

STRUCTURAL REPORT

**Moat Bridge
Devizes Castle
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1.0. Introduction

The Consultants were appointed by Kayne Howes of Gardiner and Theobald, 10 South Crescent, London, WC1E 7BD, on behalf of the owner Kazuhiko Akao, to carry out a structural survey and prepare a report on the bridge which crosses the moat at Devizes Castle, Castle Road, Devizes, Wiltshire, SN10 1HL,. The purpose of this report is to comment on the current structural condition and recommend any repair works which may be required. The moat bridge is located on the southern driveway of the castle and a general view of the east elevation of the moat bridge is shown on photograph No. 1.

We have not inspected any area which was covered, inaccessible or unexposed and we are therefore unable to report that any such part is free from defect.



Photograph No. 1

2.0. Survey

The bridge is constructed in multiple phases from mostly stonework but some brickwork, it spans north to south and has a central brickwork barrel vault. The bridge was originally narrower but was widened on the eastern side to allow vehicle access. There are five chambers in the abutments, one in each corner but two in the north-western corner.

2.1. Deck

A general view is shown on photograph No. 2, and this consists of tarmac which has drainage channels running in the east to west direction across the bridge deck to dissipate water to the edges of the bridge.



Photograph No. 2

The eastern side of the bridge has a parapet and flank walls but the western only has a small parapet and the outer eastern elevation is constructed from what appears to be tufa stonework. The deck has track marks and the tarmac is in a poor condition. There is concrete to the sides, and this is damaged, as can be seen on photographs No. 3 and 4 which show the eastern side of the bridge deck and the area to the western side of the southern flank wall where water pools and there is loose stonework and debris.



Photograph No. 3



Photograph No. 4

On the western side of the bridge deck, there is a concrete area which is damaged and a metal guardrail to which the fixings are in a poor condition and sometimes are not fixed into the concrete as can be seen on photograph No. 5.



Photograph No. 5

2.2. Eastern Parapet

A general view of the eastern parapet is shown on photograph No. 6 and this has flank walls on either side, the north of which is recorded on photograph No. 7.

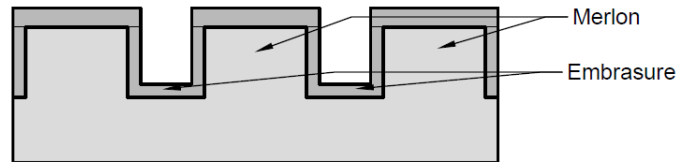


Photograph No. 6



Photograph No. 7

The parapet has a series of merlons and embrasures, the merlons having a capping which consists of stonework embedded into a mortar surround and the capping is book ended by two ashlar dressed stones.



There are examples where these have occasionally shattered, as can be seen on photograph No. 8, and a further example of this is recorded on photograph No. 9.



Photograph No. 8



Photograph No. 9

The capping to the merlons are constructed from stonework, which is bedded firstly on the horizontal, then turns to vertical on the crown. This opens the capping up to the elements and there is a large degree of damage on the top surface where water settles and will be subjected to freeze thaw action. Consequently, there is a large amount of loose and damaged stonework on top of the capping and a typical example of this is shown on photograph No. 10.



Photograph No. 10

Cementitious mortar has been applied in places and along the base are open joints caused by the spray back from puddles on the bridge deck, an example of this can be seen on photograph No. 11.



Photograph No. 11

There is minor vegetation growth in the capping and occasionally the end stones to the capping are loose and have become detached from the main section. An example of this is shown on photograph No. 12.



Photograph No. 12

On the northern face of one of the end capping stones is the initials M.J.L. and a date stamp of 1985. This is shown on photograph No. 13 and indicates that it is most likely that a major phase of repair work to the merlons was carried out 38 years ago. Photograph No. 14 shows cracking to the southernmost merlon and it is likely that this may be a localised impact damage.



Photograph No. 13



Photograph No. 14

2.3. Western Parapet

A general view of the western parapet is recorded on photograph No. 15 and this consists of seven fairly crudely built merlons which are at low level. It can be seen that the southern two are not built in alignment but may not have displaced away from the bridge as the concrete on the western side of the deck is laid to their current position. The southern two merlons are shown on photograph No. 16 and, if they have displaced, it is thought to be historic movement.



Photograph No. 15



Photograph No. 16

There is a metal guardrail, however, the southern end does not appear to be attached into the concrete as can be seen on photograph No. 17.



Photograph No. 17

There is ivy growth from the western elevation, as can be seen on photograph No. 18, and this is most evident on the northern end as can be seen on photograph No. 19.



Photograph No. 18



Photograph No. 19

2.4. Eastern Elevation

A general view of the eastern elevation is recorded on photograph No. 20 and there is ivy growth rooted into the joints in the masonry both on the crenelations and the main face of the stonework as recorded on photographs No. 21 and 22.



Photograph No. 20



Photograph No. 21



Photograph No. 22

On the northern side of the main opening, there is a series of open joints as can be seen on photograph No. 23. The majority of the elevation is pointed in a hard cementitious mortar and an example of this is recorded on photograph No. 24.



Photograph No. 23



Photograph No. 24

There are localised areas of damaged stonework, as recorded on photograph No. 25, which is to the top of the northern side of the arch and at this position there is also ivy growth, and the damaged stones will require cutting out and replacing.



Photograph No. 25

On the southern side, there is slight de-bonding around the window and the stone on the southern side of the central mullion has fractured as recorded on photograph No. 26. There are other localised areas where hard cement mortar has been patched over the stonework in a crude manner and on the remainder of the flank wall there is a slight bulge and a general view is shown on photograph No. 27



Photograph No. 26



Photograph No. 27

2.5. Western Elevation

A general view of this is shown on photograph No. 28 and there is slight vertical cracking on the southern side as can be seen on photograph No. 29.



Photograph No. 28



Photograph No. 29

Towards the northern side, there are missing blocks, and it is unknown how the blocks are fixed to the bridge and furthermore, there is ivy growth which is rooted deep into the wall, and these are both shown on photographs No. 30 and 31. There is further ivy growth on the southern side of the bridge as recorded on photograph No. 32.



Photograph No. 30



Photograph No. 31



Photograph No. 32

2.6. Underside

A general view of the underside of the bridge is recorded on photograph No. 33 and this is taken from the eastern side.



Photograph No. 33

Photograph No. 34 shows the underside of the eastern arch and there are spalled bricks and open joints as recorded respectively on photographs No. 35 and 36. Furthermore, on the southern side, there are damaged and spalled bricks at the springing position as recorded on photograph No. 37.



Photograph No. 34



Photograph No. 35



Photograph No. 36



Photograph No. 37

The outer stonework arch is of a different span to that of the main brickwork barrel vault and there is a gap between the two materials which has ivy growth as can be seen on photograph No. 38.



Photograph No. 38

On the northern side, to the east of the opening into the north-eastern chamber, there are open joints in the masonry as can be seen on photograph No. 39 and at the base of this is damaged stonework and the remnants of hard cementitious mortar pointing as recorded on photograph No. 40.



Photograph No. 39



Photograph No. 40

In the centre of the space on the underside of the bridge, there are two modern blockwork piers which are shown on photographs No. 41 and 42 and these have been built to the line of the earlier masonry.



Photograph No. 41



Photograph No. 42

Photograph No. 43 shows a view of the central stonework arch which it is likely was once an external wall but the bridge has subsequently been adapted and widened. There are three steel beams spanning between the modern blockwork piers and the beams are corroding on the surface, and this is shown on photograph No. 44.



Photograph No. 43



Photograph No. 44

On the southern side of the underside, there are stones on the eastern corner which have fractured as can be seen on photograph No. 45. There is damage and missing stonework on the top southern side of the central wall, as shown on photograph No. 46, and it is visible that there is brickwork behind so the stonework on show may be a façade on a brick structure.



Photograph No. 45



Photograph No. 46

A general view of the underside of the western barrel vault is recorded on photograph No. 47 and there is slight damage to the brickwork. This is thought to be a later arch which has been inserted beneath the older arch most likely to provide it with strengthening. On the western side, there is cracking in the earlier arch as recorded on photographs No. 48 and 49. The cracking indicates that the western elevation has displaced away from the bridge. This displacement is mainly on the northern side of this western section but the southern side indicates that the outer stonework façade of the western elevation has displaced away from the earlier brickwork structure as recorded on photograph No. 50. On the northern side, the junction can be seen between the newer brickwork and earlier masonry wall.



Photograph No. 47



Photograph No. 48



Photograph No. 49



Photograph No. 50

Photograph No. 51 shows the western corner of the earlier brickwork on the northern side of the wall and the brickwork here is in a poor condition with an amount of loose bricks and a pile of bricks on the floor indicating that a collapse has occurred at some time on the south-western corner.



Photograph No. 51

The later brickwork masks the majority of the earlier bricks, however, the earlier bricks can be seen on the western edge on photograph No. 52 and there is a slight gap between this western edge and the tufa stonework which makes up the western elevation. There is slight cracking on the springing position in the brickwork as can be seen on photograph No. 53 and this has been caused by a slight movement of the inner brickwork to the south which has caused a compression crack to occur in the brickwork at the springing position. The movement which has occurred does not appear to be of major structural concern and the inner arch is buttressed so cannot move southwards. As the cracking is not of great concern, the joint below the springing position should be raked out and repointed.



Photograph No. 52

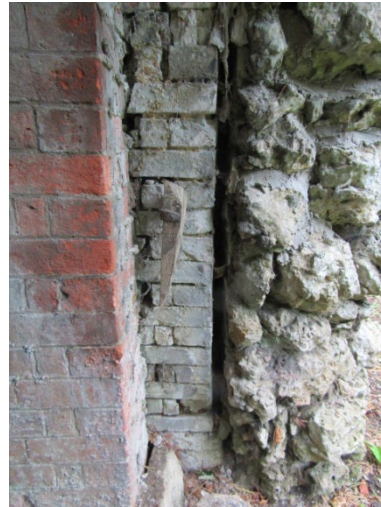


Photograph No. 53

Photographs No. 54 and 55 show that there is slight displacement between the outer stonework, which forms the western elevation, and the abutment to the brickwork arch.



Photograph No. 54



Photograph No. 55

2.7. North-Eastern Chamber

A general view of this is shown on photograph No. 56 and the underside of the brickwork barrel vault is recorded on photograph No. 57.



Photograph No. 56



Photograph No. 57

On the northern wall, which is stonework, there is occasional damage to the stones, as recorded on photograph No. 58, and on the eastern wall there is a gap between the brickwork barrel vault and the stonework wall which is the inside face of the eastern elevation. This is shown on photograph No. 59. In this gap, there is ivy growth which should be removed, and this is recorded on photograph No. 60.



Photograph No. 58



Photograph No. 59



Photograph No. 60

Above the entrance doorway into this chamber, there is a stonework arch and damage to the voussoirs as recorded on photograph No. 61. Furthermore, the arch is very open jointed as can be seen on photograph No. 62.



Photograph No. 61



Photograph No. 62

The western reveal to this opening has a large degree of damaged stonework as indicated on photograph No. 63.



Photograph No. 63

On the western wall, there is a slight gap between the brickwork barrel vault and the central wall as indicated on photograph No. 64.



Photograph No. 64

There is an opening in this division wall which is shown on photograph No. 65 and the northern mullion has displaced to the south as there is a lack of buttressing against these stone arches as can be seen on photograph No. 66.



Photograph No. 65



Photograph No. 66

The wall to which this window is supported is quite open on the surface and requires an allowance for grouting and this is shown on photograph No. 67. There is also cracking in the stonework above the northern tracery as recorded on photograph No. 68.



Photograph No. 67



Photograph No. 68

2.8. South-Eastern Chamber

A general view of the chamber is shown on photograph No. 69 and this consists of a brickwork masonry barrel vault which spans in the north to south direction and there is occasional spalling and damage to the bricks as indicated on photograph No. 70.



Photograph No. 69



Photograph No. 70

The archway through to the northern wall is generally reasonable, although there is damage to the stonework surrounding the arch and open joints that require raking out and repointing. These two items can be seen on photograph No. 71 and 72.



Photograph No. 71



Photograph No. 72

Photographs No. 73 and 74 show that on the window of the eastern wall, the reveals are quite open and voided on either side and the stonework may require locally resetting.



Photograph No. 73



Photograph No. 74

On the western wall, there is a decorative window through into the neighbouring chamber and on the top northern side, there is bulging in the masonry as the two leaves have separated as indicated on photographs No. 75 and 76. There is also a large amount of open joints.



Photograph No. 75



Photograph No. 76

Photograph No. 77 indicates that the stonework to the window on this elevation is unstable as the outer archways do not have any buttress at the inner springing and as a consequence have displaced and their joints have opened.



Photograph No. 77

Photograph No. 78 indicates that there is a lack of bonding between the brickwork barrel vault and the side walls of the chamber.



Photograph No. 78

2.9. South-Western Chamber

A general view is recorded on photograph No. 79. The roof structure consists of a brickwork barrel vault, and this has cracking through the masonry as shown on photographs No. 80 and 81.



Photograph No. 79



Photograph No. 80



Photograph No. 81

Photograph No. 82 shows the cracking on the northern wall adjacent to where the former doorway was infilled. The masonry around this point is quite open jointed and requires raking out and repointing.



Photograph No. 82

The southern wall of the chamber is generally shown on photograph No. 83 and there are large amounts of spalled and damaged brickwork and the joints are open. This is all shown on photograph No. 84.



Photograph No. 83



Photograph No. 84

There are areas of the western wall which are constructed of large stone blocks which have destabilised slightly and moved away from the masonry arch as shown on photograph No. 85. The area is quite voided and there is evidence of vegetative growth.



Photograph No. 85

2.10. North-Western Chamber

A general view of the chamber is shown on photograph No. 86 and there is evidence of vegetation trapped in the gap between the brickwork barrel arch and the stonework wall to the rear of the chamber as can be seen on photograph No. 87.



Photograph No. 86



Photograph No. 87

A general view of the brickwork barrel vault is shown on photograph No. 88 and there are localised damaged and spalled bricks as well as slight cracking on the western wall.



Photograph No. 88

Photograph No. 89 shows there is a large amount of collapsed masonry on the southern wall where the brickwork above has cracked and displaced, and this area will require localised rebuilding.



Photograph No. 89

2.11. Small North-Western Chamber

This chamber is located to the north of the main north-western chamber and a view of the entranceway is shown on photograph No. 90. No access was gained into this chamber for safety reasons as there was a plastic fence over the entranceway. Photograph No. 91 shows that there is no evidence of structural lintols to support the stonework above and that small timbers have been introduced which will be providing negligible support to the stonework. It is therefore assumed that the stonework above here acts as an interlocking mass pinned together to prevent it from collapsing in front of the entrance of the chamber.



Photograph No. 90



Photograph No. 91

General views of the chamber are shown on photographs No. 92 and 93 and there is a brickwork barrel vault spanning in the north to south direction with a brickwork rear wall and buttress. There is cracking in the rear wall, as can be seen on photograph No. 93, but this is not of major concern, and it is recommended that it is raked out and repointed in a lime mortar. There is evidence of slight opening in the joints on the masonry barrel vault and an indication of water ingress staining on the underside of the roof.



Photograph No. 92



Photograph No. 93

3.0. Discussions and Recommendations

Structural Repairs

The structure is generally in a poor condition and minor collapses have historically occurred. The item of most concern is the cracking and displacement on the western side of the bridge. The bridge has been constructed in multiple phases and using a mixture of brick and stonework.

The western half of the central section of the bridge is constructed in two arches, an 'inner' and an 'outer'. The 'inner' arch is more recent and is likely to have been introduced to stabilise the original 'outer' arch. There is evidence on the western side of the southern arch of slight cracking, identified on photograph No. 53, but this is not of great structural concern and should be raked out and repointed. On the western side of these arches, there has been separation between the original western arch and the outer section of the western elevation. There is also damaged and collapsed masonry on the western side of the northern wall of this arch.

The methodology of repair to the underside of the bridge is to secure the bridge in its current position, ensuring that it does not further deteriorate. It is recommended that the eastern and western walls are held to the main structure by installing Cintec anchors horizontally into the core of the bridge from the outer face of the masonry walls. This should be more straightforward on the eastern elevation as the stonework is regular but on the western side, there is tufa stonework and therefore will be more challenging.

Internally in the chambers, the outer stonework walls are not bonded to the brickwork arches and the gaps between the two surfaces require clearing of debris and vegetation. The gaps require grouting and Cintec anchors should be installed from the external faces to bond the outer walls to the arches and internal structure as discussed above. The openings on the inner wall have a lack of support at the inner springing positions and consideration should be given to retaining the stonework but infilling the openings.

The western elevation requires the ivy and vegetation, which is deep rooted into the structure, to be removed and the connection between the outer tufa stone wall and the brickwork behind should be investigated. The likelihood is that the cracking through the stonework on the southern side of this wall will require pinning with stainless steel pins, however, this will depend on the findings of the investigations.

Modern blockwork piers have been introduced on either side of the underside of the bridge and these support three corroding steel beams. It is likely that the piers were installed to protect/mask damaged masonry behind and provide further support to the central wall. To fully repair the bridge, the steel beams and the blockwork piers require removing to expose the masonry behind which can then be repaired where necessary.

Deck

The deck is in a poor condition with different and uneven surfaces which include depressions where vehicles have tracked over the bridge. The existing deck requires removing and relaying on a solid, compacted infill. Drainage channels should be introduced to discharge rainwater off the bridge. There is a relatively large thickness between the surface of the deck and the top of the masonry arches and therefore the loads from vehicles should be well distributed over the arches.

Parapets

The cappings on the merlons are generally in a poor condition as they are constructed from stones embedded in a semi-circular fashion which means that the central stones are vertically bedded. This allows moisture to settle on the top surface and, through freeze-thaw action, break down the stonework and mortar. This detail is commonly used for cappings throughout the walls and is prone to this failure. It is recommended that the damaged cappings are dismantled and reconstructed, the end stones pinned into position and replaced where they are damaged. The southernmost merlon on the eastern elevation requires resetting since it has likely suffered impact damage which has caused a displacement to occur.

The parapet on the western side is minimal in height and the metal rail is loose and is only partly fixed into the concrete surface. It is considered that this is too low and there is a notable risk to persons using the bridge. Following a risk assessment it would be envisaged that the parapet is rebuilt and raised in height or an appropriate railing introduced.

General Issues

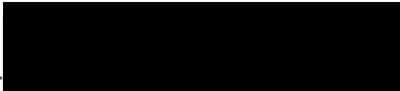
Hard cementitious mortar has been historically used, mostly on the eastern elevation including the parapets. The cementitious mortar should be removed as it does not allow the stonework to breathe and traps moisture within the stonework which will cause damage. On walls there should also be an allowance for grouting as the trapped moisture can create voids. There are open joints throughout the bridge which require raking out and repointing in a lime mortar. There are multiple bricks, mostly on the arches, which are damaged and spalled and these should be cut out and replaced with ones that match the existing bricks. Furthermore, there is also damaged, shattered, and spalled stonework on the walls and chamber structures, and these require removing and replacing. Where the masonry is missing, or there has been localised collapses, the masonry above should be propped and then the area rebuilt with the brickwork rebonded into the surrounding structure. The vegetation growth, which is mostly ivy, should be fully removed and the joints raked out and repointed where required. Where the ivy is well embedded into the masonry, it may be required to locally remove the surrounding stonework to access the root growth and then the stones reinstated once the vegetation root has been removed.

4.0. Conclusions

The bridge is generally in a poor structural condition and requires a complete overhaul. It has been constructed in different phases and there is cracking and displacement between the arches and the outer walls, particularly on the western side. Cintec anchors should be installed horizontally from the outer walls to bond them to the brickwork arches and the core of the bridge structure. The gaps between arches and the walls should be cleared of debris, repointed, and grouted to make the structure homogeneous.

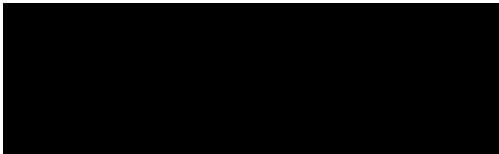
The outer western wall is constructed from tufa stone which has displaced away from the bridge and an investigation should be carried out to establish how the stones are fixed to the main structure.

There are damaged, missing, and shattered brick and stonework and this damage has mostly been caused by the effects of the freeze-thaw process. The damaged masonry requires cutting out and replacing with materials that match the existing. There is ivy on the structure which should be removed, and an allowance should be made for locally exposing the masonry to access deep root growth so it can be removed. The stonework should then be reinstated. The bridge can be repaired but does require intervention to ensure it is fully tied and acting as a homogeneous element.



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