N/mm<sup>2</sup>. The variation in test values could indicate that the quality control of the original concrete batching was not as good as it could have been, but none the less typical for time of construction.

Details of the concrete cores and the test results are included in Appendix D

The concrete strengths and cement contents measured from the ten areas tested are positive indicators for the future durability of the structure.

## ii) Acoustic Hammer Testing

A lightweight hand hammer acoustic test was undertaken over the full length of the structure on readily accessible exposed concrete surfaces. The hammer tests revealed extensive hollow concrete on the soffit of the suspended first floor slabs to all three sections with the southern having the largest affected area. A number of cross beams on the central and southern sections had localised zones of hollow concrete with some of the worst areas being around movement joints, the central stairs and the most southern bay (GLs LL-MM, 1-2) where all the beams are affected. Some of the RC beams are affected to such an extent that the safety of beams are in question and temporary propping has been installed as shown on Figures 3 and 4 [e.g. GL 1, G-H; GL Z-AA, 2 and GLs LL-MM, 1-2].

Very few areas of hollow concrete were found on the spine wall except at movement joints where there was also evidence of some water infiltration. Some of the fascia beams had localised areas of hollow concrete on their soffit and particularly around areas that had previously been patch repaired all as indicated on Figure 3 and 4 in Appendix B. No hollow concrete was found on the RC columns or on the two stair side walls and treads. The soffit of the stairs could not be inspected, but appeared to be supported off the rear slope of the sea defence revetment and not suspended.

## iii) Intrusive Testing of Concrete

### a) Carbonation Depth Measurements.

Twenty one carbonation depth measurements were undertaken over six test areas. No depth measurements were undertaken in test area 7. The depth that carbonation had penetrated the concrete and reduced its corrosion protection to the steel reinforcement and varied between 5mm (North section Slab) and 35 mm (Transverse beam South section). The maximum depth of carbonation was on the fascia beams 34mm (South section) and transverse beams 35mm (South section) and closely followed by the spine wall on the South section at 28mm. The concrete cover was also measured at each of the test sites for chloride ion and found to vary between 14mm and 92mm. All of the cover thickness to the soffit of the approximate 120mm thick suspended slabs were less than 16mm. To put these concrete cover thicknesses in perspective, as far as the structural design is concerned, the minimum recommended for the 20mm sized aggregate used in the concrete is 25mm and for a coastal environment this cover should have been increased to 35 to 40mm depending on the design compressive strength and cement content of the concrete originally specified (which unfortunately is unknown). Three of the highest concrete covers (52 to 92mm) were on the spine wall in three

different sections of central stairs, central and south. These values are unusual and probably indicate misplaced reinforcement which would be reducing the structural bending strength of the wall but increase the resistance to carbonation penetration.

With 50% of the 22 concrete cover measurements being equal to, or under 16mm suggested that there was either a design issue or some lack of control with site workmanship with the original construction.

As far as the future durability of the structure is concerned, one of the critical criteria is the ratio of the carbonation depth to the concrete cover thickness which should be less than one otherwise there is little corrosion protection to the steel reinforcement, as has been observed extensively. Eight of the twenty one test sites had a ratio greater than one putting these at greatest risk and a further one was only just below one (making 42% critical). These results were spread over all areas but with two in the south section.

The reduced concrete cover below the design minimum is also a big concern as this was shown to be critical in 15 of the 21 test sites (71%).

Please note that this set of comparisons is on the factual data for the seven test sites and not the whole structure but it can be considered a good indicator of the overall future durability status of the whole structure. The confidence level in the results could be improved with further testing but, given the extensive visual observations made, it is unlikely to improve the outcome significantly.

#### b) Extraction of Dust Samples for Chloride Ion Analysis.

Twenty two significant chloride ion test results were selected from the sixty samples tested over all the seven test areas. Only four of the selected tests showed high or very high values with two of these being in the south section, one in the central section and one in the North section. Three of the high results were in beam and slab sections which had low concrete covers. Two of the high results were in the soffit slabs of South and North sections. Twelve of the results over all sections showed elevated values which were higher than recommended for current reinforced concrete design. There were five test results which recorded low or insignificant levels of chloride ions and these were spread over four areas; South section, Central stairs, Central section and the North section. Observation of the rust on the small areas of exposed steel reinforcement did not exhibit extensive pitting corrosion associated with chloride attack.

The significant test results suggest that the whole structure has been affected by chloride contamination from the marine environment, as opposed to chlorides being added to all the original concrete mixes. Chloride ion content at the reinforcement level generally indicated a moderate risk of chloride induced damage to the reinforcement.

## iv) Non-destructive Testing Of Concrete

#### a) Resistivity Test

Twenty typical minimum resistivity results were taken from a few dozen results recorded over five test areas and three showed high values with increased risk of corrosion to steel reinforcement. Only one result demonstrates any insignificant risk of corrosion to a fascia beam in the South section, which is in conflict with other parameters measured in that test area (e.g. carbonation depth > concrete cover). Unfortunately, ten of the results fall into a category that could be artificially high due to the effects of carbonation (contamination).

The resistivity tests on the spine wall in the North section showed lower values (i.e. higher moisture content) at the bottom quarter of the wall where the concrete is double the thickness.

#### b) Corrosion Potential Survey (Half-Cell)

Twenty significant Half Cell negative potential readings were considered out of a few hundred readings undertaken over six test areas. Thirteen of these selected results indicated high risk of reinforcement being corrosively active in all the six test areas. Only one result indicated a low risk and this was in the fascia beam of the Central section. Six of the significant results, from five different test areas (except central stairs) indicated some uncertainty in the results.

The back wall visually is in good condition and this is borne out by the results of the testing undertaken. Although there are some large negative half-cell potentials recorded, the potential differences between adjacent nodes are low, which is indicative that corrosion is unlikely to be occurring. The relatively high depth of cover, found on the back wall sections, may influence the half-cell measurement, but will also provide increased protection to the reinforcement.

The half-cell readings for the soffit transverse beams are all large negative readings with <100mV differences between adjacent readings, indicating that corrosion is also occurring in areas where spalling and exposed reinforcement is not already visible.

The main reason for the defects to the structure is considered to be poor quality of reinforced concrete workmanship during the construction of the original structure, with the soffit, transverse beam and front beam especially having areas of low concrete cover (less than 14mm). Chloride ion concentration at the reinforcement level generally indicate a moderate risk of chloride induced damage to the reinforcement. Current corrosion is thought to be due to carbonation, however if left chloride induced corrosion will potentially occur.

Sutton on Sea Collonade

Summary Table of Concrete Test Results

Test Area	Location	Initial Visual Assessment	Structural Element	Minimum Resistivity	Description				Chloride contamination				Half Cell potential mV - Cu/CuSO <sub>4</sub>	Assessment to BD 43				Min Cover	Carbonation Depth	Concrete Cores	Concrete Cores	Cement Content (maximum values +/- 25kg)
				kΩ cm	Artificially high due to carbonation	Moderate to low risk of corrosion	High risk	Insignificant risk	% by wt of concrete	Low	Medium	High		Good	Fair	Poor	Un-certain	mm	mm	Ref	N/mm <sup>2</sup>	kg/m <sup>3</sup>
1	South Section Column EE, GL 1 - 2	Reasonable	Soffit slab																			
			Back Wall	128.4	✓			0.071		medium				✓		24	23	DD, 1-2 DD-EE, 2	No test 48.5	477 447		
			Soffit slab	111.2	✓		0.212		✓		15	11										
			Transverse Bm	128.0	✓		0.036	low		✓	14	8										
			Front bm	128.3	✓		0.014	Insignificant		✓	21	19										
2	Central Stairs Columns Z - AA, GL 1 - 2	Poor																				
			Back Wall	?			?				52											
			Soffit slab	16.3		✓	0.049	low		✓	14	8										
			Transverse Bm	42.1	✓		0.056		medium	✓	14	16										
			Front bm	36.7	✓		0.071		medium		17	18										
			Beam over stairway	11.9		✓	0.085		medium	✓	19	9										
			Stair Side wall										Z, 2-3	47.1	577							
3	South Section Columns BB - CC, GL 1 - 2	Poor																				
			Back Wall	9.8		✓	0.099		medium		✓	92	28									
			Soffit slab	16.2		✓	0.071		medium		✓	14	10									
			Transverse Bm	1.9		very high	0.283		✓	14	35											
			Front bm	128.6	✓		Insignificant risk	0.071		medium		✓	23	34								

## Sutton on Sea Collonade

### Summary Table of Concrete Test Results

Test Area	Location	Initial Visual Assessment	Structural Element	Minimum Resistivity	Description				Chloride contamination				Half Cell potential mV - Cu/CuSO <sub>4</sub>	Assessment to BD 43				Min Cover	Carbonation Depth	Concrete Cores	Concrete Cores	Cement Content (maximum values +/- 25kg)					
				kΩ cm	Artificially high due to carbonation	Moderate to low risk of corrosion	High risk	Insignificant risk	% by wt of concrete	Low	Medium	High			Good	Fair	Poor	Un-certain	mm	mm	Ref	N/mm <sup>2</sup>	kg/m <sup>3</sup>				
4	Central Section  Column U, GL 1 - 2	Reasonable	Back Wall	19.2	✓	✓			0.003	Insigificant	medium	✓						86	17	P2 R, 1-2 X, 1-2	62.8	483					
			Soffit GL R, 1-2							54.0											563						
			Soffit X, 1-2.							32.8											474						
			Back Wall							17.9											0.248	✓	✓	14	18		
			Soffit slab							128.6											0.071	✓	✓	14	22		
			Transverse Bm							105.0											0.021	low	✓	20	26		
5	North Section  Column K, GL 1	Reasonable	Back Wall	10.8	✓	✓			0.007	low	medium	✓						27	10	GL K 2 KW, 2	60.0	451					
			Back Wall							12.6													0.170	✓	✓	14	5
			Soffit slab							4.5													0.142	✓	✓	16	6
			Front bm							84.2													0.071	medium	✓	26	10
			Column K1							M1													44.9	474			
			Column M1																								
6	North section  Half Joint Column G - H, GL 1	Poor	Front beam					0.071		medium							<14	18									
			South Side																								
			North side																								
7	North Section  Rust stain Column J - K, GL 1	Poor	Front beam					0.071		medium		No readings					16	?									
8	North Section  Stair side wall	Reasonable	Stair side wall																	D, 2-3	26	381					

## 4. Potential Remedial Options for Concrete Structure Elements

The following remedial options are suggested for the long term strengthening of the various defects to particular structural elements that have been observed and confirmed by the concrete test results from seven selected test areas.

It should be noted that the concrete test results are related to the selected test sites and not the whole structure but it can be considered a good indicator of the overall future durability status of the whole structure. The confidence level in the results could be improved with further testing but, given the extensive visual observations made it is unlikely to improve the outcome significantly. It would be prudent to undertake further local tests during any delayed remedial measures proposed to ensure compatibility.

It is recommended that the under-croft below the timber floor to all the beach huts on the central and southern sections should be cleaned out of all heavy debris (old asphalt waterproofing and builder's debris) to reduce the dead load on the structure on weakened first floor slabs. The water leaks into the under-croft should also be sealed so the degradation to the RC concrete structure is not exacerbated. In addition, the drifting of washed up beach sand during the winter months from in front of the beach huts should also be closely controlled to mitigate overloading of suspended slabs not necessarily within the direct control of East Lindsey DC.



**Photo no 21: Under croft to huts nos 23-24 in central section showing water and drainage services.**

### i) Ageing Sound RC Concrete:

The intact ageing concrete nearing its end of design life (notionally 60 years), suffering a high depth of carbonation and a high percentage of soluble chlorides potentially putting the steel reinforcement at risk of corrosion. The general remedial measure to ensure a longer service life would require the numerous and varied coatings to be removed by shot blasting and the exposed concrete surfaces repaired and over coated with a proprietary, anti-carbonation fairing coat and decorative finish. This remedial proposal would need to be applied to the full length of the spine wall as this structure will need to be retained whichever remedial strategy is chosen as it supports part of the promenade suspended slab which may be under another ownership.

### ii) Slab Shrinkage Cracks

Cracks in top face of first floor slab (max 130mm) (other than movement joints) require local cutting out with square edges, anti-corrosion coating applied to any exposed reinforcement, joint refilled with a bonding agent



and a proprietary concrete repair mortar to BS EN 1504. The exposed concrete upper surfaces should also be coated with a waterproof material (e.g. mastic asphalt or cold applied equivalent.). A similar detail can be applied to the vertical shrinkage cracks in the spine wall but a flexible repair sealant should be used.

### iii) Low concrete cover

Low concrete cover (circa 13 to 20mm) hollow concrete and extensive spalling to soffits of first floor slab will require either:

- a) Demolition of slab and making good perimeter and the bay taken out of use for beach huts etc. Access to the top surface of the slab would be required for this remedial option i.e. beach huts and services removed. A new perimeter safety handrail would be required to the removed first floor slab.
- b) Demolition of slab and replacement with a new insitu concrete slab, or precast concrete slab units (to an external concrete exposure specification) with a structural screed topping or a grouted finish with a mastic asphalt floor waterproof coating. Access for craneage for the erection of precast units not ideal but just possible. Transportation of PC concrete floor units is likely over 50 miles from site. Access to the top surface of the slab would be required for this remedial option (as iii (a) above).
- c) Subject to a full structural design check overlay the existing slab with a new insitu concrete slab and support the existing slab by a grid of stainless steel, through-bolt anchors with large washer plates at 750mm centres. A safety mesh of stainless steel would need to be fixed on the underside of the existing slab and anchor bolts to prevent any falling spalled concrete. The safety mesh would also need to be provided with fire protection boarding or thick render. Access to the top surface of the slab would be required for this remedial option (as iii (a) above).
- d) Structurally repair the existing slab by replacing the corroded rebar and reinstate the soffit concrete by vacuum grouting with a high strength free flowing cementitious grout by a specialist company e.g. 'Balvac'. Soffit formwork would need to be sealed against vacuum actions. Access to the top surface of the slab would be required for this remedial option (as iii (a) above). This option is also shown on Figure 6 in Appendix C.
- e) Demolish and replace slab with a lightweight specialist composite slab with special fire resisting phenolic resins. Access to the top surface of the slab would be required for this remedial option (as iii (a) above).

### iv) Down-stand Beams

- a) Patch repair and supplement tension reinforcement with new epoxy coated reinforcement lapped in position with full tension lap. Where defective shear stirrups are to be replaced, localised external FRP strapping by specialist to be used. All repaired areas to have cross section reinstated with proprietary concrete repair mortar to BS EN 1504 ensuring the required degree of end use fire resistance is also achieved. This option is also shown on Figure 5 in Appendix C.
- b) Provision of supplementary RC Saddle beams to RC cross beams where tension and shear reinforcement lost. This option is also shown on Figure 7 in Appendix C.
- c) Provision of a Rectangular Hollow Section steel beam support on the internal face of the long span fascia beams without a half-lap movement joints. Two supplementary steel columns will also be required to support this eccentrically mounted RHS steel beam. This option is also shown on Figures 8 and 9 in Appendix C.
- d) Where RC beams have lost shear capacity by corrosion of steel links, enhancement can be provided by wrapping the section in bonded Fibre Reinforced Polymer with appropriate cementitious render to provide requisite fire protection. This option is also shown on Figure 10 in Appendix C.
- e) Certain beams will need rebuilding insitu to maintain the original structural design (e.g. half-lap joint and adjacent RC fascia beam Northern Section).
- f) As a precautionary measure Hybrid Anode inserts in the concrete patch repairs should be considered to prolong the life of the repairs given the high risks from chloride contamination and carbonation revealed by intrusive tests.

### v) Column Remedials

- a) Patch repair with repair mortar to BS EN 1504 and replaced corroded rebars with appropriate lap lengths. If repair near the top of the columns, bars will need anchorage drilling and grouting into the supported fascia RC beam as well.

### vi) Movement Joints

- a) Break out defects and patch repair with repair mortar complying with BS EN 1504. Reconstruct expansion joint with filler core and salt-water resistant sealant both sides where ever possible. This will

involve making new safe personal accesses, into the confined spaces, on the coastal side of the spine wall. This may involve consultation with the adjacent landlord, the Environment Agency as the ownership boundary is unclear.



**Photo no 22: Confined space behind spine wall North section (May be in EA ownership).**

**vii) Half-lap Joint in Fascia Beam Bay GL 1, G-H. (North section)**

- a) This joint has suffered severe corrosion with loss of concrete and steel reinforcement cross section in addition to structural cracking and requires rebuilding insitu with replacement reinforcement to a new improved structural design to accommodate movement, mitigate corrosion and allow inspection.

**viii) Fascia Beam over Column J1. (North section)**

- a) The fascia beam over the column has suffered severe reinforcement corrosion and a structural crack has occurred across the head of the column which needs investigating further and remediating insitu to a new enhanced structural design and detail.



**Photo no 23: Fascia beam over column J1 showing rust area and structural crack over column.**

ix) **Cross beams in Bay GL 2, Z-AA.** (Central Stairs)

- a) The cross beam over the stairs has suffered severe reinforcement corrosion and structural cracking which needs investigating further and remediating insitu to a new enhanced structural design and detail.



**Photo no 24: Cross beam over central stair access GL 2 Z-AA showing rust staining, cracking and hollow concrete.**

x) **Cross beams in Bay GL 1-2, LL-MM.** (South section)

- a) Should the south section be retained the cross beams which have suffered severe corrosion need to be replaced insitu to a new structural design to suit the proposed future use and mitigate corrosion.

xi) **Spine Wall** (All sections)

- a) The spine wall that runs through all three sections will need to be retained whatever remedial scheme is adopted. Although the wall is generally, in good condition the few shrinkage cracks and movement joints will need specific repairs. The four core sample holes need reinstating with a bonding agent and concrete repair mortar complying with BS EN 1504. With the measured chloride ion levels being elevated and the carbonation depths advancing the exposed faces of the wall should be protected with an anti-carbonation coating to BS EN 1504 and a cosmetic anti-graffiti coating. To enable this coating to perform effectively the existing decorative wall coatings will need removing by light shot blasting and any localised defects exposed remediated with repair mortar.

## 5. Grouped Defect Categorisation for Structure Section Condition Comparison.

A summary of grouped element defects for each of the three sections is attached in Appendix D.

- The shallow areas of defects to elements could be expected to be remediated by localised patch repairs.
- The moderate areas of defects would be expected to be rebuilt insitu, with supplementary strengthening by additional reinforcing of steel or fibre reinforced polymer resin band wrapping and repair mortar.
- The severe areas of defects have multiple defects and are considered to rapidly deteriorate leading to structural instability. This instability would require rebuilding or supporting.
- Defects that have already been assessed as failing require either removal along with any supported elements or complete rebuilding/replacement.

In addition, to the specific repairs to the concrete sections, the removal of the any beach huts on the promenade to gain access to the works and the consequent disruption to other parties need to be considered for a whole life costing.

An assessment of grouped defects based on our visual inspections and supported by the intrusive and non-destructive testing showed that the Central Section of the structure, including the central stairs has the least number of defects to remediate. The Southern section has the most identified and potential defects requiring remedial measures. The North section is the more challenging section to predict what is likely to deteriorate in the future, as there are some localised serious structural defects and there are a large number of defects that are at an advanced stage of deterioration that require significant remedial measures to be rectified to safeguard a significant extension to its design life.

## 6. Costing of Remedial Options

The remedial options for reinforced concrete are to be assessed for high level costs, by Gleeds Cost Consultants, as a supplement to this Structural Condition Report.

## 7. Recommendations and Conclusions

After completing our close up inspection of the condition of the Concrete Colonnade at Sutton-on-sea in May 2018, and analysing the intrusive and non-destructive concrete testing results, we would make the following recommendations.

The ageing structure is exhibiting common defects for a reinforced concrete design constructed in the 1950s and 1960s and exposed to an aggressive marine environment. For the structure to be used for the benefit of the public for the next 40 to 50 years a number of defects would need to be remediated. Some of these defects are serious and currently affecting the safe use of the structure as there is a high risk of small sections of concrete cover to the embedded steel reinforcement being jacked off by ferrous oxide expansion from the high sections of the structure and falling and potentially injuring persons moving close to and/or within the structure. This safety risk is expected to increase with time unless robust remedial measures are undertaken or parts of the structure decommissioned from its present usage. The temporary safety provisions that have already been implemented on site in the form of a physical barrier fence and structural props to the enclosed area under the first floor, and separating sections of the structure from public access, will need to be enhanced for robustness and maintained until a remedial proposal is implemented.

Since the fascia and transfer beams which span over the public access to the North stairs to the promenade are not currently closed off from the public, are showing advanced signs of degradation we would recommend that these are inspected for safety, by an engineer with appropriate structural experience, at least every 10 weeks starting from 1<sup>st</sup> June 2018.



**Photo no 25: Showing area where first floor beams over access to North stairs which need regular structural inspections for public safety.**

The defects have reached an advanced stage of deterioration so that local patch repairs are insufficient to safeguard all the structure for an extended life, and wholesale reconstruction of certain members is considered necessary. Within the report we have outlined a number of remedial options that can be considered depending on the degree of disruption and the budget that is available to finance the works and its future commercial viability. A summary of grouped element defects for each of the three sections is attached in Appendix D.

A supplementary section to this report, being prepared by Gleeds, will help focus the route for remedial strategies.

Please note that this set of comparisons is based on the factual data for the seven test sites and not the whole structure but it can be considered a good indicator of the overall future durability status of the whole structure. The confidence level in the results could be improved with future testing but given the visual observations made it is unlikely to improve significantly but it would be prudent to undertake further local tests during any remedial measures proposed to ensure compatibility.

Should the Council require further additional structural design, contract management or site supervision of specific remedial measures AECOM would be pleased to offer their professional services.

## Appendix A

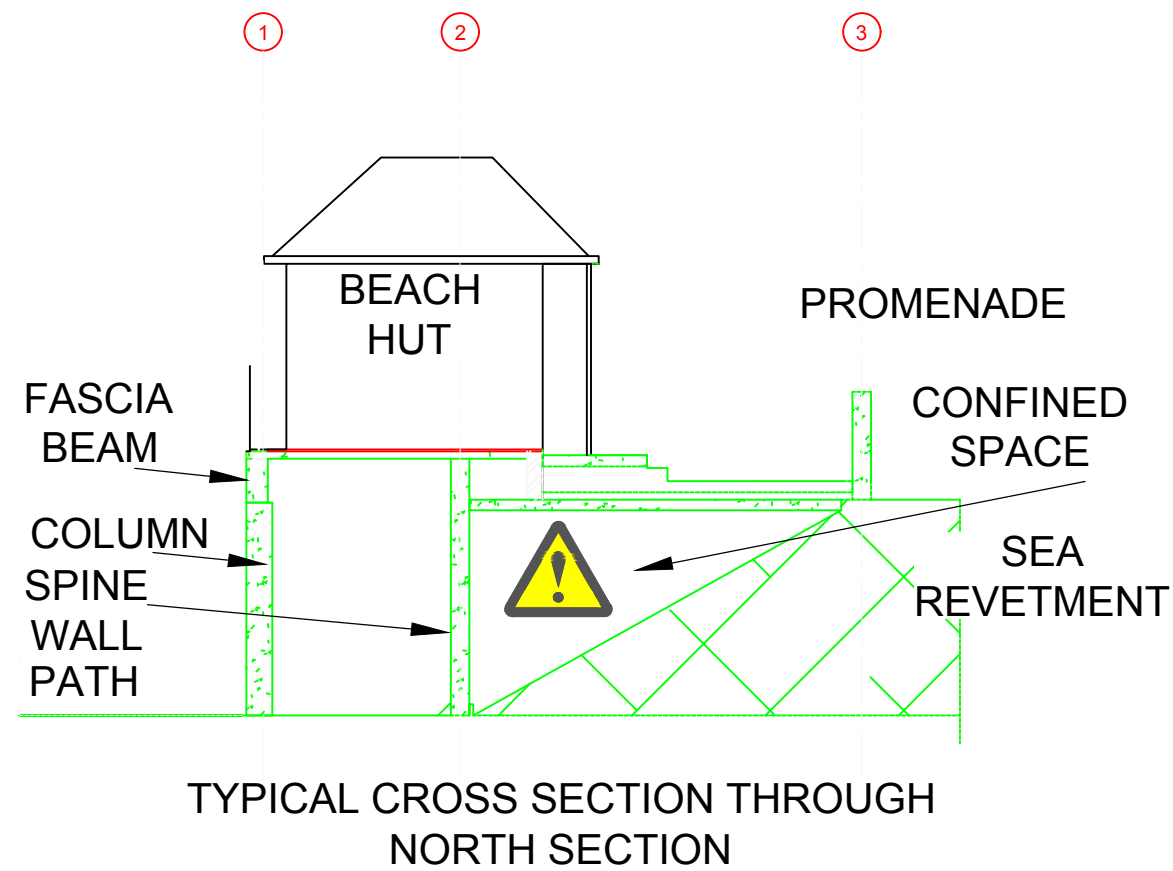
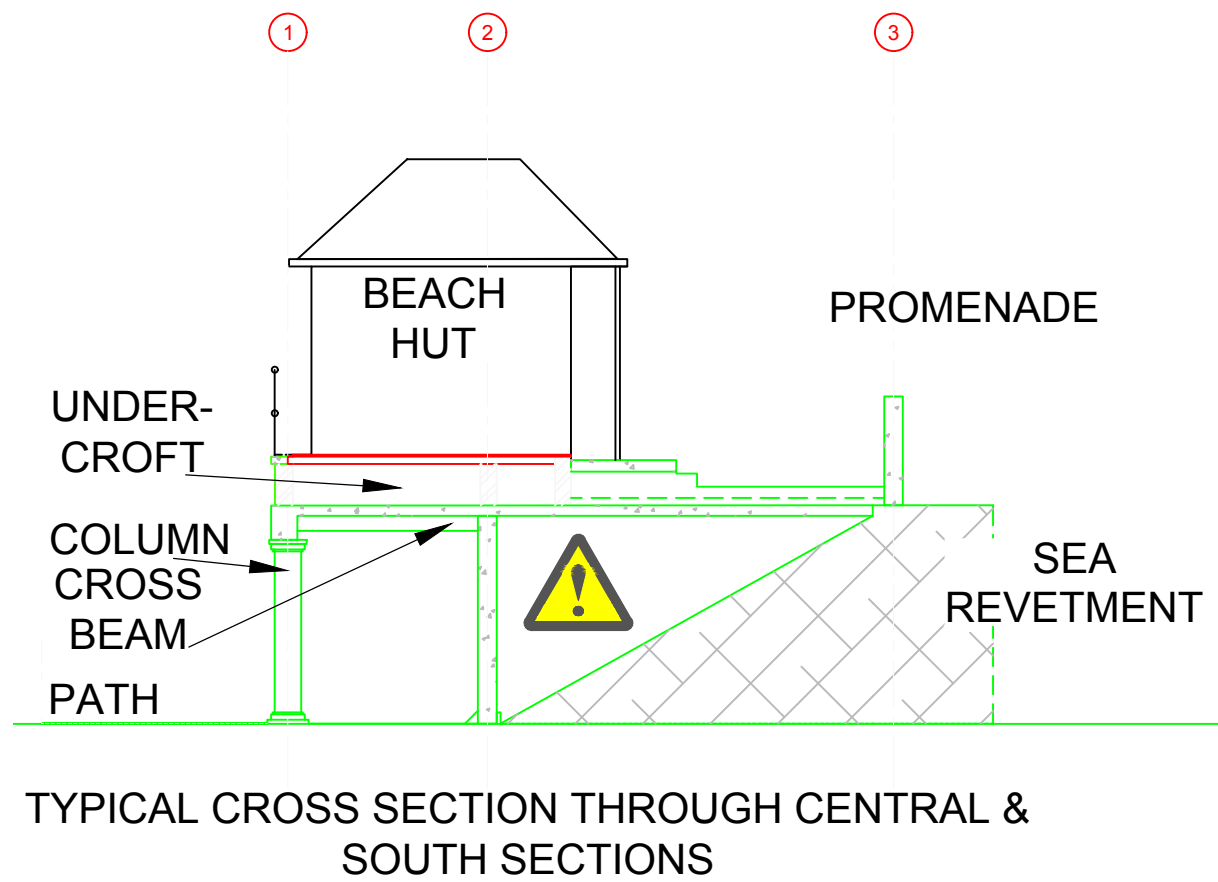
### Drawings

Location Plan Figure 1

Typical Sections Figure 2







## Appendix B

### Visual Observations of Concrete Defects

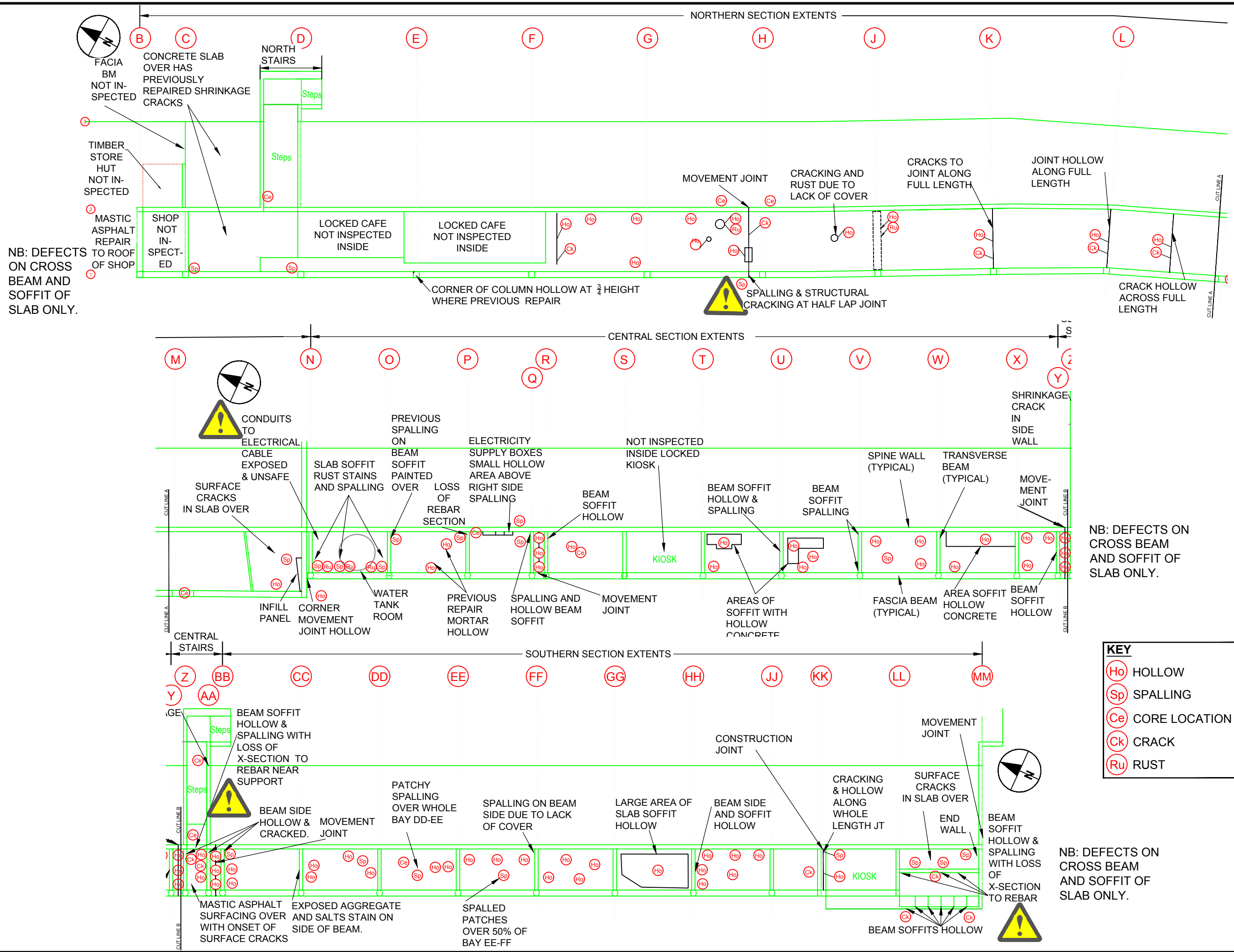
Plan Figure 3

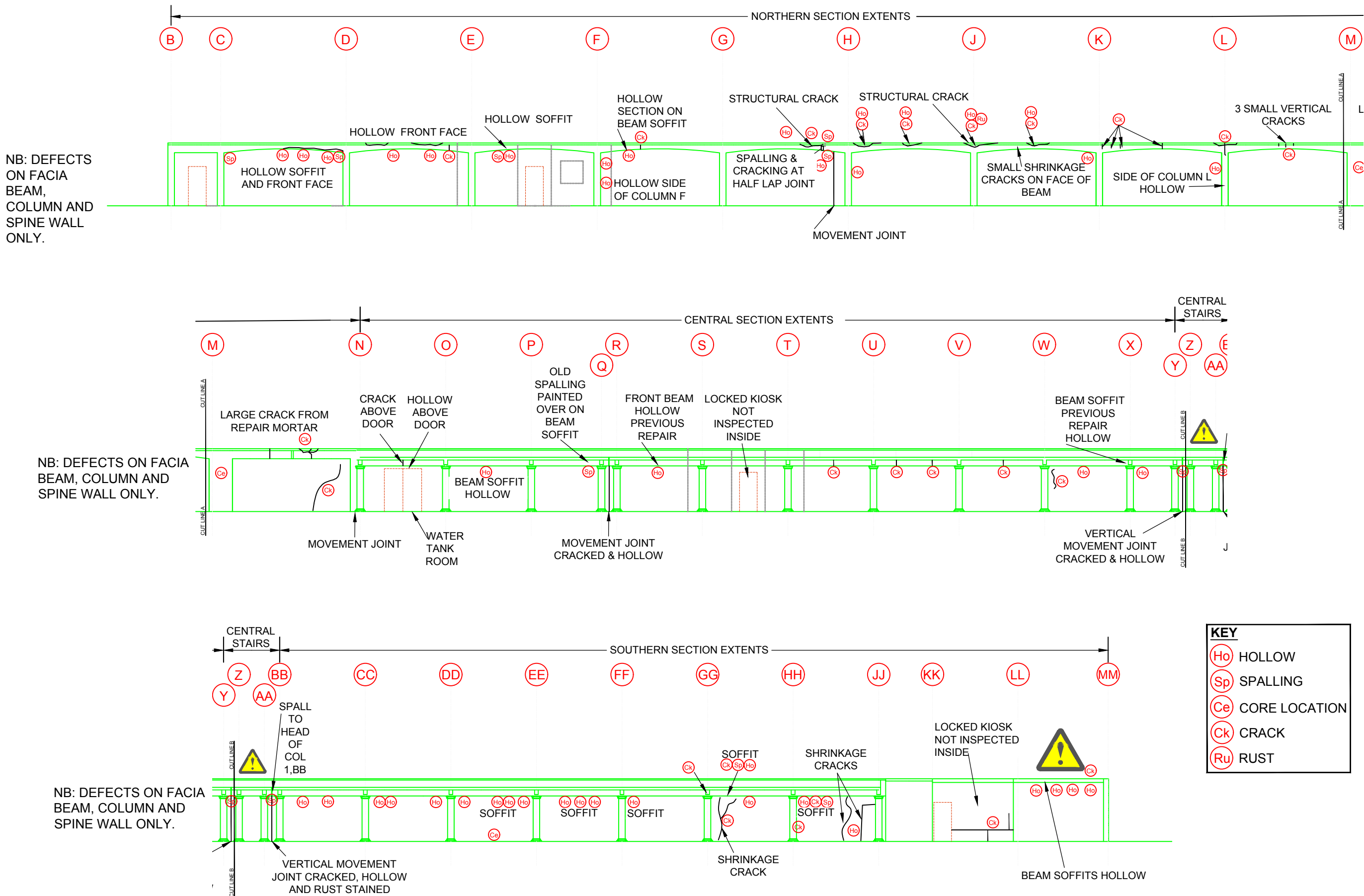
Elevations Figure 4

Figure 2 from AECOM

Concrete Testing Report

for Test Areas

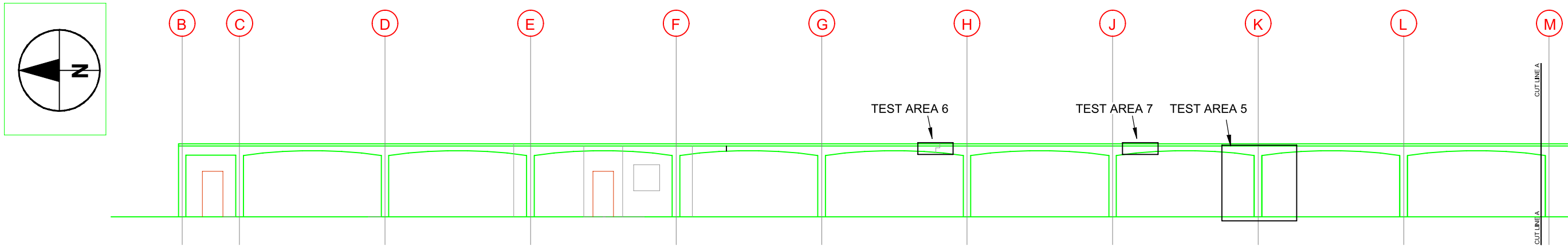




ELEVATION OUTLINE SHOWING VISUAL STRUCTURAL DEFECTS

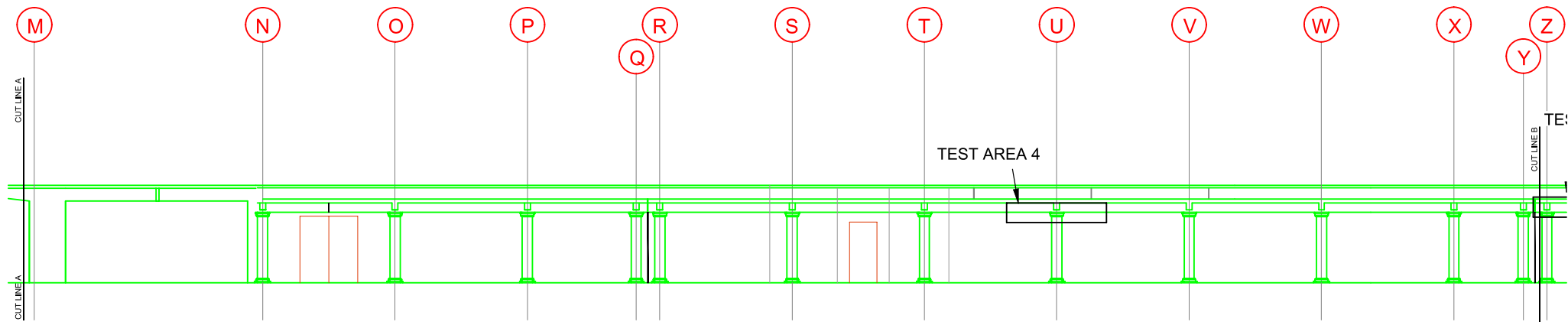


Plot Date : 17 July 2018 17:00:49  
File Name : K:\03 INSPECTIONS GENERAL\CURRENT ASSET MANAGEMENT TEAM JOBS\SUTTON ON SEA COLONNADE WALL TESTING\DEFECT SUTTON ON SEA



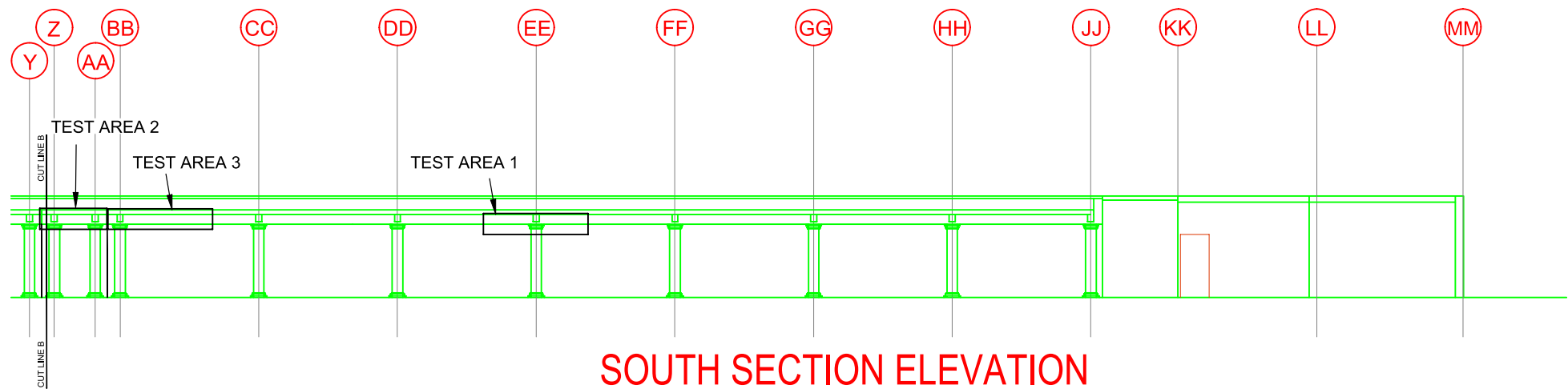
**NORTH SECTION ELEVATION**

(1:200)




**CENTRAL SECTION ELEVATION**

(1:200)



**SOUTH SECTION ELEVATION**

(1:200)

<div>Project Title</div> <div>SUTTON ON SEA COLONNADE CONCRETE TESTING</div>		<div>Drawing Title</div> <div>NORTH, CENTRAL AND SOUTH SECTION ELEVATIONS</div>		<div>Purpose of issue</div> <div>DRAFT</div>					<div>THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOM'S APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOM'S EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.</div>		<div>AECOM Infrastructure &amp; Environment UK Limited</div> <div>Royal Court, Basil Close</div> <div>Chesterfield</div> <div>S41 7SL</div> <div>Tel:+44 (0)1246 209 221</div> <div>Fax:+44 (0)1246 209 229</div> <div>www.aecom.com</div> <div></div>						
<div>Client</div> <div>EAST LINDSEY DISTRICT COUNCIL</div>				Designed ME		Drawn ME		Checked					Approved		Date JUN 18		
				AECOM Internal Project No. -		Suitability -											
				Scale @ A3 AS SHOWN		Zone / Mileage -				Drawing Number FIGURE 2		Rev -					

## Appendix C

### Typical Remedials For RC Sections

General Concrete Patch Repair. Figure 5

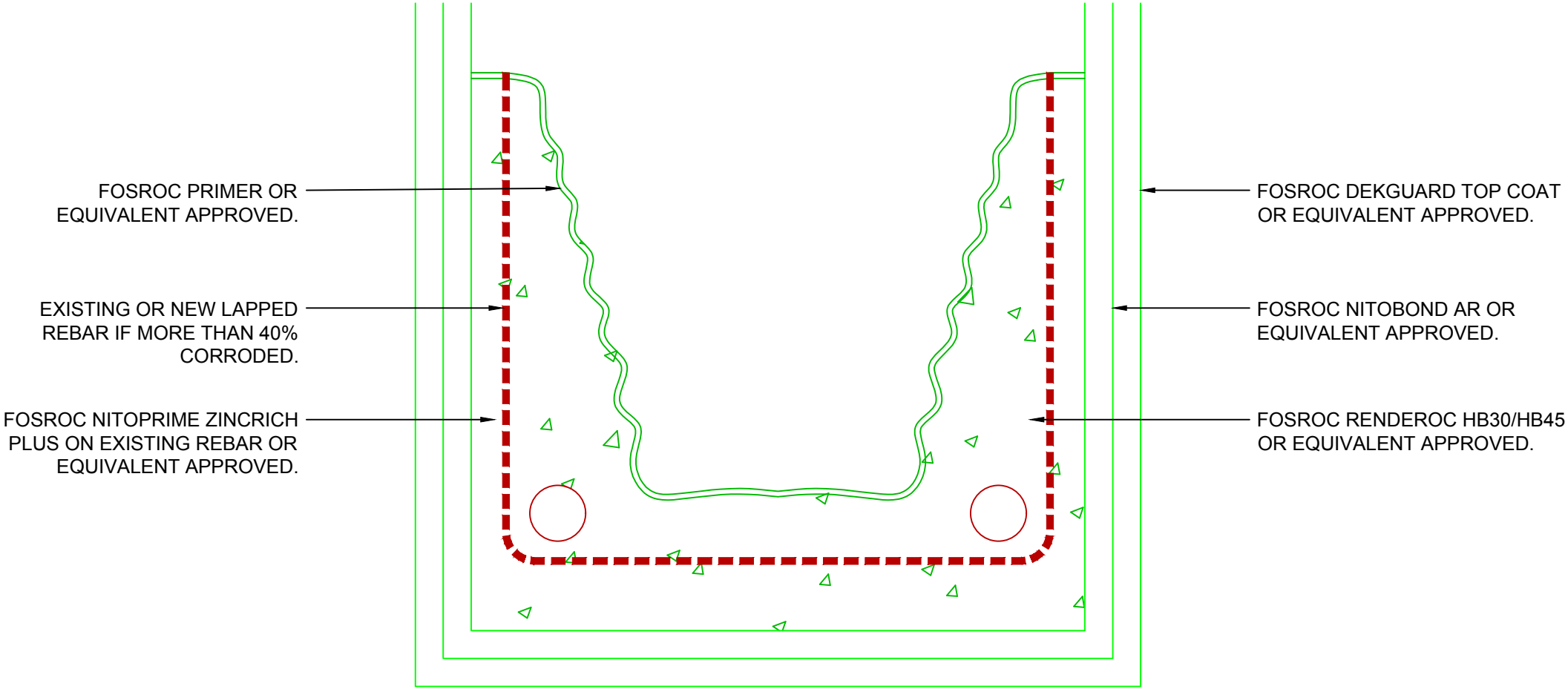
Suspended Slab Vacuum Grout Repair. Figure 6

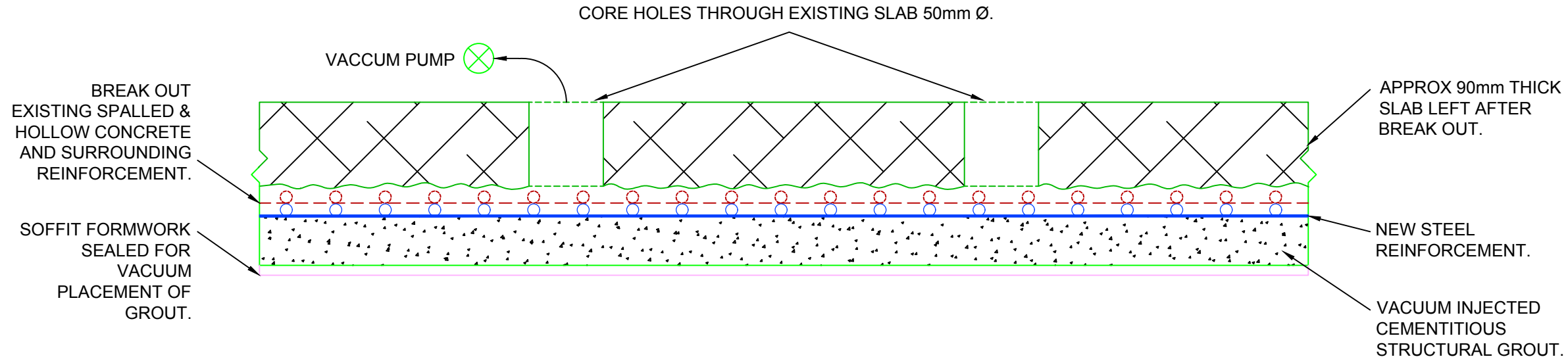
Supplementary RC Saddle Beam Repair. Figure 7

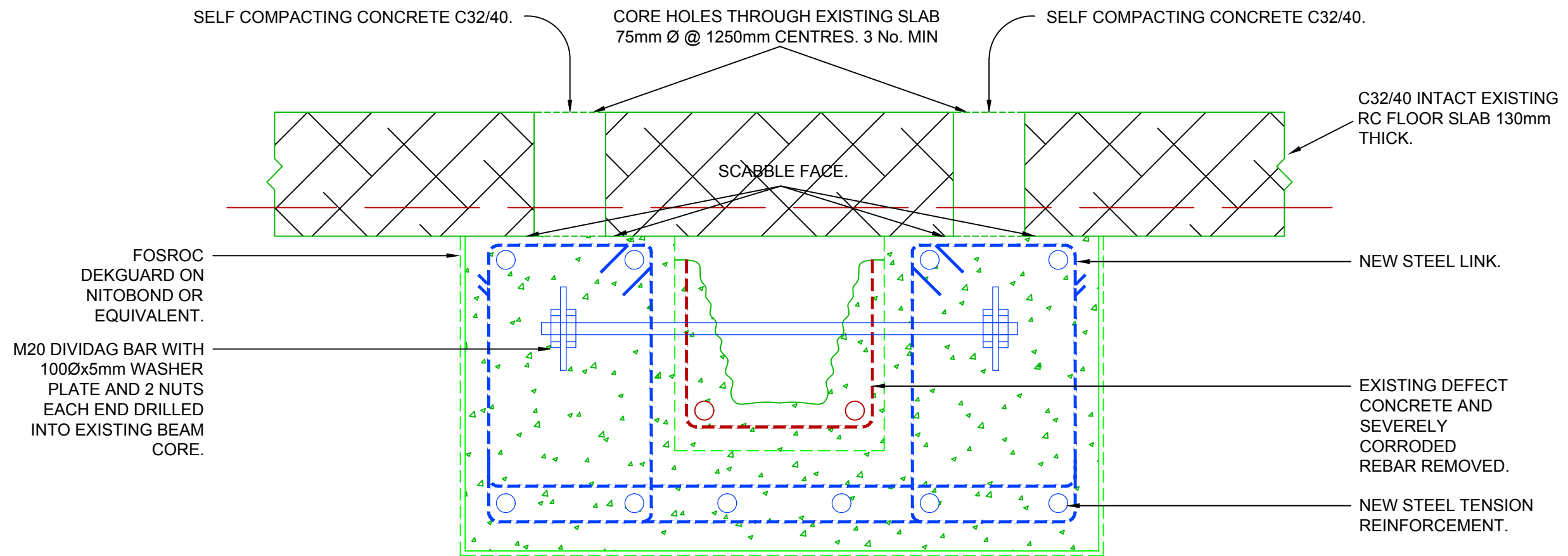
Supplementary Steel beam to Fascia Beam. Figure 8

Supplementary Steel Column to Steel Beam Strengthening. Figure 9

Fibre Reinforced Polymer Shear Enhancement of RC Beams. Figure 10

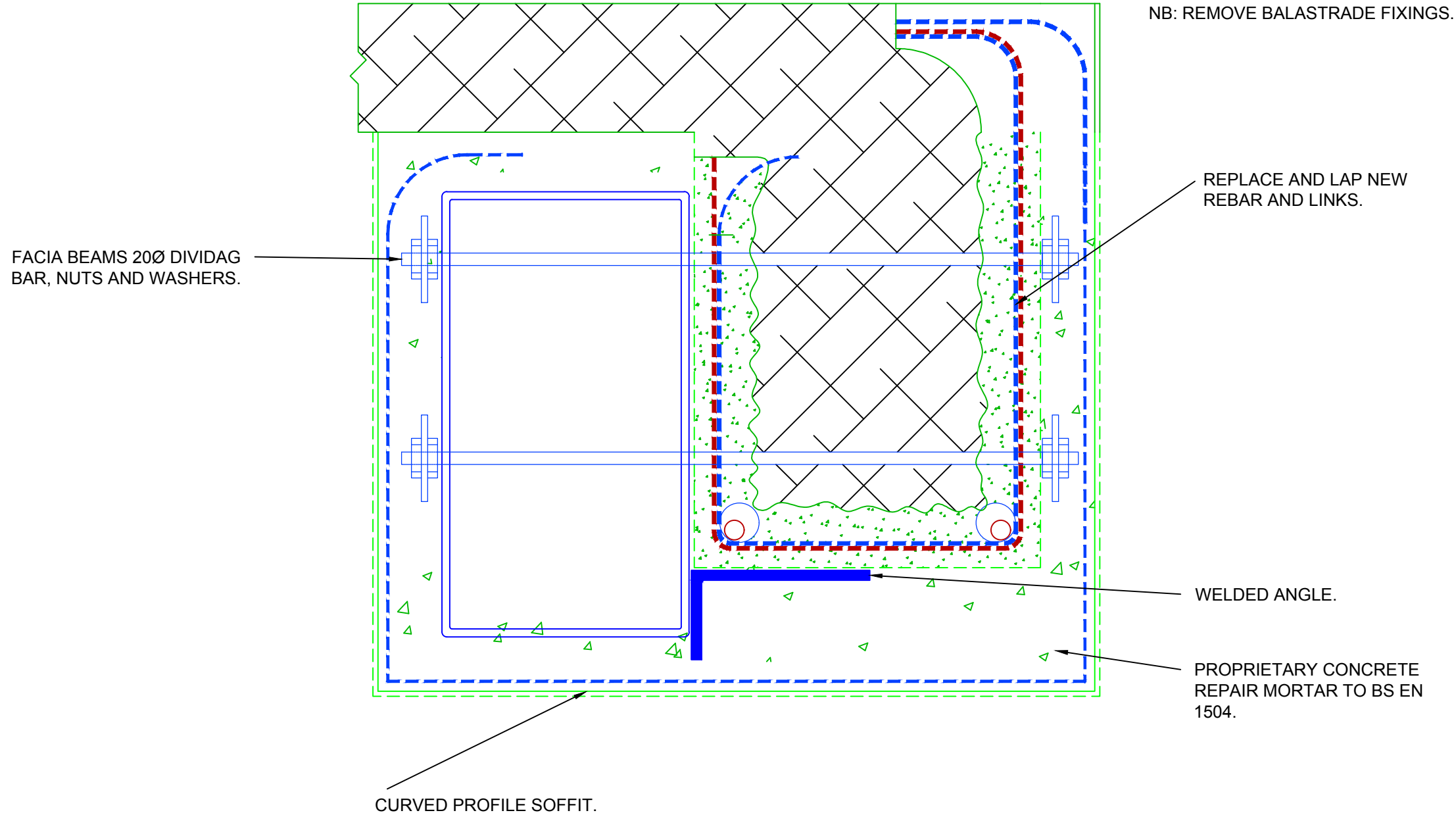


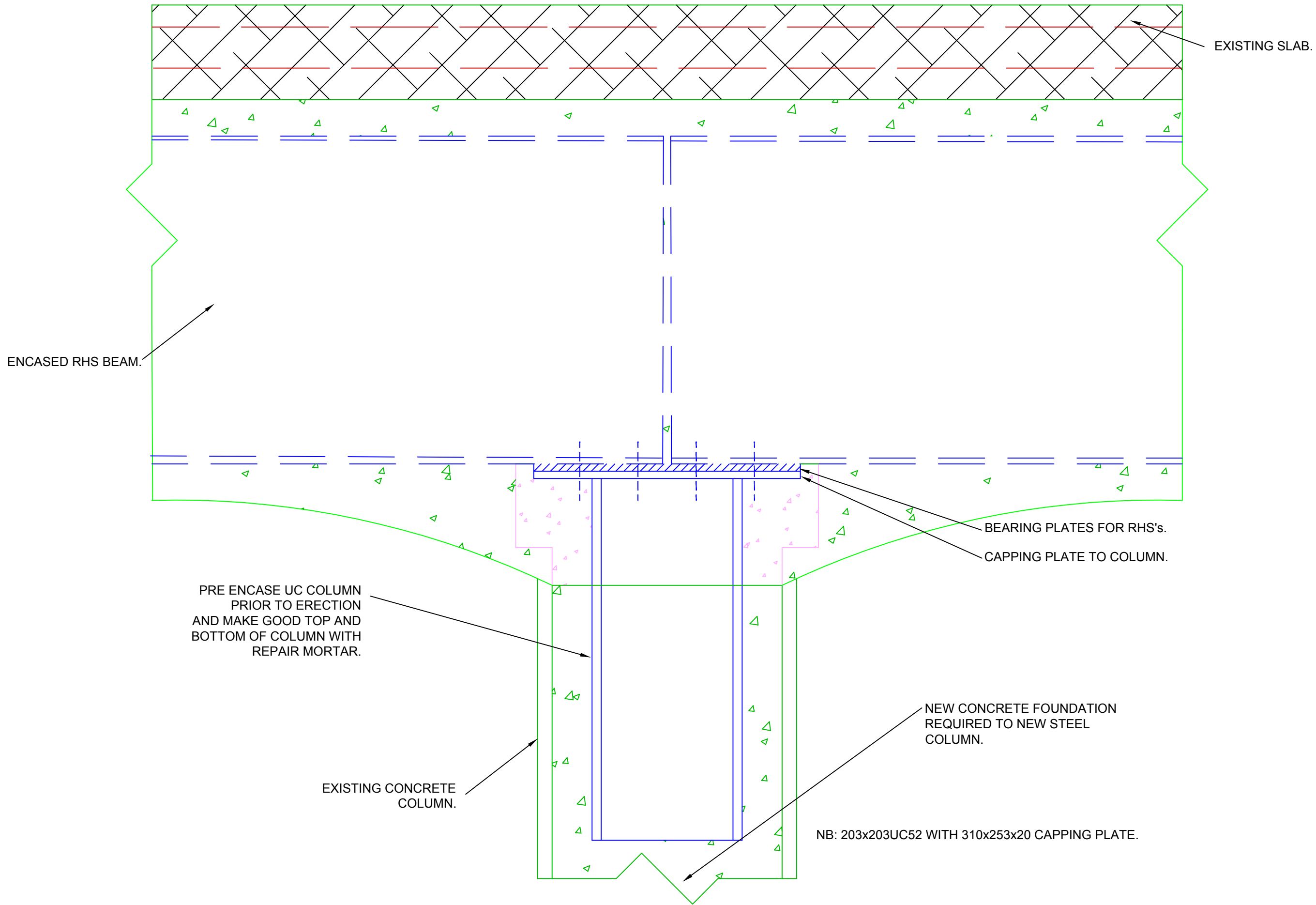




14 No. REQUIRED (3.9m LONG)







VIEW FROM GRID LINE 2 LOOKING AT GRID LINE 1.

## Appendix D

### Schedule of Visible Concrete Defects

Figure 11

Sutton on Sea - Colonnade

Schedule of Structural Concrete Defects in each section.

North Section of Structure GLs B to N (11 Bays)			Defect Severity					
Ref	Structural Element	No	Fail Rebuild	Severe e.g. Fig 6, 7, 10, or ( 8 + 9).	Moderate e.g. Fig 7 + Anodes	Light e.g. Fig. 5	Defects Totals	Protective coating
i	Circular Columns (0)	0			0	0		
ii	Rectangular Columns	13			4	1	5	
iii	Spine Wall (Bays)	10			1	2	3	
iv	Fascia Spandrel Beam Bays (1 no GL B not inspected)	13	1	3	5	3	12	
v	Cross Beams	4				2	2	
vi	Slabs at Promenade level	11		5		2	7	
vii	Stairs North	1				1	1	
viii	Stairs Central	0				0	0	
ix	Movement Joints Wall - Both sides	2			1	1	2	
x	Movement half lap Joints Bm	1	1				1	
xi	Movement Joints & Cracks in Slabs (Top & Btm)	9			4	5	9	
3 No bays not inspected - Locked Kiosks Estimate		3	1		2		3	
Total No Elements		67	2	9	17	17	45	
% Total							67	Largest recoat area.

Central Section of Structure GLs N to Y-Z (12 Bays)			Defect severity					
i	Circular Columns	12				1	1	
ii	Rectangular Columns	0				0	0	
iii	Spine Wall (Bays)	11				1	1	
iv	Fascia Spandrel Beam Bays	11			6	5	11	
v	Cross Beams (Long))	12	1	6	1	4	12	
vi	Slabs at Promenade level	11		10		1	11	
vii	Cross Beams (Short)	5	5				5	
viii	Stairs Central (3 no cross beams, 1 no slab (Severe) & 2 side walls (Crks))	5	2	1	1	1	5	
ix	Movement Joints Wall	2			2		2	
x	Movement Joints Bm	2			2		2	
xi	Movement Joints & cracks in 1 no Slab (Top & Btm)	3			3		3	
1 No bay not inspected - Locked Kiosk. Estimate		2			2		2	
Total No Elements		76	8	17	17	13	50	
% Total							66	Least serious

South Section of Structure GLs Y-Z to MM (12 bays)			Defect severity						
i	Circular Columns	8				1	1		
ii	Rectangular Columns	1				2	2		
iii	Spine Wall (Bays) + End wall (Moderate)	11			3		3		
iv	Fascia Spandrel Beam Bays	12	1	6	4	1	12		
v	Cross Beams (long)	11	1	5	2	3	11		
vi	Slabs at Promenade level	10		9		1	10		
vii	Cross Beams (short)	5	5				5		
viii	Stairs Central	0					0		
ix	Movement Joints Wall	2		1	1		2		
x	Movement Joints Bm	2			2		2		
xi	Movement Joints & cracks in 1no Slab (Top & Btm)	4		1	3		4		
I No bay not inspected - Locked Kiosk. Estimate		1		1			1		
Total No Elements		67	7	23	15	8	52		
% Total							78	Most serious	Least Repaint area

## Appendix E

### Concrete Core Testing by Kiwa CMT Testing

Report 74385/57776





## Appendix F

### Concrete Non-Destructive Testing by AECOM

Report Number: 60578623



