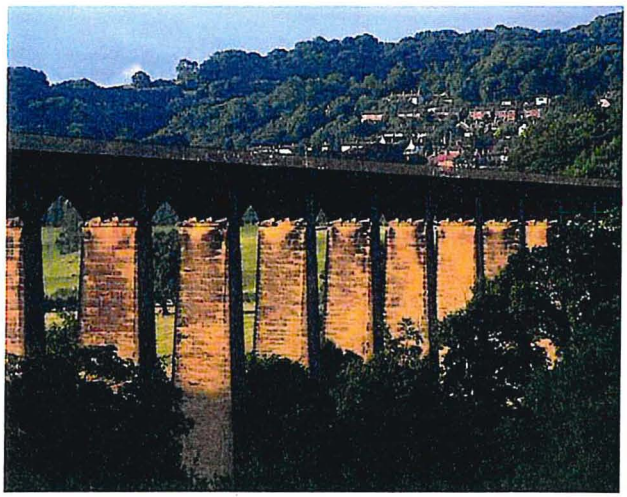
101202

British Waterways
Dyfrffyrdd Prydain



PONTCYSYLLTE AQUEDUCT REFURBISHMENT

APPLICATION FOR SCHEDULED MONUMENT CONSENT: SUPPORTING INFORMATION

Appendix 2
General items relevant to the refurbishment of the Pontcysyllte Aqueduct

JULY 2003

Contents **Page**

Appendices

1. Masonry Repair

1.1 The Trial Refurbishment (February 2000) identified that the masonry corbels are susceptible to cracking and splitting. The deterioration is exacerbated by a water trap formed by poor original detailing of the connection between the corbel and the arch girder bedplate. Photographs from the Trial Refurbishment are shown in Figures 1.1 and 1.2 below.

1.2 The masonry corbels will be inspected to assess the extent of the repairs. A photographic survey will be completed to record the current condition of the masonry and to grade the condition of the corbels.

1.3 It will be necessary to consult with Cadw's Ancient Monument Inspector at this time to ensure that the most appropriate method of repair/replacement is undertaken. Details of a typical repair as undertaken during the Trial Refurbishment is included in Appendix A.

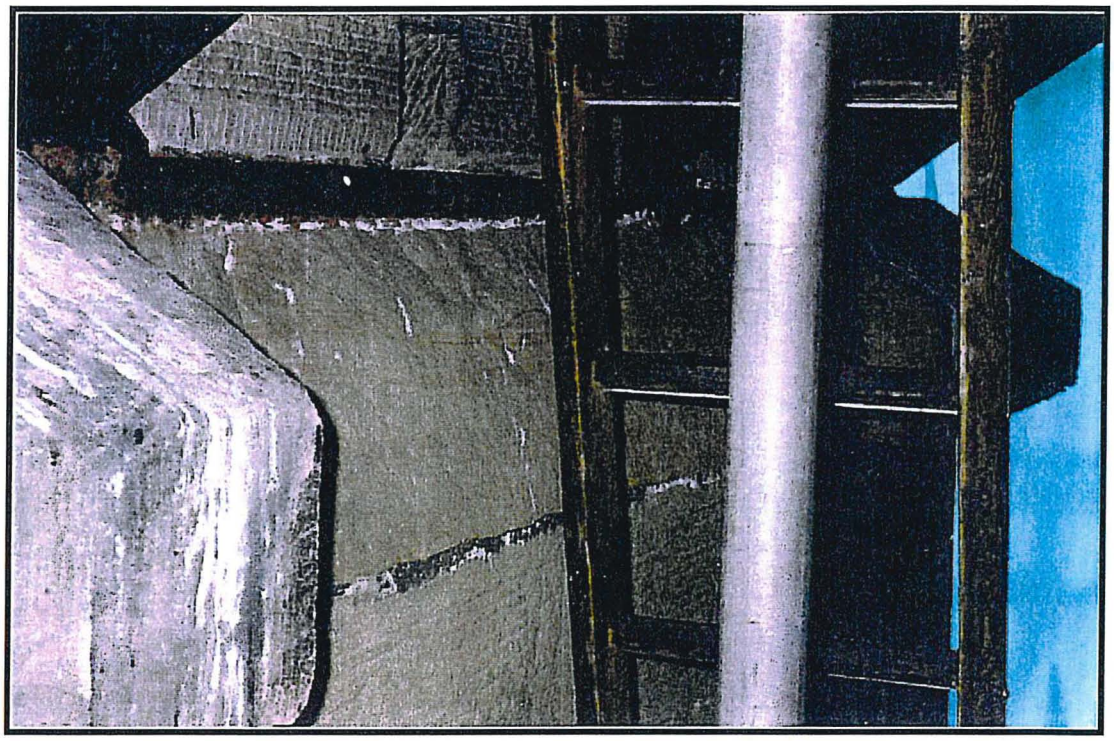


Figure 1.1 Missing masonry corbel

1.4 Every effort will be made to repair the masonry corbels in-situ. If this is not possible the damaged corbel will be removed and replaced with material matching the original masonry blocks. A stone survey has been commissioned to identify a quarry to match the original material. It is understood that the quarry which provided the original material is located in Rhosymedre.

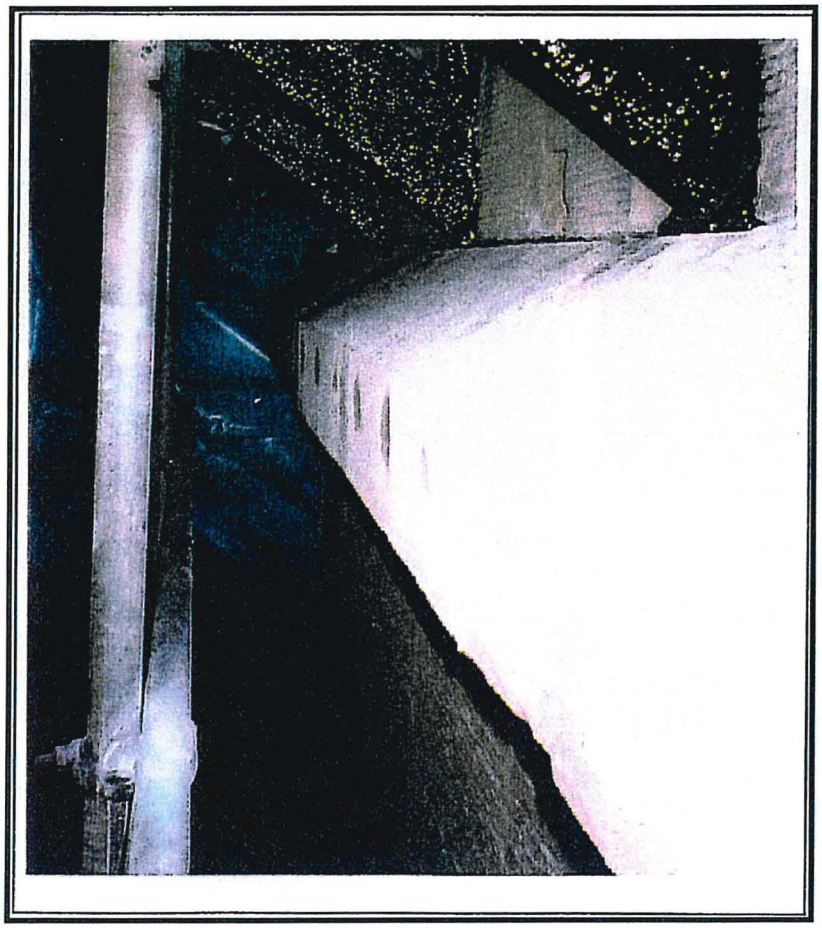


Figure 1.2 Repaired masonry corbel

1.5 The water trap will be removed by cleaning out and where practical filling with a lime mortar/sandstone mix.

2. Bolt refurbishment

2.1 During the Trial Refurbishment of Bay 11 (February 2000), a sample of bolts were removed for analysis to ascertain the condition of the bolts.

2.2 Twenty seven bolts were removed and replaced temporarily with black bolts. These bolts are to be replaced during the proposed refurbishment project with replica bolts with date stamps.

2.3 A metallurgical examination of 1 bolt, complete with washers and nut was commissioned. The report on the examination is included as Appendix B.

2.4 The bolts on the internal sections of the trough were found to be in a better condition than expected, although the nuts to the bolts have suffered more severe corrosion, especially within the base of the trough.

2.5 The Trial Refurbishment confirmed that bolts to the external elevations are in very good condition. Photographs of the existing bolts and the removed bolts are shown in figures 2.1 and 2.2 below.

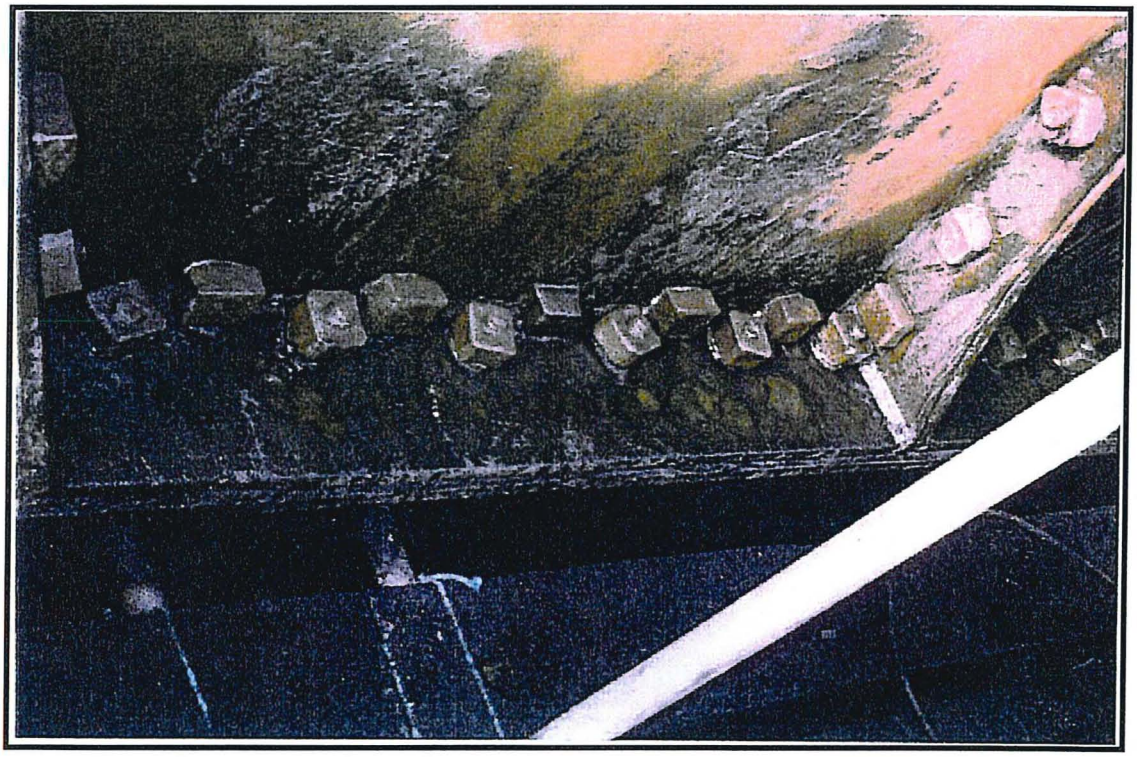


Figure 2.1 External bolts in excellent condition

2.6 Prior to works commencing on site, replica bolts and nuts will be manufactured in the original material as per the bolt analysis. A date stamp will be applied to the head of the nuts and bolts to enable easy identification in the future.

2.7 Initially it is not envisaged that the bolts will be removed as this could be detrimental to the tar/hemp sealant and also to the sealant provided by the current coating on the bolt.

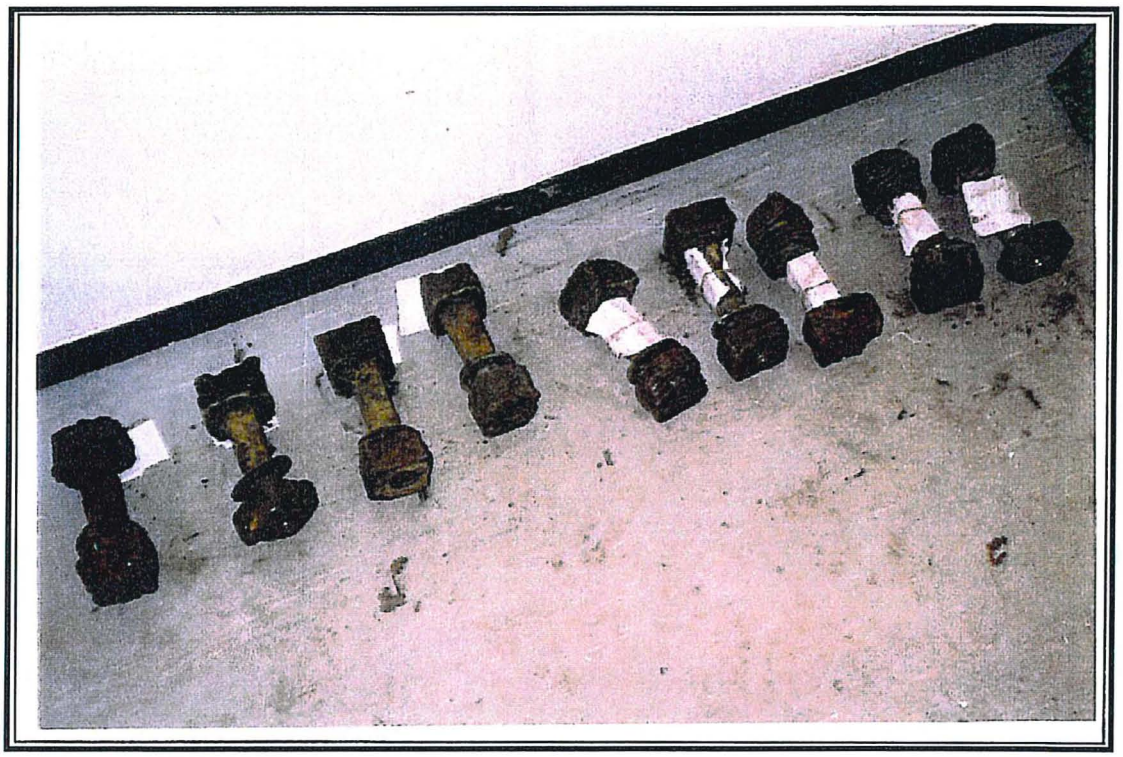


Figure 2.2 Original bolts

2.8 A visual inspection of all bolted connections will be carried out and a record identifying the specific location and condition of each bolt will be compiled.

2.9 The condition of the bolts will be graded according to the degree of corrosion/loss of section that the bolted connections have suffered. The grading system will range from "1 – Excellent condition" to "3 – Severely corroded".

2.10 The recorded information will be analysed to identify if there is a specific band, e.g. at the water line, exhibiting more significant corrosion.

2.11 After consultation with Cadw's Ancient Monument Inspector the bolted connections, which are classified as "Severely corroded", will be carefully removed and cleaned.

2.12 The critical dimensions of the removed bolts and nuts will be measured. If the bolted connection is in a better condition than the visual inspection suggested the bolted connection will be re-installed. The original tar/hemp washer will be replaced, if in a satisfactory condition. If necessary the joint will be reinforced with more tar/hemp sealant. A typical detail is included in Appendix B.

2.13 If the bolted connection is not found to be in a satisfactory condition the bolt/nut will be replaced with the pre-fabricated replica bolts. The recorded information will be updated to reflect the change in bolt.

Fascia panels

2.14 The bolt inspection and grading approach will extend to cover the fascia panel fixings.

2.15 The bolted connections of the fascia panels are known to be in very poor condition and in need of replacement.

2.16 Following the inspection survey, the relevant fascia panel bolted connections will be carefully removed and inspected. As with the trough bolts the fascia panel bolts will be re-installed if they are in a satisfactory condition. Otherwise replacement replica bolts will be used as replacements.

3. Parapet repairs

3.1 An inspection survey of the parapet has been undertaken and the drawing is included as Appendix C (Dwg No. 2458 SK101). The survey identified defects, weld locations, expansion joints and replaced sections. This survey drawing will be updated as part of the refurbishment project.

Curved Braces – Northern end

3.2 In 1987, as part of a safety improvement, the curved braces at the northern end of the aqueduct were removed and the existing parapet extended around the approach abutment. The original curved braces are currently stored in the brick building located to the north east of the aqueduct. The original position of the braces is shown in figure 3.1 below, and the modification shown in figure 3.2.

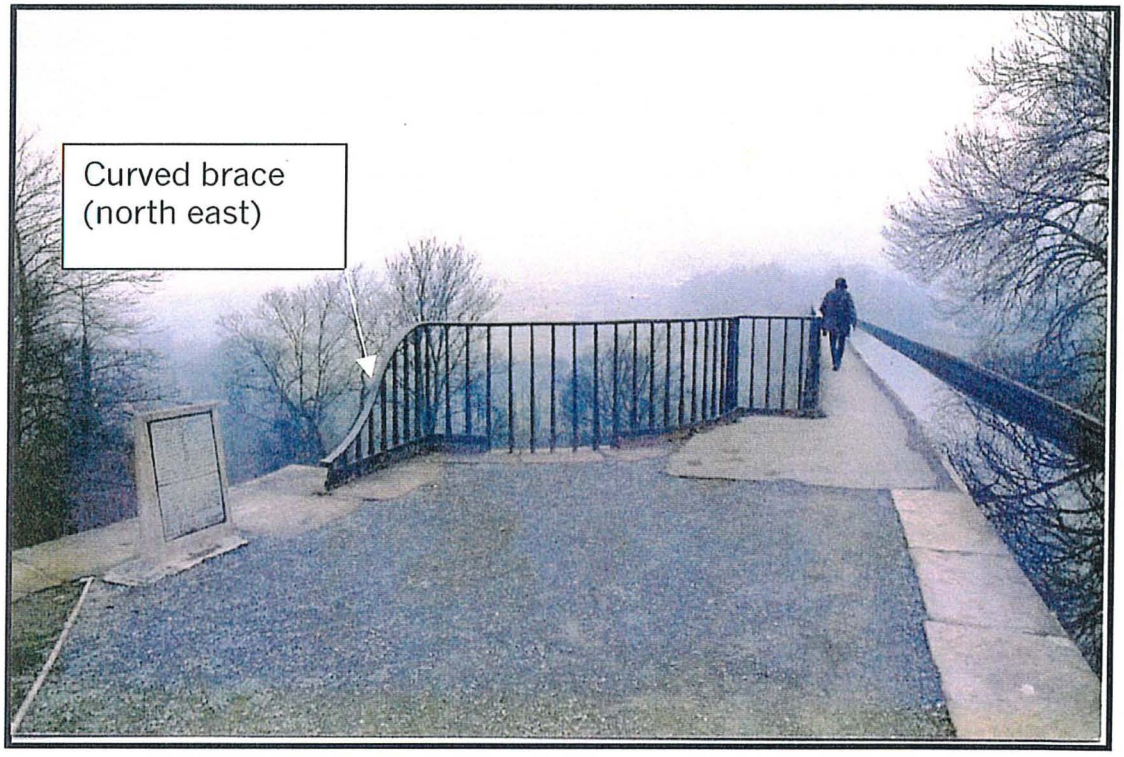


Figure 3.1 – Curved braces – northern end

3.3 The refurbishment proposals include restoring the curved braces to the northern end of the aqueduct but in a more northerly position as indicated in figures 3.2 and 3.3. The braces at the southern end remain in place and are original.

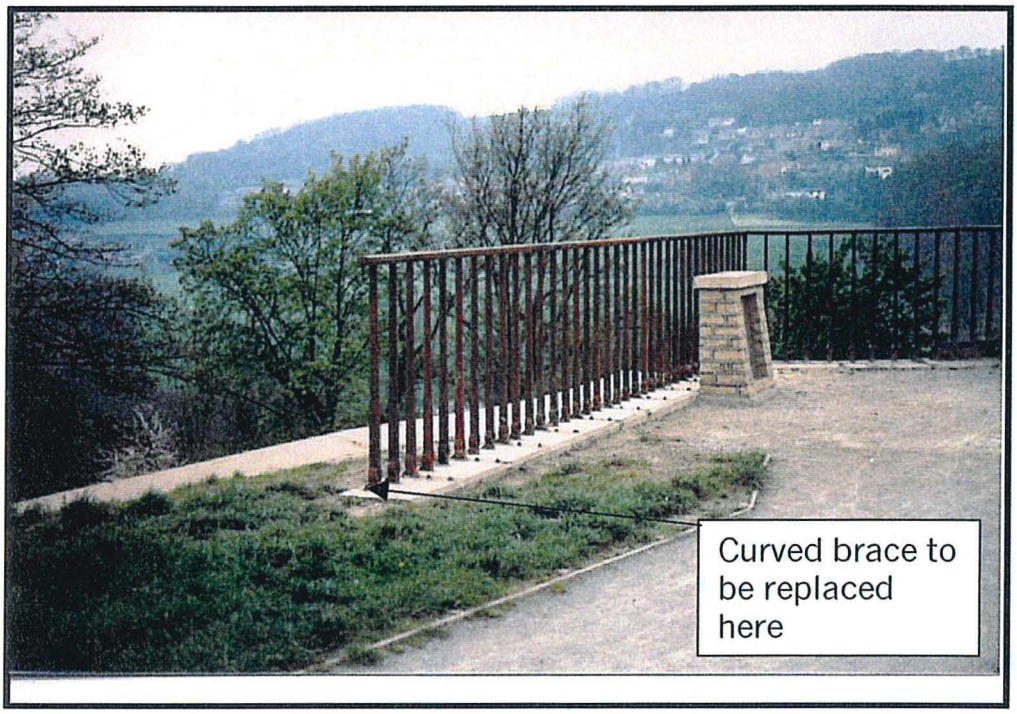


Figure 3.2 – Proposed location of curved braces (north east)

Figure 3.3 – Proposed location of curved braces (north west)

Parapet Top Rail

3.4 The cast iron top rail is in poor condition, expansion joints have seized causing cracking and displacement. The standard of weld repairs previously undertaken is generally poor.

3.5 The parapet posts fit within purpose built openings within the underside of the top rail. The openings have been weathered and elongated.

Parapet Posts

3.6 There are two different types of posts and fixing; every fourth post is bolted to the original towpath cross beam. The other posts simply sit/fit in the purpose built holes within the top of the trough wall.

Proposals

3.7 Repairs to the defective locations will, where appropriate, consist of

(i) welded repairs to the parapet top rail
(ii) reinstating seized expansion/contraction joints. The details of the joints are included in Appendix D.

4. Joint sealant

4.1 The original core sealant between trough sections is a coarse flannel, cut into pieces and covered in white lead. The internal and external faces of the trough joint have been caulked firmly with hemp melted in tar to protect the white lead core.

Proposal – Option 1 (Preferred)

4.2 This option includes refurbishment and strengthening of the joints by caulking the joints using the tar and hemp materials as used in the original construction.

Option 2 - Sikaflex 11FC

4.3 The alternative option is to use a modern day sealant, Sikaflex 11FC. This material was used during the trial refurbishment and has worked successfully. Technical details are included in Appendix E.

5. Graffiti removal

5.1 Graffiti damage can be found to the masonry and cast iron sections to the northern and southern ends of the Aqueduct. The graffiti consists of aerosol spray paint, felt tip markers and ballpoint pen markings (see figure 5.1).

Figure 5.1 Graffiti

5.2 A site trial to determine the most effective removal system will be undertaken at the start of the main refurbishment works.

5.3 The site trial will consist of chemical removal and mechanical removal techniques.

5.4 The chemical agents for graffiti removal will include solvent-based paint removers (based on methylene dichloride), other organic solvents, and alkali-based paint removers.

5.5 Air abrasive methods will also be trialled to determine their effectiveness and suitability for removing the graffiti without damaging the Aqueduct.

5.6 The results of the site trial will be analysed and the most suitable method(s) will then be applied to remove the remaining graffiti.

6. Vegetation removal

6.1 The masonry piers of the Aqueduct are overgrown with vegetation. Creepers and other invasive species are damaging the structure of the masonry and invading the masonry joints.

6.2 Deep-rooted trees are a cause for concern to the structural stability of the masonry piers as shown in figure 6.1

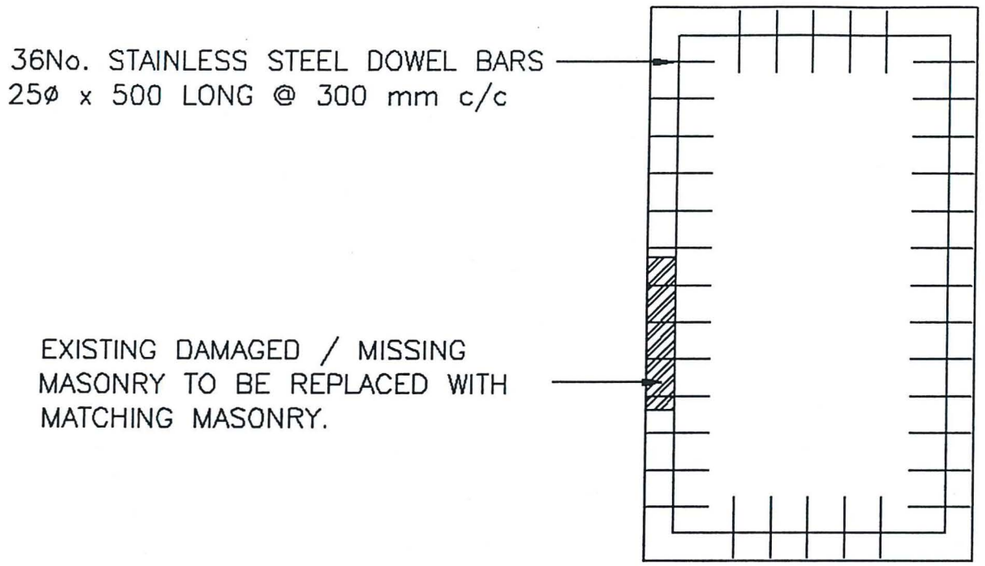
Figure 6.1 Vegetation near the Aqueduct

6.3 A topographical survey is to be undertaken to record the location of all substantial trees in the vicinity of the Aqueduct. The survey drawing will be used to identify the trees for removal.

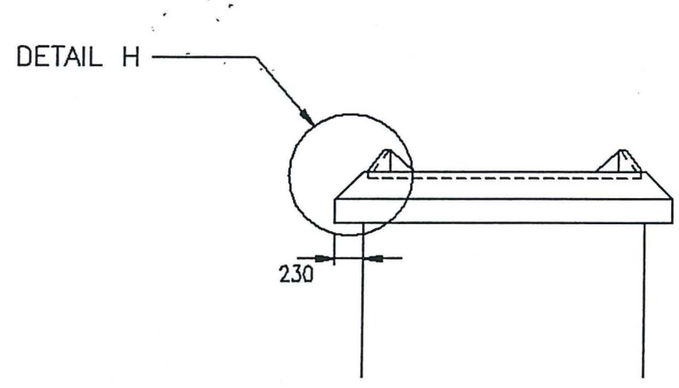
6.4 The trees are located within a Conservation Area and subject of a Tree Preservation Order. The local Arboricultural Officer will be consulted on their removal and an application will be submitted for approval to remove the trees. Substitute trees will be planted in a more controlled and managed approach.

6.5 The trees will be carefully removed by a tree surgeon ensuring that the trees are felled in a manner that does not impinge on the Aqueduct.

Appendix A –Typical masonry corbel repair details



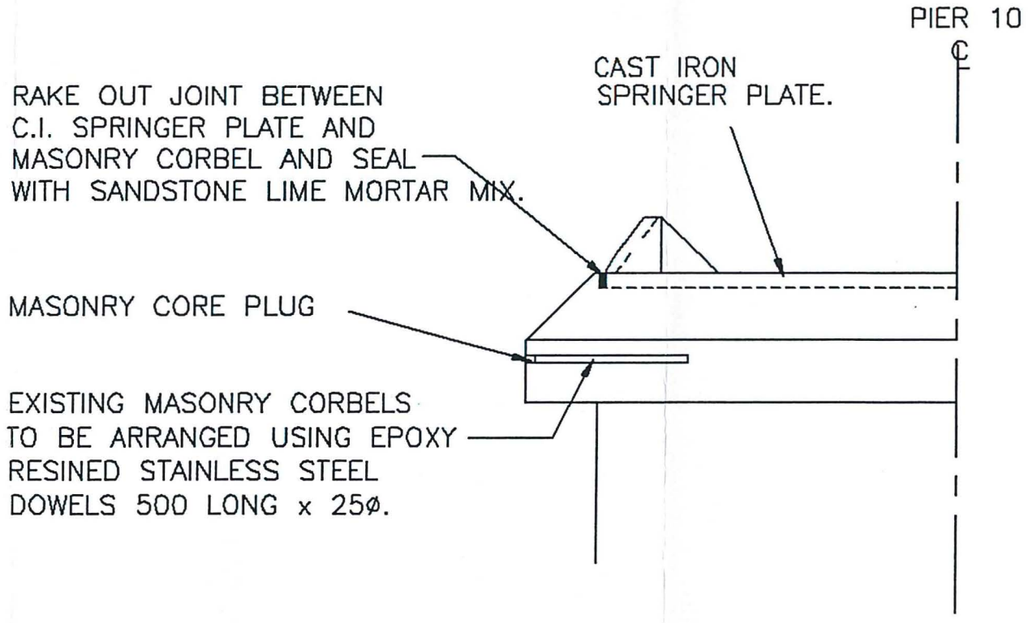
PLAN.



ELEVATION

MASONRY PIER 10

SCALE 1:50



DETAIL H – MASONRY CORBEL

SCALE 1:20

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Cheshire
CW8 1BH
Telephone: 01606 723800
Fax: 01606 871471

British Waterways

North West Region

TITLE
Llangollen Canal.
Pontcysyllte Aqueduct Refurbishment.
Masonry Corbel – Repair Details.

DATE 17/06/03	REVISIONS	
	DRAWN BY A.F	APPROVED BY
DRG. NO. ?	CHECKED BY	SCALE AS SHOWN
	DESIGNED BY	REVISION A

Appendix B – Metallurgical examination report and typical connection detail

THERMAL ENGINEERING
INTERNATIONAL LTD

METALLURGICAL SERVICES
PO BOX 80 CALDER VALE ROAD
WAKEFIELD
WEST YORKSHIRE WF1 5YS
Tel: +44 (0) 1924 780327; FAX +44 (0) 1924 386539
E-mail: metserv@tei.co.uk

TEST REPORT

LABORATORY REF: MS360/00/9475

RECEIPT DATE: 29:11:00

METALLURGICAL EXAMINATION OF 1-OFF PONTCYSYLITE AQUEDUCT BOLT C/W NUT & WASHERS

FOR: BRITISH WATERWAYS

ORDER No: SD/28nov/cc

CONTENTS

DISTRIBUTION: Mr S DENNIS, BRITISH WATERWAYS. X 2
TEi METALLURGICAL SERVICES FILE X 1

REPORT COMPILED BY: R.K.HEYWOOD DATE: 12:12:00

TEST REPORT

FOR: **BRITISH WATERWAYS Ltd.** **Report No. MS 360/00/ 9475**

FEARNS WHARF, LEEDS

Order No. SD/28nov/cc

Date received: 29:11:00

Report Date: 06:11:00 **Sheet 1 of 7**

SUBJECT: METALLURGICAL EXAMINATION OF 1-OFF PONTCYSYLITE AQUEDUCT BOLT c/w NUT and WASHERS.

Introduction:

One complete unit of bolting materials comprising a Bolt, one metallic washer and two hemp/white lead washers, and a nut were submitted to establish their Chemical composition and method of manufacture. The examination was instigated to replicate the bolt and observations in respect of replication are included in the report.

The bolt was reported to have been removed from the Pontcysylite Aqueduct, a grade 1 listed building and Scheduled ancient monument of international historic importance. Notable and significant corrosion had taken place over the life of the bolt. (Reference Photograph Figure 1).

Examination was facilitated using Combustion, Induction coupled plasma-Atomic energy spectra, Gravimetric and Photometric techniques to determine the Chemical composition and conventional metallography supplemented by Hardness test and Tensile test to establish the method of manufacture and physical properties.

Chemical Analysis:

A random section was removed from each component and submitted for chemical analysis using Combustion, Induction coupled plasma-Atomic energy spectra, Gravimetric and Photometric techniques

The following results were obtained.

	Mass % /%							
	Carbon	Silicon	Sulphur	Phosphorus	Manganese	Chromium	Molybdenum	Nickel
Bolt	0.010	0.02	0.014	0.44	<0.02	<0.02	<0.02	0.04
Nut	0.007	<0.02	0.004	0.26	<0.02	<0.02	<0.02	0.04
Metallic washer	0.038	0.50	0.023	0.41	0.08	<0.02	<0.02	0.03

Mass % /%

	Lead	Tin	Antinomy	Bismuth	Arsenic	Cadmium	Copper	Iron
Hemp/White Lead Washer	1.53	3.14	<0.02	<0.02	<0.02	<0.02	<0.02	2.85
	Moisture	Loss of Ignition @800°C		Carbon content of organic				
Hemp/White Lead Washer	6.53	78.83		28.1				

Metallography:

The bolt was sectioned longitudinally and prepared by polishing and etching in a 10% Nital solution for macroscopic examination. The section contained numerous oxide and slag inclusions revealing the forging pattern. The inclusions follow the contour of the outer surface showing the bolt was forged to shape, with exception of the threaded portion. Machining of the thread had cut across discontinuities in the material. The macro section also showed light and dark etching regions following the forging pattern indicative of carbon segregation and variation in grain size, coarse grained towards the centre of the section and finer at the surface. (Reference figure 2)

Additional sections were removed from the bolt and section taken from the nut and metallic washer for microstructure examination. The sections were hot mounted, ground and polished to a 1 micron finish. Examination was performed under optical microscope before and after etching in 2% Nital solution.

Bolt: Microstructure of the bolt comprised equiaxed grains of ferrite with banded pearlite indicative of carbon segregation. (Reference figures 3 and 4 respectively) Pearlite colonies showed generally lamellar cementite platelets, consistent with finish forging temperature above the lower critical temperature of 723°C. (Reference figure 5). Pearlite distribution and ferrite grain size is further indicative of temperature higher than the upper critical temperature of circa 900°C, However, in-homogeneity throughout the section would suggest that the bolt had not been uniformly heated above 1050°C for a significant period of time.

Nut: The nut displayed similar microstructure features to the bolt with equiaxed ferrite grains and bands of pearlite The section examined showed appreciable elongation of ferrite grains local to the threaded area. Indicative of cold work introduced in manufacturing the thread. Principal orientation of the slag and non-metallic inclusion was parallel to the threaded hole with evidence of up-set towards the non contact face of the nut.

Metallic washer: Microstructure of the washer again showed equiaxed grains of ferrite. Ferrite grain size was homogenous throughout the section and there was no evidence of pearlite banding or carbon segregation. A more uniform dispersion of non-metallic and slag inclusion was apparent which suggests higher working temperatures and greater reduction in section size during manufacture. The inclusions were orientated planar to the flat surface.

Comments:

The bolt, nut and metallic washer all revealed microstructure comprising equiaxed ferrite grains with nut and bolt showing localised areas of lesser volume fraction of pearlite. Chemical analysis of the components showed a higher carbon content for the washer suggesting that the higher volume fraction of carbon rich phase pearlite in the bolt and nut were related to segregation. A high volume fraction of oxide and slag inclusion was apparent in all sections, which, together with the chemical composition is considered consistent with wrought Iron produced from Cast Iron in a reverberatory type furnace. This type of furnace used additions of Iron oxide that react with the molten Iron to remove impurities, which result in the formation of a slag. Silicon, Manganese, Phosphorus and Carbon are combined in the slag during processing. Due to the higher melting point of the purer wrought Iron solidification takes place and the slag is trapped. Subsequent working elongates the slag normal to the applied pressure. The slag deformation pattern through the bolt showed that the bolt had been forged to shape with the exception of the thread, which cut across the slag lines. Microstructure was indicative of forging temperature above the upper critical temperature, circa 900°C.

Variations in chemical composition between the bolt nut and washer may reflect differences in the source of Iron used in the blast furnace or differences in processing time and temperature.

The production of wrought iron is no longer of economic importance and has been replaced by steels that offer higher strength to weight ratio.

Control in manufacture of modern day steels results in a much more uniform product without high non-metallic content. The cleaner steels with purpose additions of carbon and manganese for improved strength generally have inferior corrosion properties and are less resilient to shock compared to wrought iron. Consideration should be given to the application of a protective coating e.g. galvanising in order to extend the life of the modern steels. Shock is not thought to be a major consideration given the application of bolting. Typical steels, which may be appropriate with a galvanising treatment, include BS970: 1991 grade 045M10.

Comparable material could be selected for the nut. We would recommend selection of a spring type metallic washer to prevent loosening of the nut and bolt during service.

Chemical analysis of the hemp/white lead washer showed higher tin content than lead. The washer had degraded during service so as to make a reasonable assumption as to the manufacturing origin difficult. The ratio of lead to tin as analysed or the ratio between metal and hemp may not agree with the composition at the time of manufacture due to degradation. It is thought that the washer may have either been manufactured with hemp wound around a lead/tin metal core or hemp interwoven with a metal strand. Modern day equivalent washers are generally manufactured using polymeric materials, PTFE or Nylon.

For Thermal Engineering International Ltd.

Metallurgical Services

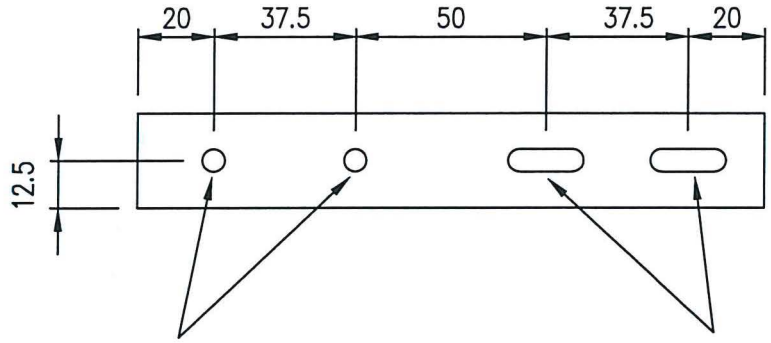
R K Heywood

Chief Metallurgist

Issued: 12:12:00

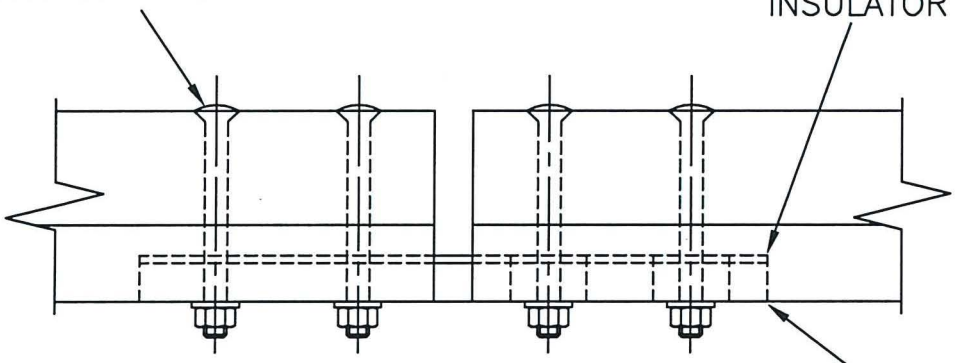
Appendix C – Parapet Survey Drawing

Appendix D – Parapet repair details



PLAN ON CONNECTION PLATE AND INSULATOR

4No. 6mmø STAINLESS STEEL C/S MACHINE SCREWS WITH NUTS AND WASHERS. APPROX 60mm LONG CONTRACTOR TO DETERMINE ACTUAL LENGTH ON SITE.



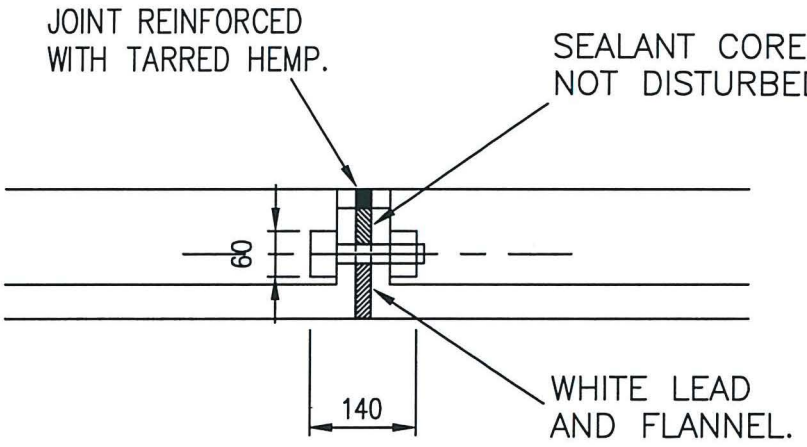
ELEVATION

PARAPET HANDRAIL EXPANSION JOINT DETAIL

British Waterways
North West Region

Navigation Road
Northwich
Cheshire. CW8 1BH
Tel: 01606 723800
Fax: 01606 871471

REVISION		TITLE	DRAWN BY	A.F
		Llangollen Canal.	DATE	17/06/03
		Pontcysyllte Aqueduct Refurbishment.	SCALE	1:2
CHECKED BY		Parapet – Expansion Joint Repair.	DRG. No.	?



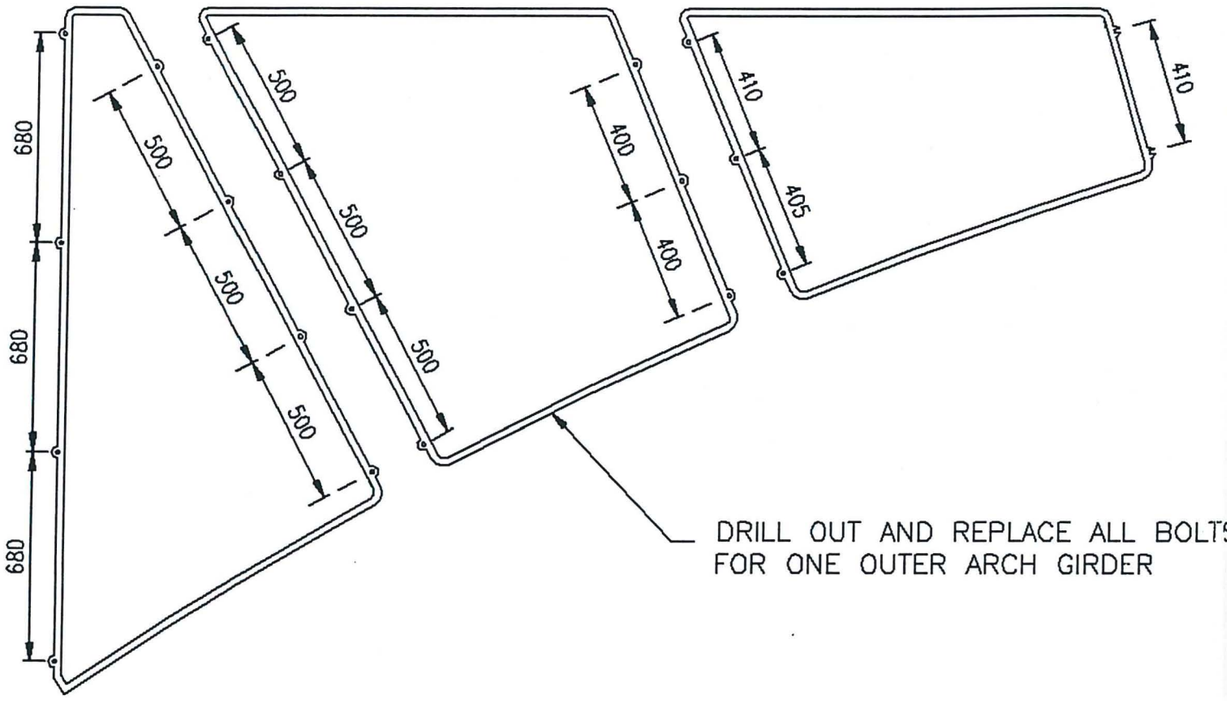
PROPOSED JOINT DETAIL

TYPICAL BOLTED CONNECTION TO CAST IRON SEGMENTS

British Waterways
North West Region

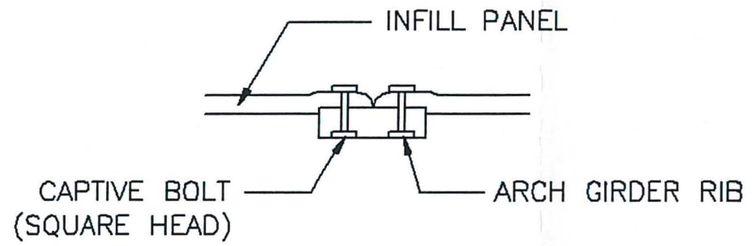
Navigation Road
Northwich
Cheshire. CW8 1BH
Tel: 01606 723800
Fax: 01606 871471

REVISION		TITLE	DRAWN BY	A.F
		Llangollen Canal.	DATE	17/06/03
		Pontcysyllte Aqueduct Refurbishment.	SCALE	1:10
CHECKED BY		Joint Sealant.	DRG. No.	?



ELEVATION ON FASCIA PANELS TO OUTER ARCH GIRDER.

SCALE 1:20



TYPICAL BOLTED CONNECTIONS BETWEEN THE FASCIA PANELS AND THE OUTER ARCH GIRDER

SCALE 1:10

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British Waterways

North West Region

TITLE
Llangollen Canal.
Pontcysyllte Aqueduct Refurbishment.
Fascia Panels – Bolt Replacement.

DATE
17/06/03

DRG. NO.
?

REVISIONS

DRAWN BY A.F	APPROVED BY
CHECKED BY	SCALE AS SHOWN
DESIGNED BY	REVISION A

Appendix E – Sikaflex joint sealant information

CONSTRUCTION

March 1999

Sikaflex® 11FC

Fast Curing One Part Polyurethane Universal Sealant/Adhesive

Technical Data Sheet

DESCRIPTION

Sikaflex 11FC is a one component adhesive and sealing compound of permanent elasticity. This dual purpose material is based on a special moisture cured polyurethane with an accelerated curing time.

USES

Elastic adhesive for example with:

- ★ Cover plates, gaskets and coverings.
- ★ Acoustic ceiling tiles.
- ★ Floor mouldings and door sills.
- ★ Lightweight construction materials.
- ★ Wood, metal or plastic window and door frames.
- ★ Roof tiles.

Elastic joint sealant for example in.

- ★ Flexible draught proofing.
- ★ Air ducts and high vacuum systems.
- ★ Containers, tanks and silos.
- ★ Aquariums.
- ★ Gaskets in openings in walls or floors for ducts, piling, etc.
- ★ Reservoirs or water retaining structures.
- ★ Flanges, crimping and interlocking surfaces.
- ★ Aluminium fabrication.
- ★ Bolted tap joints.
- ★ Sanitaryware purposes.

ADVANTAGES

- ★ Excellent adhesion on all cement based materials, brick, ceramics, glass, metals, wood, epoxy, polyester, acrylic resin, plastics.
- ★ Fast cure rate.
- ★ Good weathering and water resistance.
- ★ Non-corrosive.
- ★ Can be painted over with water, oil and rubber based paints. (Preliminary tests recommended.)
- ★ High durability.
- ★ Non-sag on vertical joints up to 40 mm width.

Technical Data (typical)

Colours:	Refer to colour swatch and current price list for availability and minimum order quantities
Density:	Approximately 1.15 - 1.2 kg per litre
Movement Accommodation Factor (MAF):	10%
Service temperature range:	Dry: –40°C to +80°C Wet up to +50°C (temporary up to +60°C)
Curing rate:	Approximately 3 mm/day (+20°C / 65% rh)
Application temperature:	+5°C to +40°C (material and substrate temperature)
Shore A hardness:	40 - 45 after 28 days (+23°C / 50% rh)
Tack free time:	1 to 2 hours

Primer waiting time:

	Sika Primer 3S	Sika Primer 3
Min	1 hour	30 minutes
Max		5 hours

Elastic recovery:	> 90%
Elongation at break:	> 450%
Tensile strength at break:	> 1.4 N/mm²
Maximum joint width:	40.0mm
Minimum joint depth for expansion joints:	8.0mm
Modulus:	< 0.5 N/mm²
Complies with the Performance standards of:	– BS4254 : 1983 – Water Bylaws Scheme (WRC) WFBS No 9103508

24-FEB-2000

PREPARATION

All surfaces must be sound, clean, dry and free from any surface contaminants.

All loose particles, paint, laitance, rust and other poorly adhering materials should be removed with a rotary mechanical wire brush, grinding or grit blasting followed by blowing out with oil free compressed air. Use epoxy mortars for making good spalled or damaged joints.

Iron and steel must be protected by an anti-corrosion primer such as Icosit EG1 prior to sealing.

PRIMING

For the selection of the suitable primer, please consult the Primer Chart. When using **Sika Primer 3** on moist substrate, maximum substrate moisture content must not exceed 8%.

APPLICATION

- ★ Insert **Sika Joint Backing Rod** to required depth.
- ★ Apply appropriate primer to joint sides and observe waiting time.
- ★ Firmly extrude **Sikaflex 11FC** into the joint making sure that it is in full contact with the sides of the joint.
- ★ Fill the joint, avoiding air entrapment.
- ★ **Sikaflex 11FC** should be tooled to a smooth finish.

Masking tape should be used where sharp exact joint lines or exceptionally neat lines are required. Remove the tape whilst the sealant is still soft.

IMPORTANT CONSIDERATIONS

- ★ **Sikaflex 11FC** should not be used for structural glazing.
- ★ Protect the finished joint from water for at least 3 hours.
- ★ **Sikaflex 11FC** should be used with care in resealing joints that were previously filled with silicone sealants. All silicone residue must be removed.
- ★ Bonded elements may require additional holding or support during curing period.
- ★ **Sikaflex 11FC** may be painted. However some coatings may crack if movement occurs, preliminary tests recommended.
- ★ White colour material may discolour with age, durability will not be affected.
- ★ **Sikaflex 11FC** should not be applied to coated substrates.

CLEANING

Clean tools immediately with **Sikadur Cleaner**.

PACKAGING

Refer to latest price list.

JOINT DESIGN

Refer to BASA/CIRIA Guidelines. (CIRIA Publications 80)

CONSUMPTION

Theoretical consumption of **Sikaflex 11FC** per 600cc sausage (without wastage):

$$\text{Length of joint per 600cc (m)} = \frac{600}{\text{Joint width (mm)} \times \text{joint depth (mm)}}$$

$$\text{Litres per metre run of joint} = \frac{\text{Joint width (mm)} \times \text{joint depth (mm)}}{1000}$$

STORAGE/SHELF LIFE

15 months from date of production if stored in cool, dry conditions (at + 10°C to + 25°C).

CONSTRUCTION
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