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Dudley Zoo

Structural Engineering Report on the Four Tectons

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1. Introduction

Stand Consulting Engineers was instructed by Dudley Zoological Gardens to prepare a structural engineering report for the repair of four structures designed by Tecton Architects. This report is part of a submission for grant-funding to the Heritage Lottery Fund.

We have made two visits to the zoo, on 12th July 2011 with the architect, Bryant Priest Newman and Rowan Technologies Limited, and a visit and project team meeting on 25th July 2011.

This report is based on a desk study of our own information, together with reports and drawings provided by others, together with our assessment of the four structures. The condition and repair of the existing reinforced concrete structures is covered in the report by Rowan and so is not repeated here.

It is proposed to repair four of the structures; the Entrance, the Safari Shop, the bear ravine, and a kiosk adjacent to the bear ravine. During our visits we also had a general look at the other structures from the same period to get an overall impression of the quality of construction and their condition. Our brief comments on these are included with this report.

We worked on many 20th century buildings and structures including a 1930 steel and reinforced concrete factory designed by Wallis Gilbert, the Barbican Art Centre in London, and the Melnikov House in Moscow. We have lectured for a number of years on the repair of reinforced concrete structures and buildings at West Dean in Sussex and at an ICOMOS conference in Madrid this year on the conservation of 20th century heritage.

2. Summary of the existing structures

Thirteen structures for a variety of uses were built at Dudley Zoo between 1935 and 1937. The architect was the Tecton Partnership with the structural design and construction by JL Kier & Co. Ltd. The principal structural material is reinforced concrete. Patch repairs to corroded reinforcement and spalled concrete has been carried out to most of the structures we saw. The majority of these repairs have failed.

The zoo is sited around Castle Hill which is shown on the British Geological Survey map as an outcrop of siltstone from the Coalbrookdale formation.

1. The Entrance Canopy

This grade II* listed structure is formed by solid steel columns which support five separate, curved reinforced concrete slabs. The columns are shown on a record drawing to bear onto a shallow reinforced concrete foundation. We assume that the roof slabs act as two-way spanning structures with additional reinforcement between the columns as noted on drawing EC 01. There is corrosion of the steel columns at ground level which has resulted in a reduction in size from 90 mm to approximately 70 mm in diameter.

There is extensive corrosion of the reinforcement and spalling of the concrete to the underside of the slabs. Providing temporary support to the reinforcement of the slab in the curved slabs as they were cast in order to maintain adequate cover seems to have been a particular problem and there are areas where the reinforcement is visible on the soffit.

1. Dudley Zoo Shop

This is a reinforced concrete framed structure. Some internal alterations have taken place in the past to create a more open plan area including the removal of one of the reinforced concrete columns which has been replaced by a steel beam supported on a steel column at each end. There are some local areas of corroded reinforcement and spalled concrete but no obvious signs of significant structural defects. It is listed grade II.

2. The Bear Ravine Kiosk

This small, grade II* listed structure is formed by four circular steel hollow section columns which support a flat reinforced concrete roof slab. It is partly enclosed by reinforced concrete walls and a slab at counter level. We assume that the foundations are shallow mass concrete pads and strips. The existing structure is summarised on drawing K 01.

The base to one of the columns has completely corroded and the support is now provided by the encasement of the steel in the reinforced concrete slab at counter level. There is corrosion to the counter and roof slabs and some erosion of concrete to one side of the roof slab.

3. The Bear Ravine

The grade II* listed former bear enclosure is one of the largest structures at the zoo. It is built against part of Castle Hill and is formed of reinforced concrete retaining walls and columns onto pad and strip footings, with reinforced concrete slabs and stairs. Circular hollow steel columns have been used locally around the stair well. There is a large viewing platform which cantilevers over the animal enclosure below.

Parts of the structure are in a poor or very poor condition. There is extensive corrosion of the reinforcement and steel columns and large areas of spalled concrete. There are longitudinal cracks in the cantilevered slab that indicate deflection of the structure. The existing structure is summarised on drawing B 01. The structural action of the cantilevered viewing platform is shown on drawing B 02.

3. What were the contexts for the structural design?

The first British code of practice for concrete was the 1933 document, "Report of the Reinforced Concrete Structures Committee of the Building Research Board with recommendations for a code of practice for the use of reinforced concrete in buildings". This provides useful information on the design and specification of reinforced concrete structures from this period. For example the cover

to main bars “shall be 1 inch” (25 mm) and ½ inch for secondary bars. As a comparison the modern practice for structures with a similar exposure condition would be a minimum of 40 mm concrete cover to all bars.

Concrete would have been mixed on site using mechanical equipment. The proportions for the cement, sand and aggregate are typically in a ratio of 1:2:4 which would give strength in the order of 25N/mm². The results from the Rowan tests found a higher strength, for the bear ravine it was generally 40 N/mm² to 55 N/mm². This indicates good design practice, together with good quality control and supervision during the placing of the concrete.

The reinforcement is from one of the many propriety systems that were available at the time. Some of the bars exposed in the parapet wall to the bear ravine are square twisted bars and may be the Ransome system which was developed by Ernest Ransome in the USA and first patented in 1844.

Support to the reinforcement is described in “Cassell’s Reinforced Concrete” edited by Bernard Jones which was first published 1913 and “new and enlarged edition” made in 1920. This shows that bars are laid on wood blocks and strips which are “removed as soon as there is sufficient concrete in the moulds to keep the bars in place.” This process does have the risk that the bars will not be fully supported and if walked on during concreting the cover will be less than specified.

Design books were available from the beginning of the 20th century for the majority of the reinforced concrete structures. These included Design of Arch Roofs in 1932, and Design of Domes in 1937 both by J.S. Terrington. The Analysis of Engineering Structures by A. J. S. Pippard and J. F. Baker published in 1936 took engineers through the design from first principles. With his European background Arup would have been familiar with the analysis from more innovative structures built in France, Germany and elsewhere. The majority of the structures at Dudley would have been designed following established principles. Special structures such as the entrance canopy roof slabs, the cantilevered slab to the bear enclosure and the ramps for the now demolished the penguin pool would have required analysis from first principles.

4. The Ove Arup/Tecton relationship

Ove Arup was born on the 16th April 1895 in Newcastle where his father was working as a consultant for the Danish government supervising the health of beef cattle. Within a year the family relocated to Hamburg where they lived for twelve years. Between 1907 and 1913 Ove was at a boarding school in Sorø in Denmark before studying philosophy and then engineering at the Polytekniske Læreanstalt in Copenhagen. Arup's approach from his time at the Polytekniske is summed up early in Peter Jones's biography; "Gropius's goal of unity and Le Corbusier's celebration of engineering provided the core and foundation of everything for which Ove subsequently campaigned." After graduating, his expertise in reinforced concrete led him to work for the Danish contractor, Christiani and Nielsen, initially in Hamburg then, by virtue of his British citizenship, to London in November 1923.

The construction industry in the UK during this period was dominated by the use of steelwork; a steel frame will be behind most of the brick or stone-clad elevations of buildings from the 1920s and 1930s. The influence from Europe of the Modern Movement was beginning to feature in the late 1920s with houses like High and Over in Amersham and was spurred by the arrival of émigré architects during the 1930s. One of the first to arrive was Berthold Lubetkin who was born on 14th December 1901 in Tbilisi, Georgia and had worked in Paris during the 1920s before arriving in London in 1931 where he set up Tecton.

An early Tecton commission, in 1933, for the Gorilla House at London Zoo led Lubetkin to Arup. Lubetkin had decided it should be constructed in reinforced concrete but without any experience of this in England he contacted the Paris office of Christiani and Nielsen. They referred him back to the Christiani and Nielsen office in London and to Ove Arup. The next collaboration was to be the eight-storey residential block, Highpoint in Highgate, north London. It seems that C+N was reluctant to tender for works that went beyond the reinforced concrete structure to include the internal finishes.

Around this time Arup was approached by Jorgen Lodz, another Dane, who with Olav Kier had set up the contractor Lodz and Kier which by 1932 was known as JL Kier & Co. Ltd. Their head office was in Stoke and they wanted Arup to become Chief Designer for a new office in London. Kier, lead by Arup won the tender for Highpoint in 1934. This was followed by projects such as the Penguin Pool at London Zoo where the detailed calculations for the spiral ramps were carried out by Felix Samuely. After Samuely left Kier the complex analysis was carried out by Ronald Jenkins who joined Kier in 1935 and it is likely he was involved at Dudley Zoo. In 1938 Arup with this cousin Arne set up Arup and Arup Ltd as civil engineering contractors. Ove N. Arup Consulting Engineers was formed in April 1946 and the Arup/Tecton collaboration continued after the war with buildings like the Spa Green Estate in London.

5. The Proposed Structural Repairs

A conservation-based approach to the structural repairs is proposed. This will include the design of repairs based on an understanding of the existing structures and their defects, the specification of compatible materials for repairs, and the reversibility of any repairs.

The repair of 20th century listed buildings follows the conservation principles of buildings from previous centuries but there are new challenges from the use of modern materials. These include whether to let the repairs 'read' as an intervention – in line with SPAB principles – or should the repair be a match to the surrounding material. In our work at the Barbican Art Centre the latter approach was adopted and trial repairs were carried out to determine the best concrete mix and finish to achieve a close match to the original concrete. A similar approach is likely to be the most successful here, both in terms of maintaining the architectural coherence and the presentation of the buildings to the public.

A key part of our role has been to identify whether the defects are due to decay to the materials (such as corrosion of the reinforcement) or the result of structural problems such as settlement or deflection. The majority of the problems are due to corrosion of the reinforcement and these are identified in the Rowan report. There are some specific structural problems and repairs to steel elements of the structures which are noted below.

5. The Entrance Canopy

5.1.1 The pattern of some of the longitudinal cracks in the concrete at roof level of the entrance canopy indicates some deflection of the curved slabs. The movement is likely to be historic and there are no signs of significant deformations to indicate that major remedial work is required.

2. There is corrosion to a number of the columns at ground level. These are solid circular sections, probably made from steel. Some investigation of the material and the loss of section below ground level are required and from this we can assess whether any remedial repairs are needed. The repair would likely be the addition of new steel sections which would be welded to the existing structure. All the steelwork will need to be prepared to remove loose rust, scale and paint, and then coated to prevent further corrosion. A summary of these repairs is shown on drawing EC 02.

1. Dudley Zoo Shop

5.2.1 There have been some internal changes to the original structure with the introduction of a steel columns and beam where one of the original columns has been removed. There are no obvious signs of any structural problems as a result of these changes. Repairs of the damaged concrete are proposed and as noted in the Rowan report.

2. Bear Ravine Kiosk

- 2.1. A repair is required to the corroded base of one of the circular hollow steel columns. This will involve the local breaking out around the base of the column and the welding of a new circular steel section as shown on drawings K 11 and K 12. All the steelwork will need to be prepared and then coated to prevent further corrosion. General repairs are required to the reinforced concrete structure.

3. The Bear Ravine

- 3.1. The diagonal cracks above the entrances to the bear dens may indicate some settlement of the foundations. We understand that remedial work was carried out nearby following the collapse of a disused mine. A trial pit has been dug as part of an initial investigation of this area. Further investigations will follow as part of the design development stage.
- 3.2. A number of the circular hollow section steel columns are in a very poor condition. Some have previously failed and we issued a drawing for temporary support works which was installed after our first visit. New steel columns to match the existing will be used for the repair.
- 3.3. The main item of structural work is to the cantilevered viewing platform. This is in a very poor condition with extensive corrosion and spalling of concrete. The approach here is to deal with the main structural decay issues and add new reinforcement to enhance the performance of the existing structure. It is feasible to carry out these remedial works without any significant change to the visual appearance of the bear ravine.
- 3.4. The structure is formed by a thin, approximately 120mm thick, reinforced concrete slab with a 130mm wide reinforced concrete parapet. From the pattern of the cracks it appears that the slab was designed to span between the parapet walls which are then anchored to the main structure. This is summarised on drawing B 02.
- 3.5. Structural stiffening is required together with traditional concrete repairs. The structural stiffening will involve the removal of all the damaged concrete and reinforcement to the parapet. New steel reinforcement will be installed which will be anchored to the walls at each side of the balcony. The parapet bars will be tied to new reinforcement added to stiffen the slab. A summary of the proposed works is shown on drawing B 03.

6. Literature references

Cassell's Reinforced Concrete. Edited by Bernard E. Jones. The Waverley Book Company Limited, London. 1920

Historic Concrete: Background to appraisal. Edited by James Sutherland, Dawn Humm and Mike Chrimes. Thomas Telford Limited. 2001

Code of Practice for the use of Reinforced Concrete in the Construction of Buildings. April 1942

Report of the Reinforced Concrete Structures Committee of the Building Research Board with recommendations for a Code of Practice for the Use of reinforced concrete in buildings. HMSO. 1933

Ove Arup 1895-1988. Published by the Institution of Civil Engineers, 1995

Ove Arup, Masterbuilder of the twentieth century. Peter Jones. Yale University Press. 2006

Appendix A

Photographs taken during 2011

The Entrance Canopy



Top of roof slab



Longitudinal crack in top of roof slab



Underside of roof slab



Corroded reinforcement and spalled concrete to underside of roof slab



The close centres of reinforcement bars indicate a beam strip in the slab

Dudley Zoo Shop



Additional steel beam and columns



Additional steel frame where a reinforced concrete column has been removed



Spalled concrete edge beam at roof level

Bear Ravine Kiosk



General view



Corrosion to bars in roof slab around top of posts



Base of steel post has completely corroded



Corrosion to steel post at reinforcement in counter

The Bear Ravine



General view showing cantilevered viewing platform



Extensive corrosion to parapet wall which supports and anchors the cantilevered viewing platform



Corrosion to parapet wall to high level walkway



Failure of steel posts supporting stair landing
(before temporary support was installed)

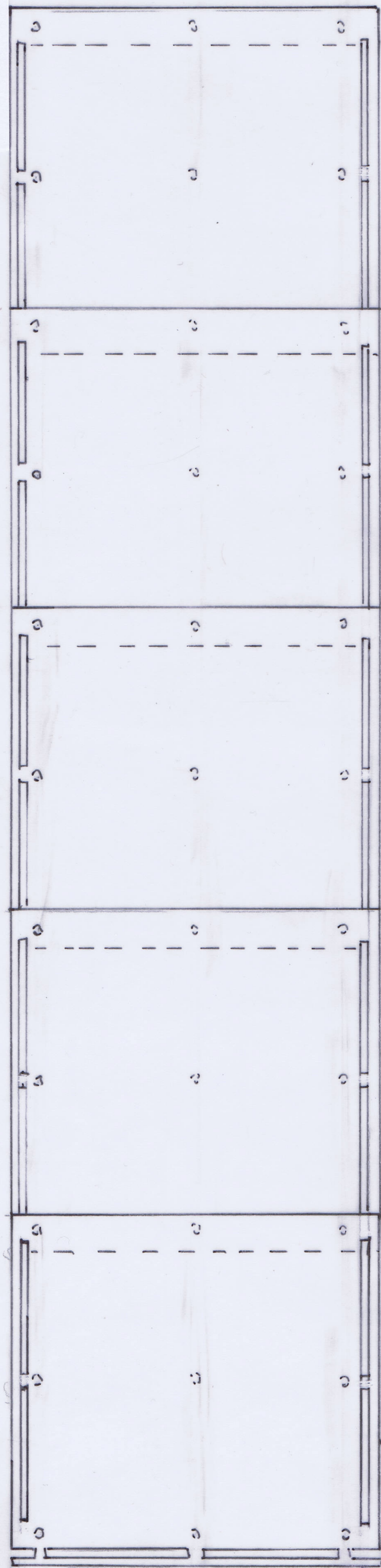


End pier provides vertical support and restraint against lateral loads & Corrosion to end pier



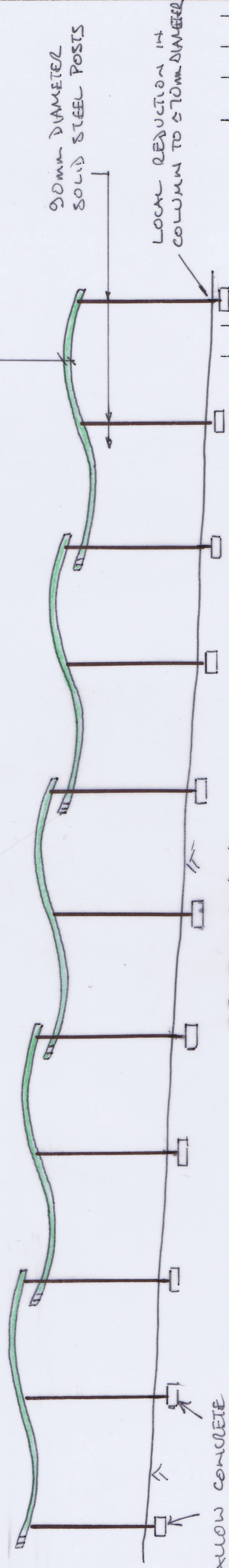
Appendix B

Structural Drawings



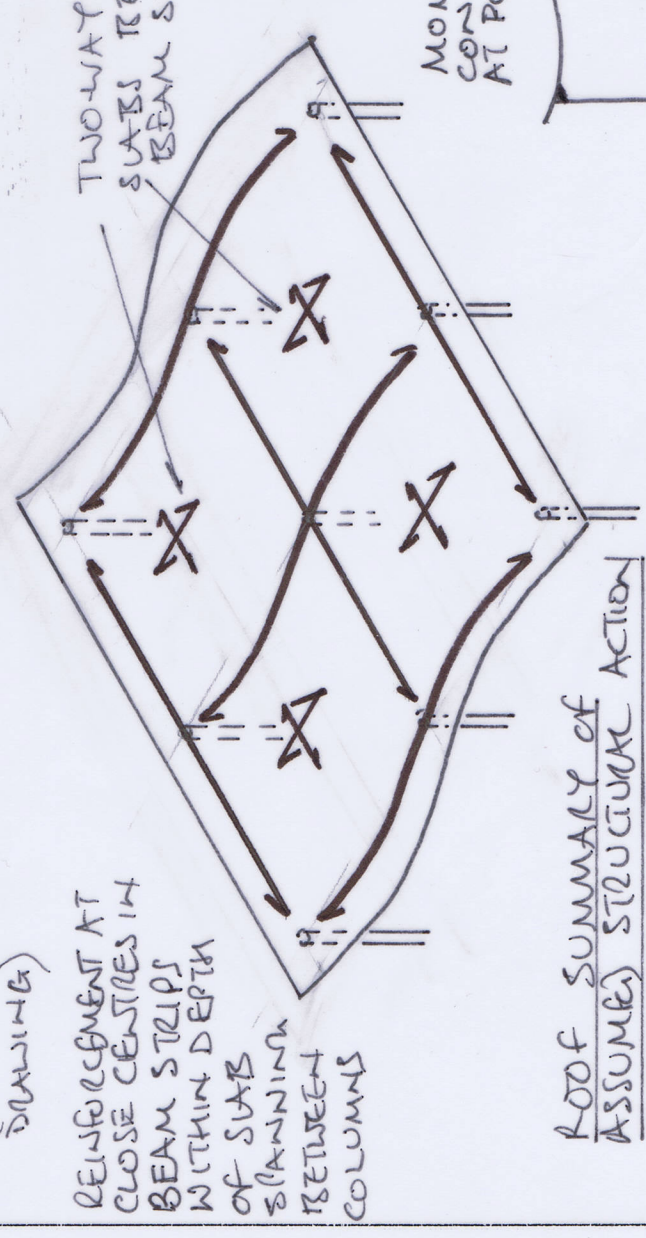
ROOF PLAN

FASCIA BEAMS
CAST WITH MAIN
ROOF SLABS



SECTION A-A

SHALLOW CONCRETE
STRIP FOOTINGS
(BASED ON ORIGINAL
DRAWING)

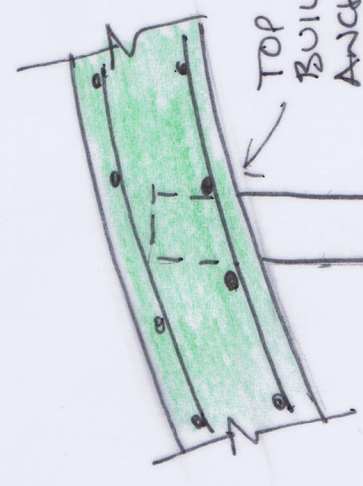


REINFORCEMENT AT
CLOSE CENTRES IN
BEAM STRIPS
WITHIN DEPTH
OF SLAB
SPANNING
BETWEEN
COLUMNS

TWO-WAY SPANNING
SLABS BETWEEN
BEAM STRIPS

MOMENT
CONNECTIONS
AT POST/SLABS

ROOF SUMMARY OF
ASSUMED STRUCTURAL ACTION



POST/SLAB DETAIL (1:10)

STRUCTURAL SUMMARY

REV	DESCRIPTION	DATE	BY	AUTH
P1	DOCUMENT BUDGET	28.9.01		

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PROJECT DUDLEY 200

TITLE
ENTRANCE CANOPY
SUMMARY OF
EXISTING STRUCTURE

DRAWN	AUTHORISED	SCALE	DATE	STAGE
81		1:100	27.9.01	
PROJECT NO.	DRAWING NO.	REV		
300	EC-01	P1		

SEE ALSO HALLLOW/LOWAN REPORTS
 FOR AREAS OF CONCRETE REPAIR

NEW WATERPROOF FINISH

ALLOW FOR WORK
 REMOVAL OF CONCRETE
 ON LONGITUDINAL
 CRACKS TO CONFIRM
 REPAIRS

ALLOW FOR BREAKING
 OUT CONCRETE AROUND
 TWO POSTS TO EXPOSE
 REINFORCEMENT

CONCRETE REPAIR
 WHERE CORRODED BARS
 SPALLING CONCRETE

CLEAN POSTS TO REMOVE
 ALL PAINT, RUST & SCALE

BREAK OUT CONCRETE
 TO CONFIRM DEPTH +
 CONDITION OF POSTS

DIG TRAP TO
 CONFIRM DEPTH OF
 FOOTING + GROUND

SECTION THRU POST
 SHOWING INVESTIGATION
 & INDICATIVE REPAIRS

SPICES WELDED TO
 BASE OF POSTS

POSTS & SPICES
 PAINTED WITH
 ANTI-CORROSION
 COATING &
 FINISH COAT

FINISHES
 REINSTATED

CONCRETE
 BREAK OUT
 TO BASE OF
 POST &
 REINSTATE
 ON COMPLETION
 OF SPICE

SPICE FORMED OF
 SPLIT CHS & WELDED
 BASE PLATE

SECTION THRU BASE OF POST
 SHOWING INDICATIVE REPAIR

REV	DESCRIPTION	DATE	BY	AUTH
P1	FOR COMMENT & BURET	28.9	ST	

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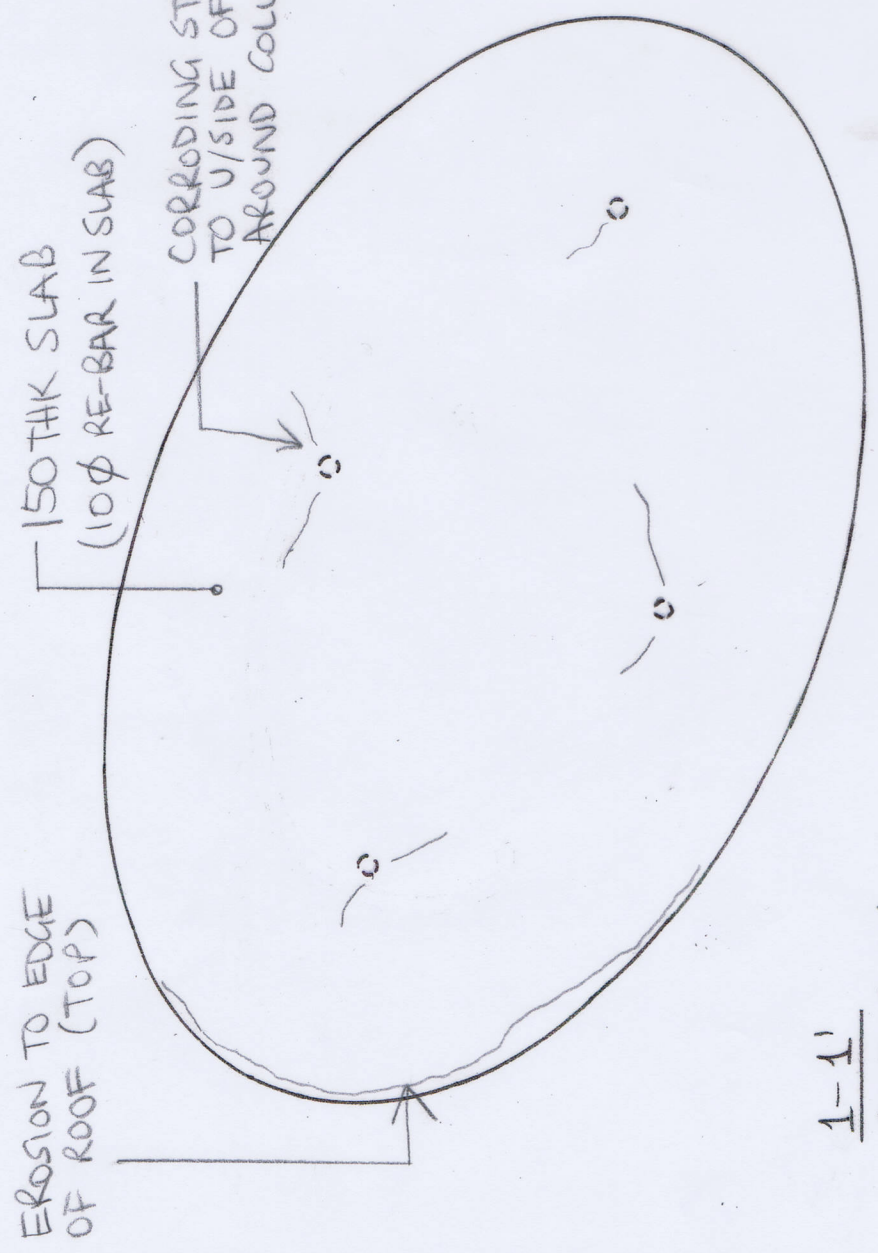
PROJECT

DUDLEY ZOO

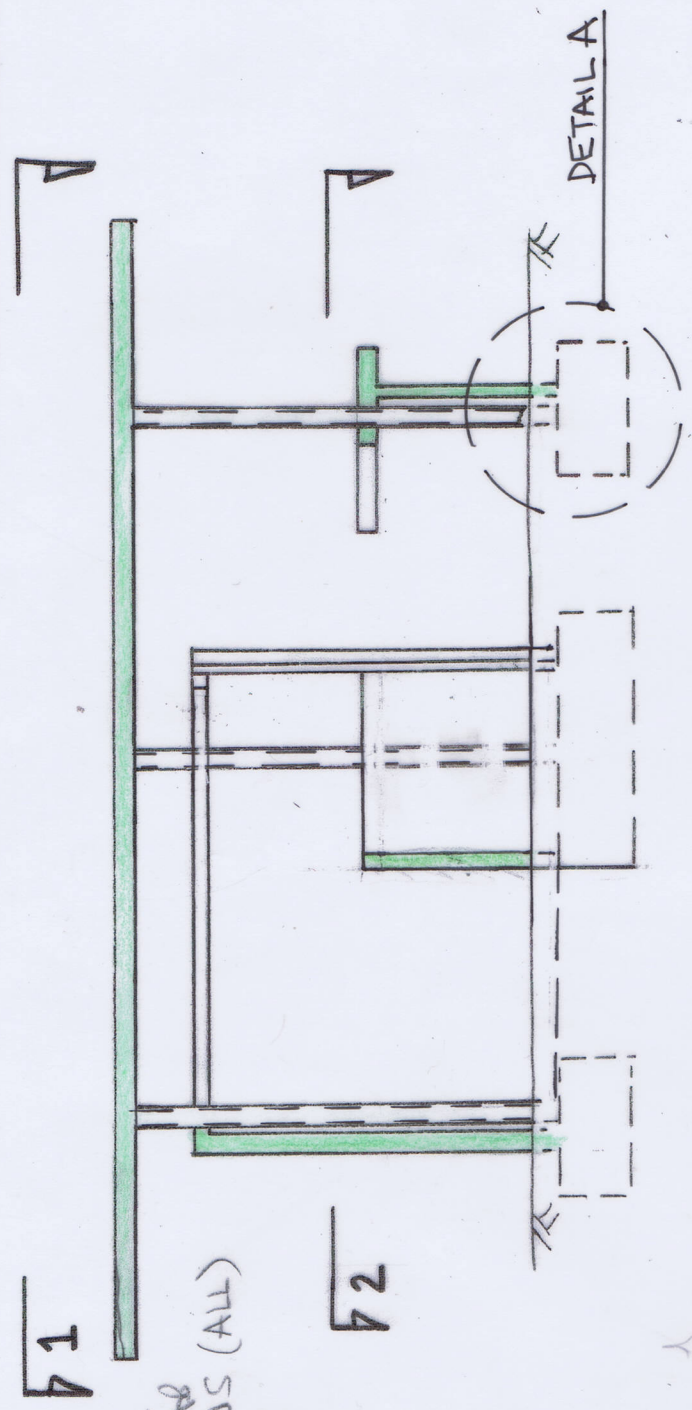
TITLE

ENTRANCE CANOPY
 SUMMARY OF STRUCTURAL
 REPAIRS

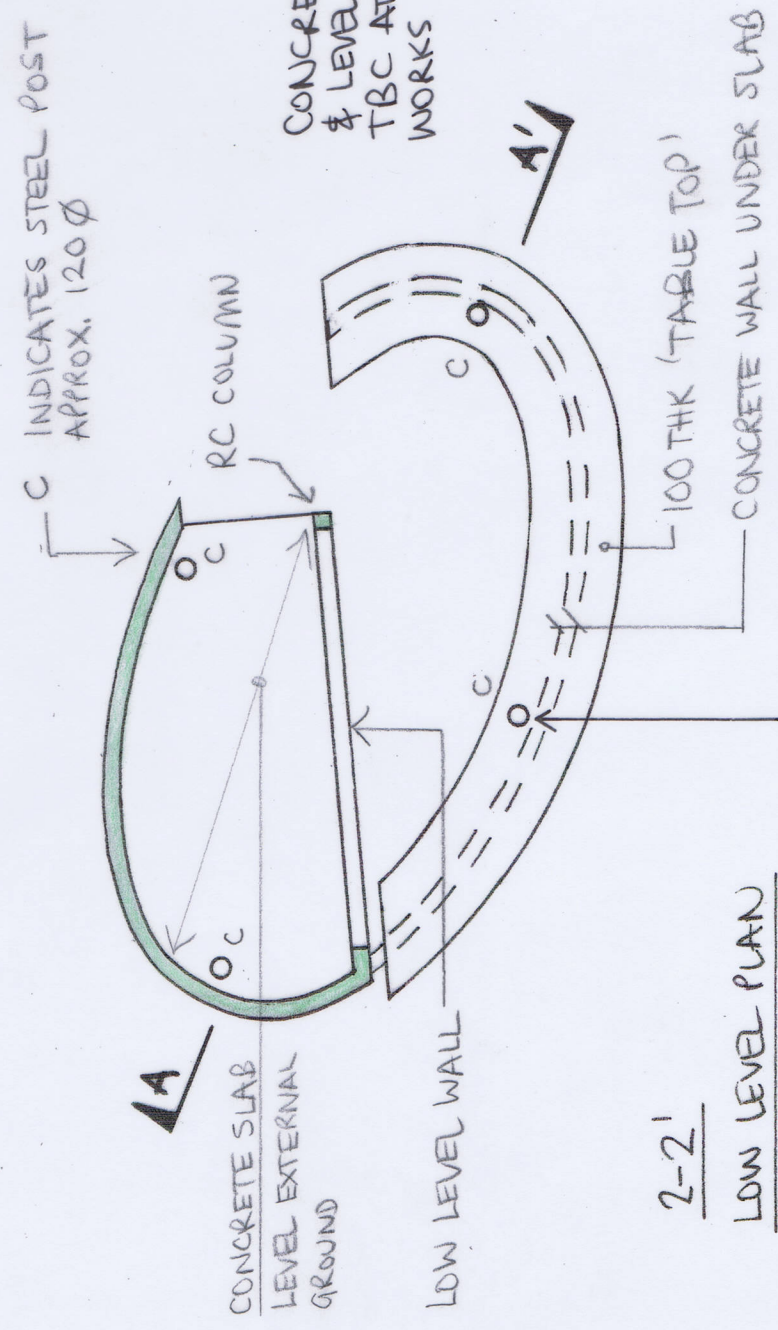
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PROJECT NO.	DRAWING NO.	REV		
300	EC 02	P1		



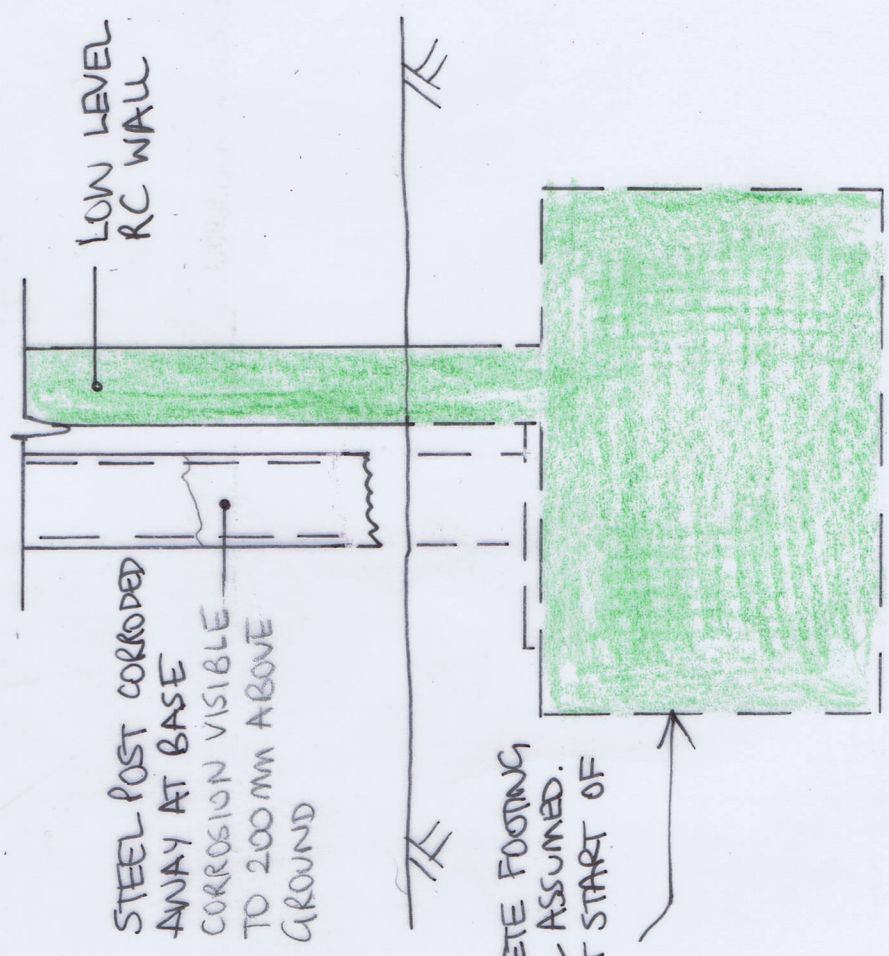
1-1'
 ROOF PLAN



SECTION A-A'



2-2'
 LOW LEVEL PLAN



DETAIL A (1=10)

REV	DESCRIPTION	DATE	BY	AUTH
P1	ISSUED FOR COMMENTS	6/9	AW	ST

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DUDLEY ZOO

DRAWN AW		AUTHORISED ST	SCALE 1=50	DATE Sep 11	STAGE
PROJECT NO. 300		DRAWING NO. K01		REV P1	

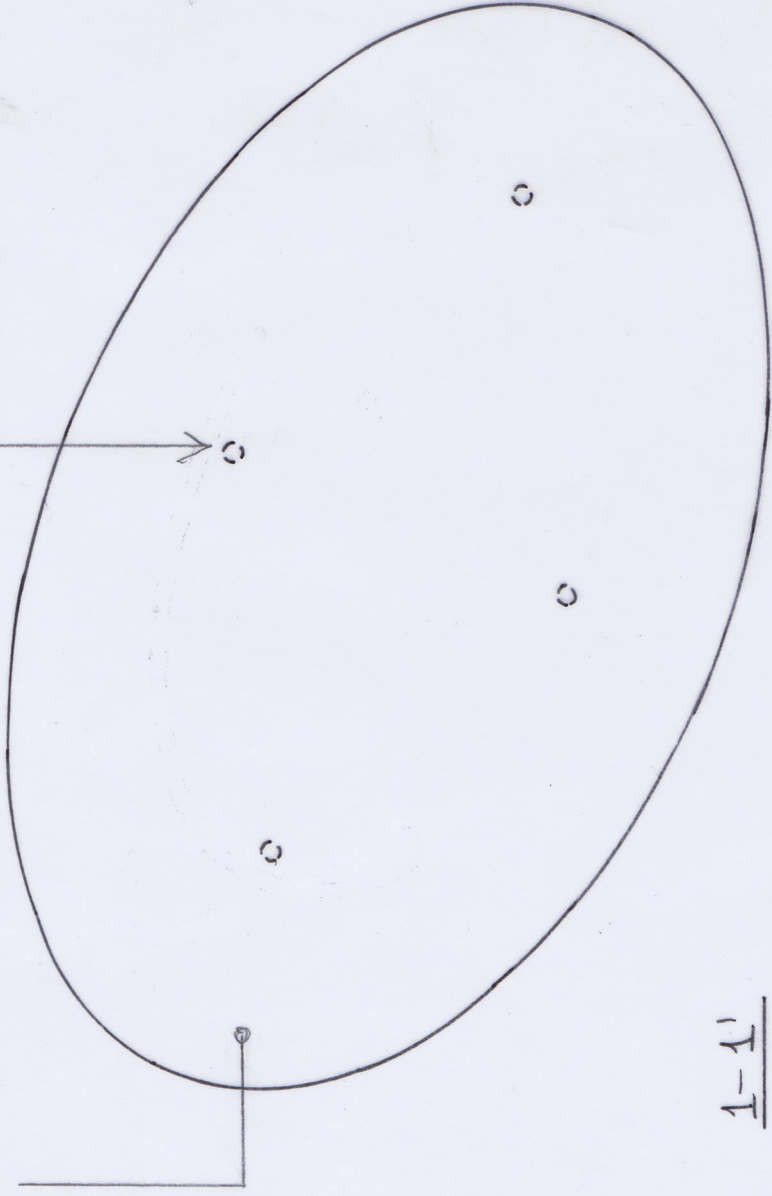
**KIOSK 1 (EAST OF BEAR
 RAVINE)
 EXISTING STRUCTURE**

REPAIR TO ROOF SLAB

ERODED AREA CUT BACK
CONCRETE REPAIR TO REINSTATE
ORIGINAL PROFILE

REPAIR AROUND COLUMN

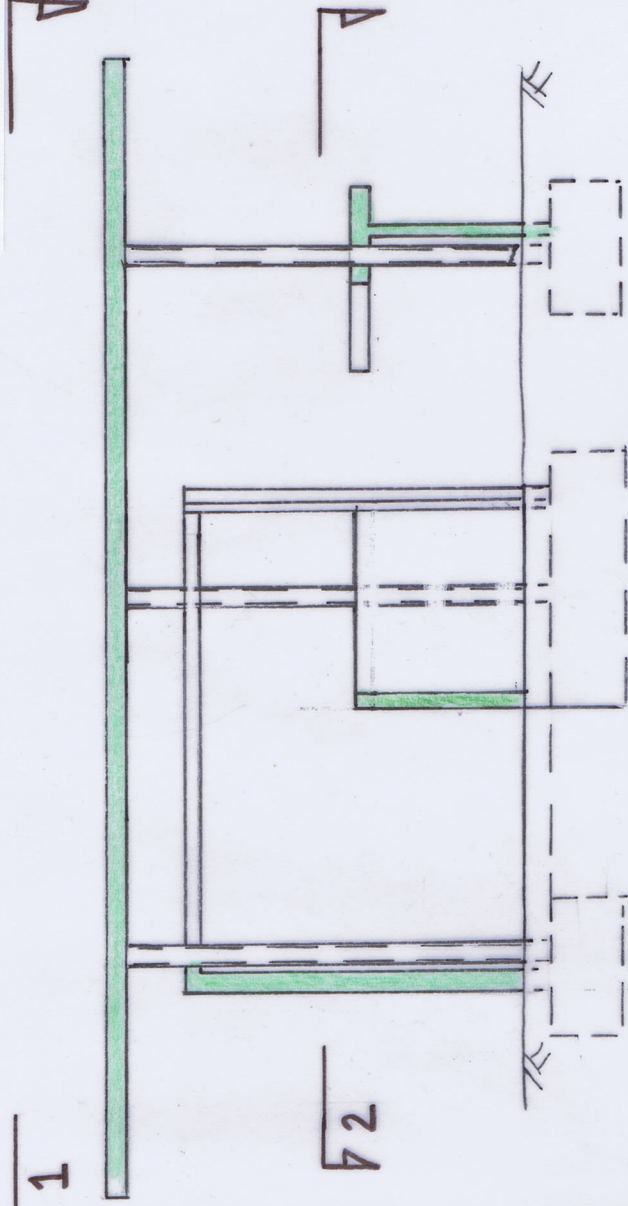
CORRODED STEEL CLEANED,
TREATED & COVER WITH
CONCRETE REPAIR



1-1'
ROOF PLAN

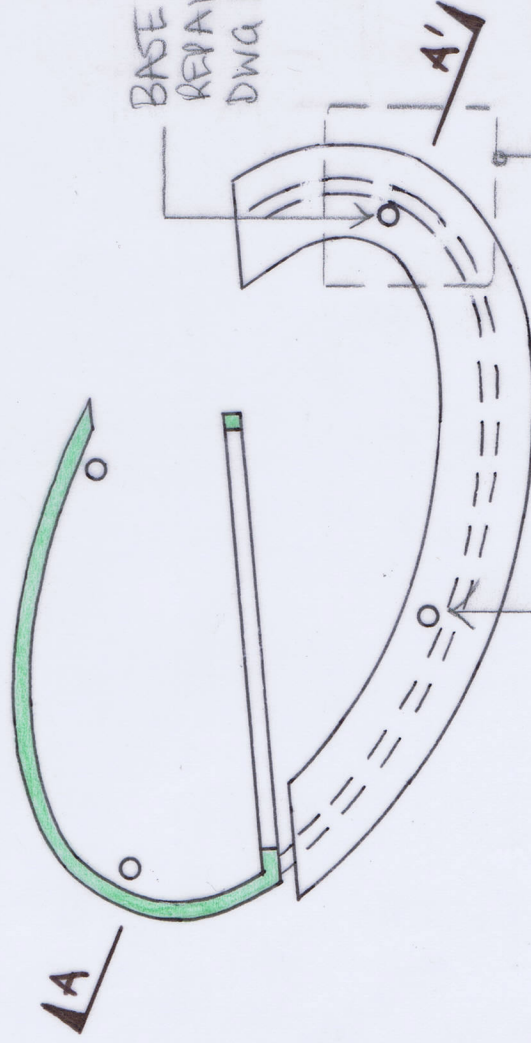
1

2



SECTION A-A'

PAIN TO BE REMOVED IN ALL STEEL
COLUMNS & GRIT BLASTED TO SOUND
METAL - FINAL DETAILS TBC FOLLOWING
INVESTIGATIONS



2-2'

LOW LEVEL PLAN

BASE OF EXIST. COLUMN
REPAIRED TO DETAILS TO
DWG K12

DETAIL TO DWG K12
PLAN A

ALLOW FOR CUT BACK OF EXIST. COLUMN 200MM ABOVE LEVEL OF
'TABLE TOP'. PROVIDE NEW SECTION WITH DETAILS SIMILAR TO DWG K12.

REV	DESCRIPTION	DATE	BY	AUTH
P1	ISSUED FOR COMMENT	6/9	AW	ST

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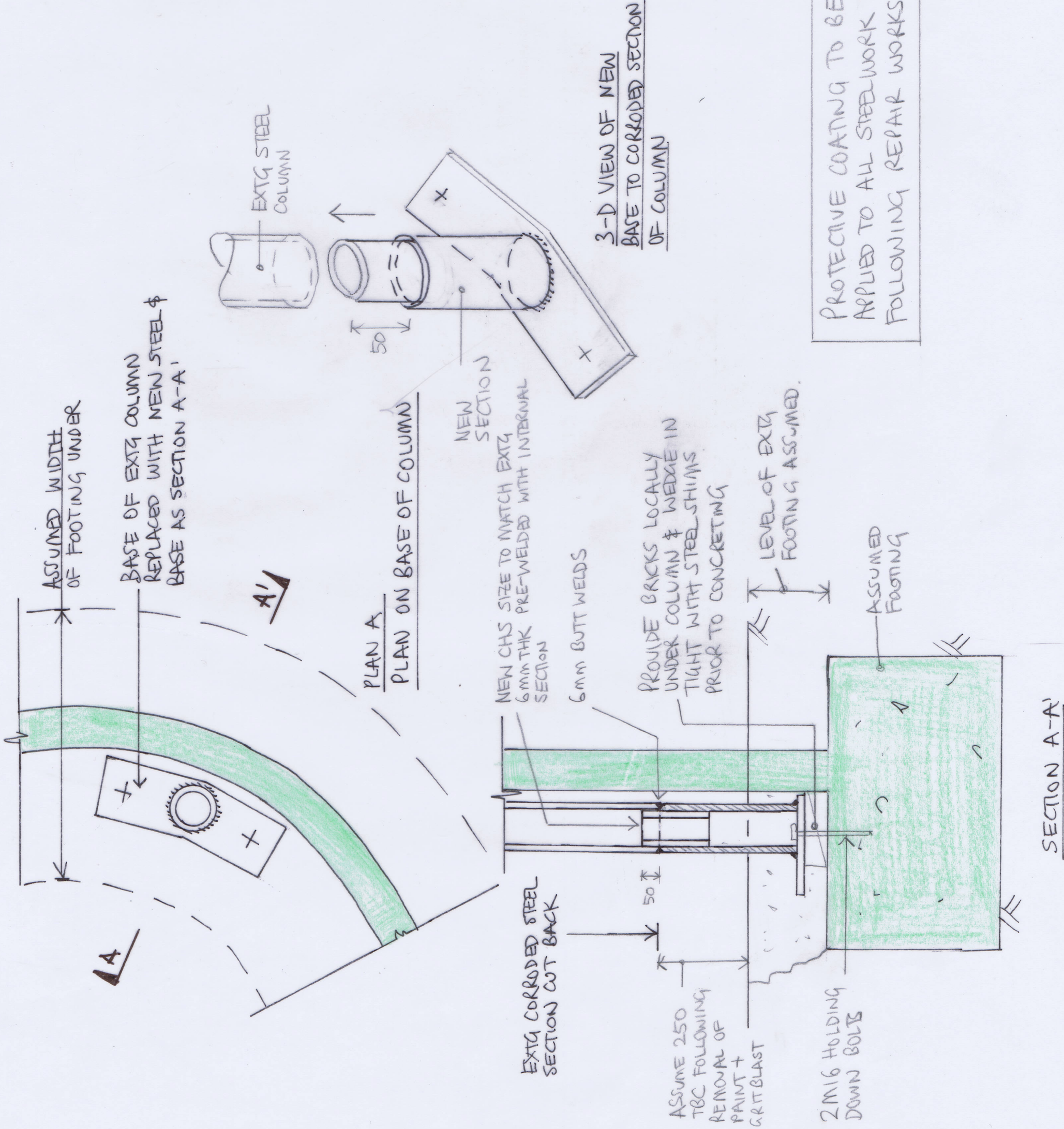
PROJECT
DUDLEY ZOO

TITLE

**KIOSK 1 (EAST OF BEAR
RAVINE)**

PROPOSED STRUCTURE

DRAWN	AUTHORISED	SCALE	DATE	STAGE
AW	ST	1:50	Sep 11	
PROJECT NO.	DRAWING NO.	REV	REV	REV
300	K11			P1



REV	DESCRIPTION	DATE	BY	AUTH
P1	ISSUED FOR COMMENTS	6/9	AW	ST

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PROJECT

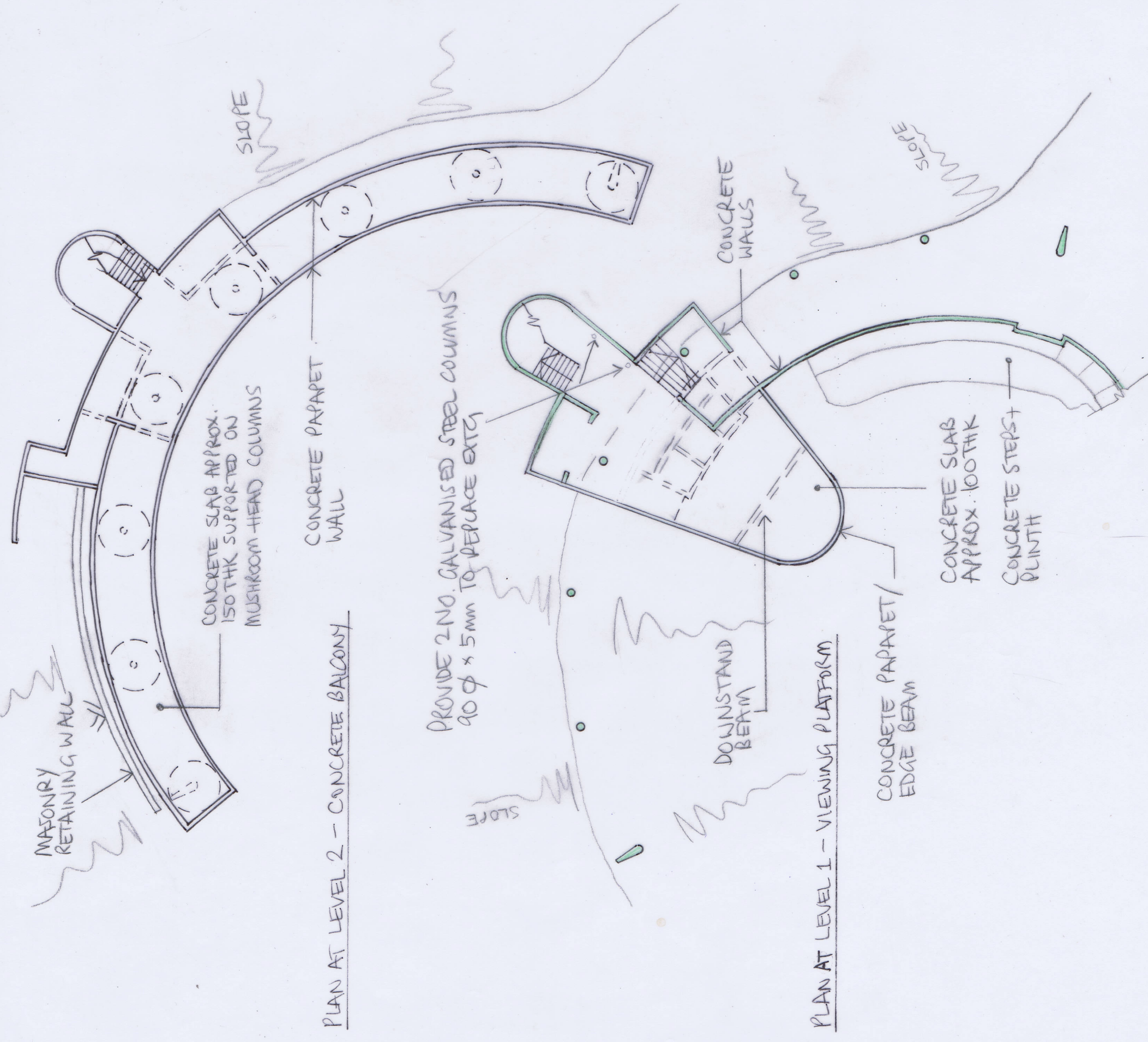
DUDLEY 200

TITLE

KIOSK 1

PROPOSED REPAIR DETAILS

DRAWN	AUTHORISED	SCALE	DATE	STAGE
AW	ST	1:50	SEP 11	
PROJECT NO.	DRAWING NO.	REV	REV	REV
300	K12			P1



LEVEL 2

LEVEL 1

KEY SECTION

REFER TO ROWAN REPORT FOR EXTENT OF CONCRETE REPAIR IN GENERAL

DWG B02 SUMMARISES STRUCTURAL PRINCIPLES OF VIEWING PLATFORM & EXTRA CRACKS

REFER TO DWG B03 FOR STRUCTURAL REPAIRS & ADDITIONAL REINFORCEMENTS

REV	DESCRIPTION	DATE	BY	AUTH
01	FOR COMMENT	23-9		

Stand Consulting Engineers

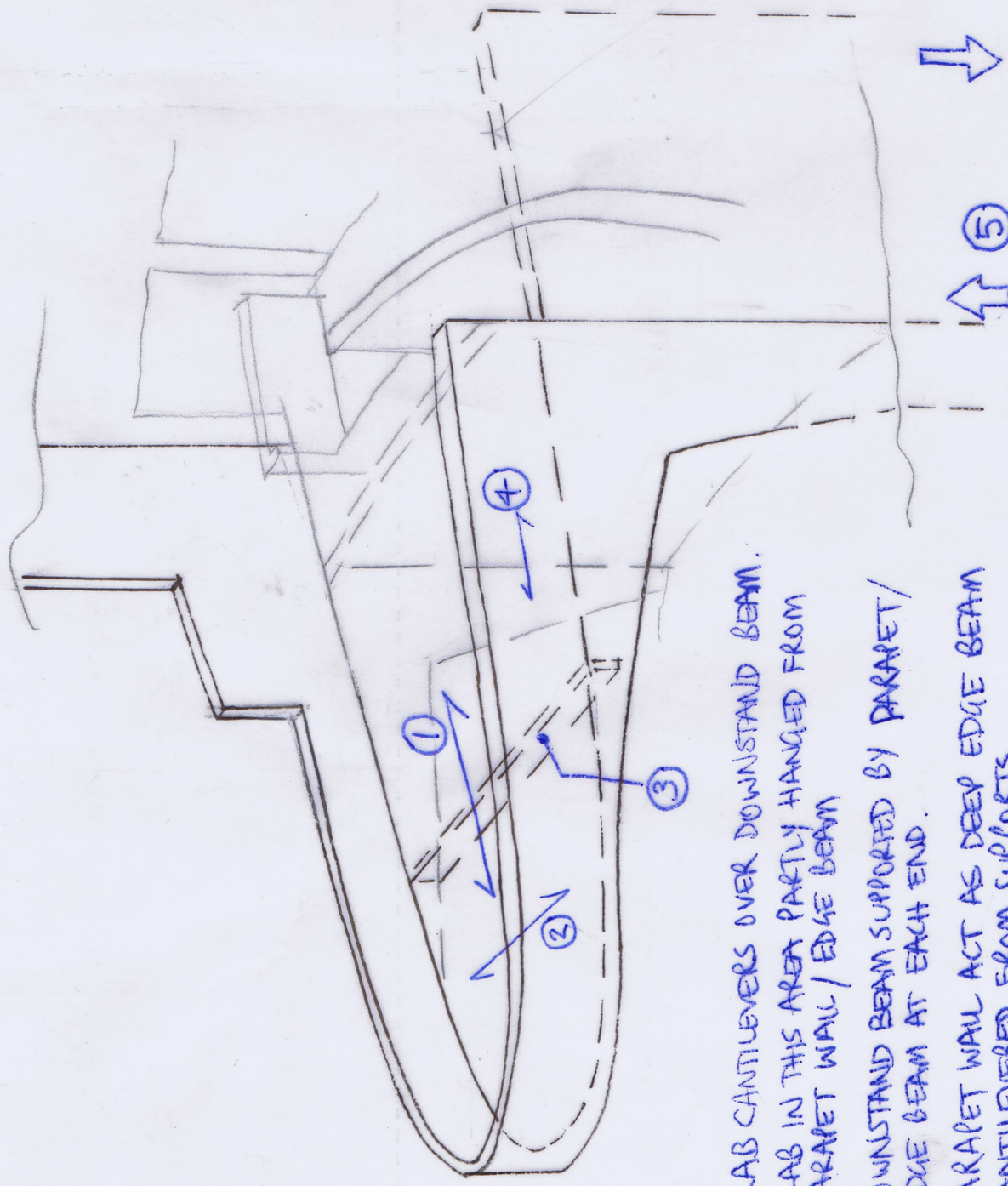
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DUDLEY ZOO
 BEAR RAVINE

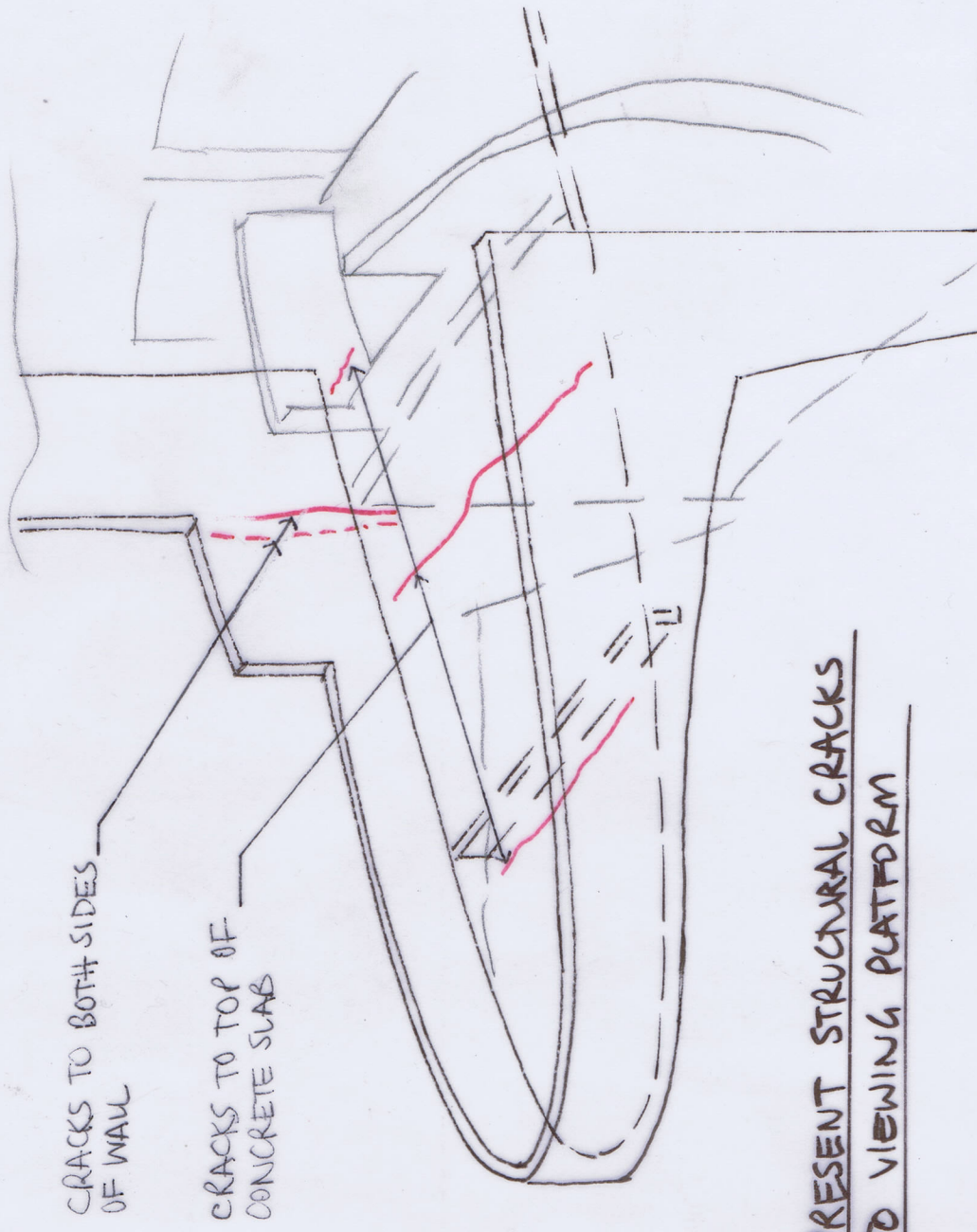
TITLE
 EXISTING STRUCTURE

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PROJECT NO.	DRAWING NO.	REV		
300	B01	P1		



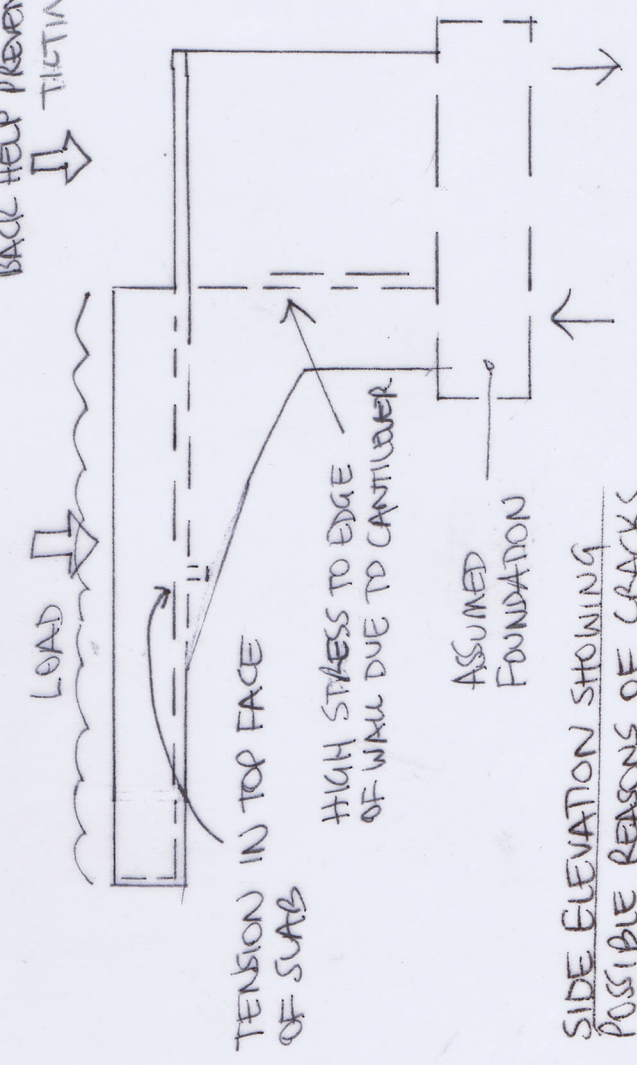
- ① SLAB CANTILEVERS OVER DOWNSTAND BEAM.
- ② SLAB IN THIS AREA PARTLY HANGED FROM PARAPET WALL / EDGE BEAM
- ③ DOWNSTAND BEAM SUPPORTED BY PARAPET / EDGE BEAM AT EACH END.
- ④ PARAPET WALL ACT AS DEEP EDGE BEAM CANTILEVERED FROM SUPPORTS.
- ⑤ FOUNDATION WITH PUSH-PULL ACTION TO PREVENT STRUCTURE FROM TILTING FORWARD.

3-D VIEW OF VIEWING PLATFORM SHOWING SUMMARY OF ASSUMED STRUCTURAL ACTION



PRESENT STRUCTURAL CRACKS TO VIEWING PLATFORM

LOAD TOWARDS THE BACK HELP PREVENT TILTING



SIDE ELEVATION SHOWING POSSIBLE REASONS OF CRACKS

REV	DESCRIPTION	DATE	BY	AUTH
P1	RECOMMENT	23.9		

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DUDLEY ZOO
BEAR RAVINE

STRUCTURAL SUMMARY

DRAWN	AUTHORISED	SCALE	DATE	STAGE
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PROJECT NO.	DRAWING NO.	REV		
300	B02	P1		

END WALL

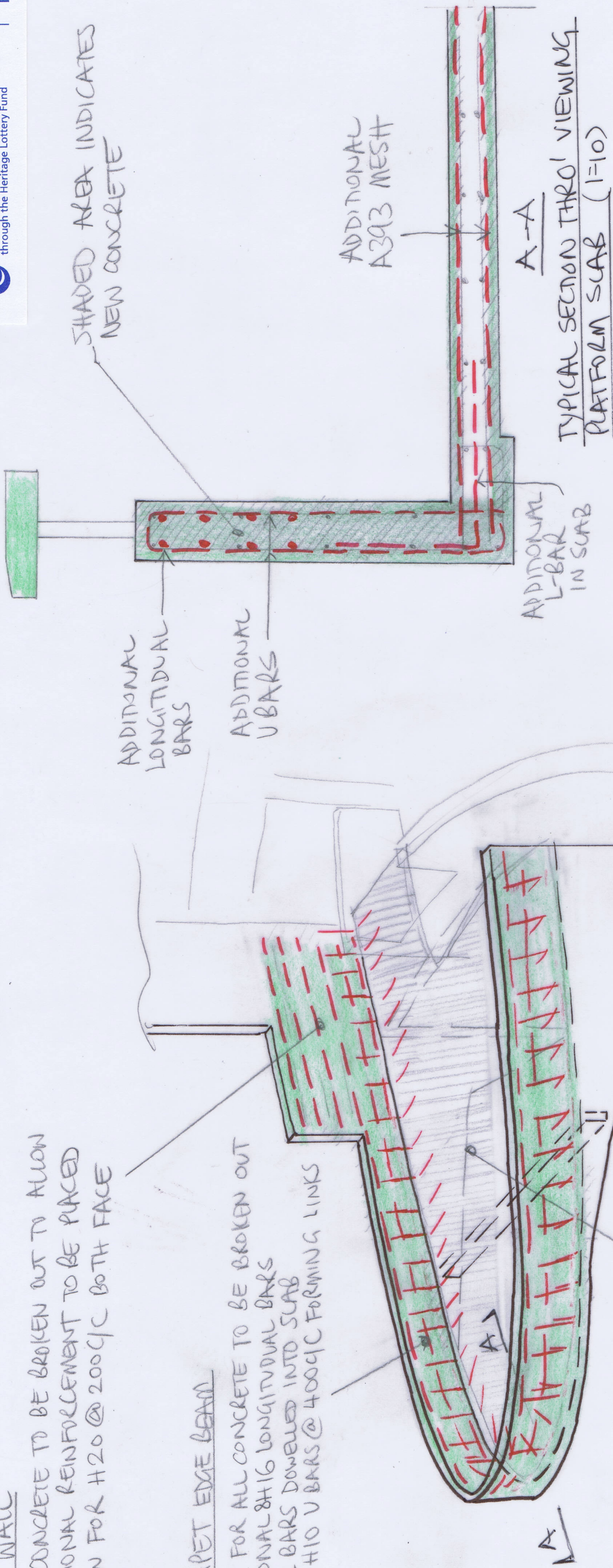
ALL CONCRETE TO BE BROKEN OUT TO ALLOW
 ADDITIONAL REINFORCEMENT TO BE PLACED
 ALLOW FOR H20 @ 200/C BOTH FACE

PARAPET EDGE BEAM

ALLOW FOR ALL CONCRETE TO BE BROKEN OUT
 ADDITIONAL 8#16 LONGITUDINAL BARS
 #16 L BARS DOWELLED INTO SLAB
 2 NO #10 V BARS @ 400/C FORMING LINKS

CONCRETE SLAB

TOP & BOTTOM OF SLAB SCABBLE BACK
 PROVIDE 1 LAYER A393 MESH OVER ENTIRE
 SLAB AREA TOP + BOTTOM



REV	DESCRIPTION	DATE	BY	AUTH
1	FOR COMMENT	23-9	ST	

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DUDLEY ZOO

BEAR RAVINE

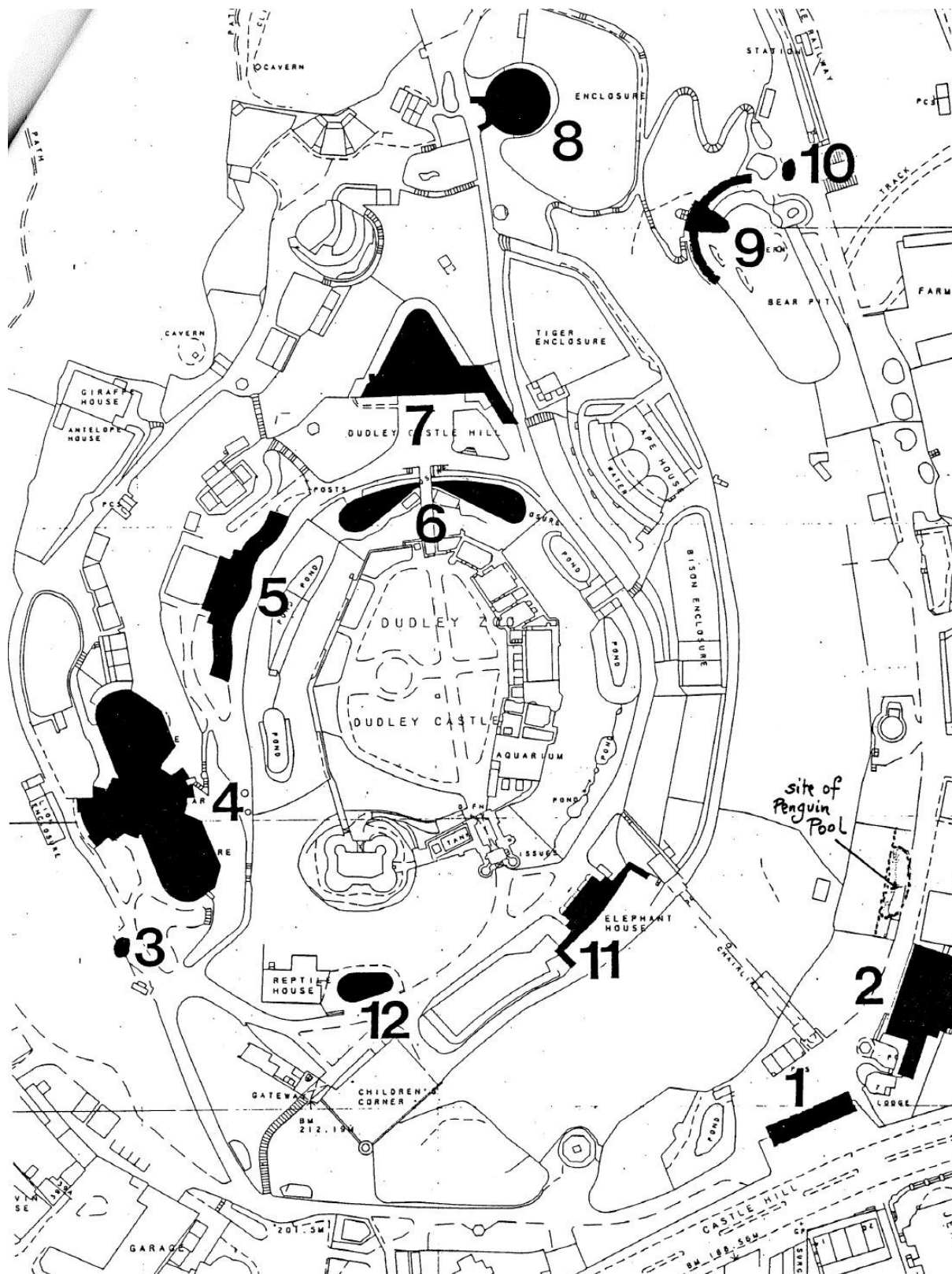
**STRUCTURAL REPAIRS
 DETAILS**

DRAWN	AUTHORISED	SCALE	DATE	STAGE
AW	ST	AS NOTED	SEP 11	
PROJECT NO.	DRAWING NO.	REV		
300	B03	P1		

THE PROPOSED STRUCTURAL REPAIR SHOWN ON THIS DWG WAS DEVELOPED
 BASED ON LIMITED INFORMATION & ASSUMPTIONS ON THE % & CONDITIONS OF
 THE EXISTING REINFORCEMENT.
 THE DETAILS SHOWN ARE PRELIMINARY & FOR ESTIMATION PURPOSES ONLY
 FURTHER INVESTIGATIONS ARE REQUIRED IN DUE COURSE

Appendix C

Summary of our brief structural engineering comments
on all 13 Tecton Structures



Key plan of the Tecton structures at Dudley Zoo

Identifier:	Tecton 1
Building name:	Entrance
Listing:	II*
	
Original use:	Entrance, ticket control cabins & turnstiles
Current use:	As original
Has it been altered:	No
Description of the structure:	Five single storey masonry buildings form the ticket control cabins and turnstiles with five overlapping “S” shaped reinforced concrete roof slabs (7” thick), each supported on 9 no. solid 90mm diameter steel posts, which are independent to the masonry buildings. The steel columns vary in heights between 3.0m and 3.3m.
Comments on the structure:	• The masonry structure is in a reasonable condition • There are signs of weathering of finishes to the top of the concrete roof slabs. • There are cracks to the top surface near the centre of each roof slab. • There is corrosion to reinforcement to the underside of the roof slabs. The exposed reinforcements are at close but irregular centres • Corrosion is evident to the base of a number of the steel columns up to 200mm above ground level.
Investigations required:	Trial pit dug and paint to be removed towards the base of all columns to check degree of corrosion. Samples taken to confirm metallurgy.
Structural works required:	• Corrosion to base of columns; cut back to sound metal and repaired with new steel base onto existing footings and protective coating applied to all columns. • Exposed reinforcement to be cleaned, treated and concrete repaired. • All cracks repaired

Identifier:	Tecton 2
Building name:	Safari shop (former Station cafe)
Listing:	II
	
Original use:	Self-serviced cafeteria with rear servicing and kitchens
Current use:	shop
Has it been altered:	Extensively altered – separated into two spaces in 1965
Description of the structure:	Rectangular reinforced concrete structure with circular columns spaced at regular intervals. There is an additional non-original structure to the rear with a basement (following the slope of ground). Internal alterations had been carried out with steel beams and steel columns in both the shop and store rooms to increase column spacing.
Comments on the structure:	• One RC beam is propped in the store area. • There is a vertical crack in the fascia beam due to shrinkage or thermal movement.
Investigations required:	
Structural works required:	Corrosion repairs

Identifier:	Tecton 3
Building name:	Kiosk 2 (south of polar bear pit)
Listing:	II
	
Original use:	Serving refreshments
Current use:	Not in use
Has it been altered:	No
Description of the structure:	Elliptical reinforced concrete structure supported on four hollow steel columns. The structure has an integrated "table top" and curved walls.
Comments on the structure:	The structure appears to be in good condition. The structure had been recently repaired and painted.
Investigations required:	Not part of the current works
Structural works required:	Not part of the current works

Identifier:	Tecton 4
Building name:	Polar bear, lion & Tiger Ravine & separate W.C.
Listing:	II*
	
Original use:	Polar bear, lion & Tiger Ravine & separate w.c.
Current use:	Animal enclosure
Has it been altered:	No
Description of the structure:	Circular pit with pool, ramps, retaining walls, galleries, parapets & steps
Comments on the structure:	The structure had been recently repaired and painted.
Investigations required:	Not part of the current works
Structural works required:	Not part of the current works

Identifier:	Tecton 5
Building name:	Cafe No. 2 (Moat)
Listing:	II
	
Original use:	Cafeteria & kitchen
Current use:	Educational building/ discovery centre
Has it been altered:	Originally the building was open; the front elevation is now enclosed with glazing.
Description of the structure:	Long, serpentine, single-storey structure to the front with mullion and transom glazing & two storeys structure at rear.
Comments on the structure:	No visual structure defects to the front or internal area. The rear structure is in poor condition with spalling of concrete to different parts.
Investigations required:	Not part of the current works. Extensive investigations are recommended to be carried out by Concrete Specialist.
Structural works required:	Not part of the current works. To be confirmed following detailed concrete survey.

Identifier:	Tecton 6
Building name:	Sea lion pool
Listing:	II
	
Original use:	
Current use:	As original
Has it been altered:	
Description of the structure:	A pair of shaped pools connected under the bridge to the castle, with retaining walls, viewing platform and shaped shelves
Comments on the structure:	Evident of erosion to cast edge of “viewing balcony” retaining wall to the rear.
Investigations required:	Not part of the current works
Structural works required:	Not part of the current works

Identifier:	Tecton 7
Building name:	Queen Mary (castle) restaurant
Listing:	II
	
Original use:	restaurant
Current use:	As original
Has it been altered:	No
Description of the structure:	Single-storey triangular open-plan reinforced concrete structure.
Comments on the structure:	Some corrosion to the entrance area
Investigations required:	Not part of the current works
Structural works required:	Not part of the current works

Identifier:	Tecton 8
Building name:	Tropical bird house (Aviary)
Listing:	II
	
Original use:	Bird house
Current use:	Not in use
Has it been altered:	Yes. 3 columns added to support centre of roof
Description of the structure:	Circular building of 2 storeys with balcony supported on concrete columns. Canopies etc to upper part. Lower part has been altered to form bison house
Comments on the structure:	Some areas of corrosion to steel reinforcement and columns.
Investigations required:	Not part of the current works
Structural works required:	Not part of the current works

Identifier:	Tecton 9
Building name:	Bear Ravine
Listing:	II*
	
Original use:	
Current use:	Not in use
Has it been altered:	
Description of the structure:	Substantial structure with shaped retaining wall against the hill behind. Cantilevered balcony and upper terrace supported on mushroom columns. Steps, ramps etc
Comments on the structure:	Refer to main report
Investigations required:	Refer to main report
Structural works required:	Refer to main report

Identifier:	Tecton 10
Building name:	Kiosk 1 (East of Bear Ravine)
Listing:	II*
	
Original use:	For serving refreshments
Current use:	Not in use
Has it been altered:	
Description of the structure:	Circular hollow steel columns support a flat reinforced concrete roof slab. Curved reinforced concrete wall and counter.
Comments on the structure:	Refer to main report
Investigations required:	Refer to main report
Structural works required:	Refer to main report

Identifier:	Tecton 11
Building name:	Elephant house
Listing:	II
	
Original use:	To house elephants
Current use:	Not in use
Has it been altered:	?
Description of the structure:	Single-storey concrete structure with two flanking staircases. The roof forms a terrace on two levels. The lower tier terrace extends in a shallow curve and cantilevers over the columns. The rear wall forms a retaining structure to the hillside
Comments on the structure:	The structure appears to be in a reasonable condition. The structure had been recently repaired and re-painted.
Investigations required:	Not part of the current works
Structural works required:	Not part of the current works

Identifier:	Tecton 12
Building name:	Reptiliary
Listing:	II
	
Original use:	To house reptiles
Current use:	To house meerkats
Has it been altered:	
Description of the structure:	Concrete. Low wall surrounding double apse ended pit, and supporting concrete shelf. Wall dips to north side where horizontal tubular metal bar is inset
Comments on the structure:	Parts of the wall around the enclosure are in a poor condition.
Investigations required:	Not part of the current works
Structural works required:	Not part of the current works