BURO HAPPOLD

COPPERHOUSE SLUICE GATE

DOCUMENT REVISION RECORD

Document Number: C0395/006/DOC
Number of Pages: 31
Document Title: REPORT ON THE MECHANICAL SURVEY OF THE COPPERHOUSE SLUICE VERTICAL LIFT GATE
Saved as: K:\Contracts Working\351-400\C0395B Copper House Sluice\Documents\C0395B_006_DOC Rev A1.doc

<table>
<thead>
<tr>
<th>REV</th>
<th>DATE</th>
<th>AUTHOR</th>
<th>CHECKED</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>30.09.2006</td>
<td>C Appleton</td>
<td>R Digby</td>
<td>K Grubb</td>
</tr>
</tbody>
</table>

Refer to the Revision Sheet at the rear of this document for details of modifications.
CONTENTS

1. INTRODUCTION .................................................................................................................. 3

2. SURVEY FINDINGS .............................................................................................................. 4
   2.1 Review of documentation ......................................................................................... 4

3. SURVEY OF THE GATE STRUCTURE, CIVIL INTERFACES AND LIFTING GEAR ....... 5
   3.1 Gate Structure ........................................................................................................... 5
   3.2 Civil Work Interfaces ............................................................................................... 13
   3.3 Gate Sealing System ................................................................................................ 18
   3.4 Lateral Gate Guiding System .................................................................................. 19
   3.5 Gate Lifting Gear ...................................................................................................... 20
   3.6 Electrical Equipment ............................................................................................... 23

4. ISSUES AND CONSTRAINTS .............................................................................................. 25

5. RECOMMENDATIONS ........................................................................................................ 27
   5.1 Gate Structure ........................................................................................................... 27
   5.2 Civil Works Interfaces ............................................................................................... 27
   5.3 Gate Sealing System ................................................................................................ 28
   5.4 Lateral Gate Guiding System .................................................................................. 28
   5.5 Gate Lifting Gear ...................................................................................................... 28
   5.6 Electrical Equipment ............................................................................................... 29

6. CONCLUSIONS ................................................................................................................... 29
1. INTRODUCTION

At the request of Buro Happold (BH) (the consultants retained directly by the Hayle Harbour site developer, ING), Kenneth Grubb Associates Ltd (KGAL) has undertaken a mechanical survey of the Vertical Lift Gate sited at Copperhouse Sluice on Copperhouse Pool and operated by the Environment Agency Operations Delivery Staff.

The survey was of a non-intrusive nature and undertaken during tidal conditions. There is some residual risk that problems relating to the gate were not uncovered.

Members of the Environment Agency (EA) staff were on hand to assist the surveyors with information regarding the history of the installation and the site in general. They were also able to provide information with regard to the operation and maintenance of the gates. In addition, Dave Turner of the EA was contacted and provided useful background information.

The purpose of the survey was to determine the condition and serviceability of the existing gate and drive mechanisms, take measurements of the installation, establish the need for any refurbishment work and ensure that no other problems exist. Also, to consider the possibility of the gate being capable of being used in a sluicing/scouring capacity.

As the gate is owned and operated by the Environment Agency, no attention was given to operational, management or Health and Safety issues, though problems in this regard are obvious on the site.

The survey was undertaken between 4th and 6th September 2006.

Personnel involved: Chris Rose (BH) Part-time
Ken Grubb (KGAL)
Chris Appleton (KGAL)

The purpose of the vertical gate is, primarily, to act as a flood defence mechanism to prevent flooding of the area from tidal water.

The secondary purpose of the gate is to regulate the saltwater inundation within the Copperhouse Pool.

Note that historically the gate was used as a means of scouring sand from the harbour channels. Since that time the gate design has been changed by the EA. There may be some advantage to the potential Hayle harbour development if this functionality could be restored.

The gate was originally manufactured and installed in 1981 as the direct replacement for a pair of mitre gates. It was originally designed to work as a roller gate. The roller axles are still fitted to the ends of the gate.
However, at some time following original installation, the rollers were removed and the gate was modified to run on non-metallic wearing strips mounted on the opposing inner faces of the existing civil guide section.

Mr. Dave Turner of the Environment Agency stated that the reason that the gate was converted to a sliding gate was the high cost of maintenance attributed to the roller bearings which had continually seized.

The gate is generally maintained in a position with the lowest edge of the gate approximately 600mm above the civil sill.

No special problems associated with the operation of the equipment had been reported to KGAL prior to the inspection.

Discussions with the EA site staff indicated that the very nature of the gate operation (i.e. either tidal flood defence or undershot gate to relieve upstream flooding) had meant that the gate was very rarely operated.

2. SURVEY FINDINGS

2.1 Review of documentation

There were no drawings of the installation made available to the surveyors.

It is understood that drawings are available from the EA.
3. SURVEY OF THE GATE STRUCTURE, CIVIL INTERFACES AND LIFTING GEAR

3.1 Gate Structure

The survey focused initially on the gate structure.

NB: For the purpose of this survey, downstream will be defined as the water in the foreground as shown in Photograph 1 below (i.e. that level open to the sea) and upstream will be defined as water on the other side of the gate as shown in Photograph 1 below (i.e. the impounded Copperhouse Pool).

Photograph 1 General view of the gate, lifting frame superstructure, access footbridge, plant room and control cubicle of the vertical lift gate at Copperhouse Sluice
The gate is a steel fabrication consisting of a rectangular skinplate stiffened on the rear face by a series of steel castellated beam sections and small vertical web plates.

Photograph 2  General view of the front or downstream face of the gate showing the rectangular skinplate

The upper section of the skinplate above the tidal marks appears to be in very good condition with no evidence of degradation of the painting system.

The lower section of the skinplate below the tidal marks has large areas where the paint has been removed and widespread surface corrosion of the exposed substrate is evident (see photograph 3).
Photograph 3  General view of the bottom right hand corner of the front or downstream face of the gate showing the widespread corrosion on the skinplate

Localised measurements were taken and established that "pitting" or indentations up to 2mm deep were common.

The rear or upstream face of the gate appeared to be in a very similar condition to that described for the front or downstream face of the gate in that the areas above the nominal tidal marks were generally in better condition than those below.
Photograph 4  General view of the rear or upstream face of the gate showing the castellated beam and vertical web plate stiffeners

The horizontal castellated beams had accumulated a wide range of debris varying from seaweed to timber flotsam.
Photograph 5  General view of the rear or upstream face of the gate showing the accumulation of debris on the castellated beams
There was some very limited surface "weepage" of corrosion products around the castellated beams where the paint system had been damaged.

Photograph 6    Local view of the rear or upstream face of the gate showing the localised limited corrosion present on the castellated beams

The bottom edge of the gate fabrication has not been designed as a knife-edge and would be unsuitable to act as a sluicing structure without modification. This is because the current design of both the structure and sealing system would be prone to vibration.

The gate structure has plates closing off the open gate sections at each end.

This original carbon steel end plate has additionally been clad at some time post-commissioning with a bolted stainless steel plate over almost its entire length. The roller wheels originally fitted to the gate had also been removed. The roller gate has effectively been converted to a sliding gate by this modification.

However the axles to mount the wheels onto the gate had all been left in place.
Photograph 7  View of the end section of the gate showing additional "all over" plate with local cut-outs for original roller axles and two folded guide angles acting as front and rear load bearers.

The stainless steel plate itself has circular holes cut out of it to permit the original roller axles to protrude through.

The lowest section of original end plate that remained uncovered by the stainless steel plate had corroded badly.
Photograph 8  View of the end section of the gate showing extent of additional "all over" stainless steel plate

On top of the stainless steel plate at the extreme upstream and downstream edges are two folded and bolted stainless steel "angles".

The purpose of these angles is to act as load bearing guides in the absence of the original roller wheels. However, the design of the modification does not lend itself to load transference because of the use of slotted holes and tapered washers. The strength of the bolted detail is a concern and may not be fit for purpose.

The angles bear upon non-metallic bearing strips bolted into the upstream and downstream internal faces of the civil work guide. A difficulty with this detail is that a flat sliding face is screwed to a crowned rail face with a flexible sealant taking up the neutral voids. It is believed that this contributes to the damage found at lower sections (see civil work interfaces).
Photograph 9 View of the end section of the gate showing folded stainless steel angles and upstream and downstream bolt-on bearing / sealing faces

3.2 Civil Work Interfaces

The non-metallic bearing strips run the full height of the civil guide slot on both the upstream and downstream faces.

The upper sections of the bearing strips appear to be intact and in reasonable condition.
Photograph 10  General view of the upstream and downstream bolt-on bearing / sealing faces

However the lower sections of both the upstream and downstream sealing faces are badly damaged and in some cases, missing completely.
Photograph 11  Localised view of the damage apparent on the lower section of the downstream bolt-on bearing / sealing faces
The very lowest sections of the civil work guide are the worst affected, with evidence of extreme scouring, loss of material and build up of marine life.

Photograph 12 Localised view of the erosion damage and build up of marine life on the lowest section of the civil work guide slot

At the sill, there is a cast in sill beam that acts as the sealing surface for the seal along the bottom edge of the gate.

The surface of the beam suggests that it is made from stainless steel, although this is uncertain, and it appears to be in reasonable condition.

There is local damage to the harbour walls in the vicinity of the gate. No attempt has been made to evaluate this or assess the impact of potential sluicing operations. This should be considered by a qualified civil engineer.
Photograph 12  General view of the cast in sill beam
3.3 Gate Sealing System

The gate sealing system is intended to seal in both directions.

The system consists of two L shaped or “Hockey Stick” seals back to back that act full length down one end of the gate (against a plate mounted on the downstream lip of the civil work guide) across the cast-in sill beam and up the opposite side of the gate.

The L or “Hockey Stick” seal is an active seal in that it is “activated” by hydrostatic pressure impinging on the leg of the seal. The higher the load, the more the seal is pressed into the mating surface and in theory, the more effective the sealing. However, there are gaps between the side seals and their sealing faces.

Photograph 13 View of the end section of the gate showing the back to back L shaped or “Hockey Stick” seals and metallic clamp strip.

The only problem with this is that higher up on the gate (i.e. near to the free surface of the water when the gate is lowered), there is almost no hydrostatic loading on the seal. In these positions, the seal will probably leak slightly.
Looking at the lowest corners of the gate, the back to back seal turns through 90° and travels along the bottom edge of the gate.

Photograph 14 View of the bottom corner section of the gate showing the interface between the side and bottom back to back L shaped or "Hockey Stick" seals and metallic clamp strips.

The corner sections between the side and bottom seals have large gaps visible.

This means that the seal is not effective in this position and given the head acting at this point, that water will tend to jet through the gap and impact on the civil works behind. Over the course of time, this could lead to erosion of the civil works.

3.4 Lateral Gate Guiding System

The gate structure is guided laterally by two pairs of guide rollers on each end of the gate.

The rollers act against a plate mounted on the upstream lip of the civil work guide.
Photograph 15  View of the end section of the gate showing one pair of lateral guide rollers and the lateral guide plate that they act against

The rollers are thought to be manufactured by Brauer. They are approximately 200mm diameter and 50mm tread width.

3.5  Gate Lifting Gear

The gate structure is lifted and lowered using a motor-driven, steel-wire, rope-winches system.

The motor drives a grooved drum on which a stainless steel wire rope (of approx ¾ of an inch diameter) is wound.

The steel wire rope passes over a series of sheaves and pulleys at both ends of the gate and is terminated at a fixed point on the gate support superstructure at the motor drive end.

Thus as the drum turns, the steel wire rope is either paid out or wound onto the drum depending on the direction of drum rotation. This in turn therefore acts to either lower or raise the gate.
The pulley / sheave configuration basically means that the gate is raised or lowered at 25% of the amount of steel wire rope paid out from the drum.

Photograph 16 View of the gate actuation mechanism consisting of an electric drive motor, drum, steel wire rope and Slack Rope mechanism / switch

The steel wire rope leaving the drum is fitted with a Slack Rope mechanism consisting of a guide pulley and lever frame together with a switch.

This device is fitted to prevent the steel wire rope becoming loose on the drum in the event that the gate was being lowered, became jammed in its guides and could not be physically lowered further.

The steel wire rope exits through a slot in the roof of the protective enclosure.

The slot is protected by a moveable guard which moves as the steel-wire rope pays out from the drum.
Photograph 17 shows the steel wire rope passing under one pulley, up and over the pulley at the top of the gate support superstructure (not shown), back down under the other pulley and across to the corresponding pulley on the opposite side of the gate.

The motor and gearbox appeared to be in satisfactory condition and the operator did not report any problems with the operation or availability of the drive mechanism.

The steel wire rope appears to be serviceable and generally in good condition.

The pulleys and sheaves have been greased and were all found to rotate without slippage or sticking.

There does not appear to be any mechanism for preventing the wire ropes from becoming detached from the gate pulleys in a slack-ropes situation.

There is not an obvious method for renewing the wire rope without exposing persons to Health and Safety hazards of working at height.
3.6 Electrical Equipment

The majority of the electrical equipment is housed in a control panel in an adjacent plant room. Access to the control panel was not available and no reasonable opinion could be made as to its condition.

Photograph 18  General view within the motorised winch housing showing the electrical incoming supply and distribution enclosures

Additional electrical equipment is housed within the electrical enclosure.

The interior of the housing appeared to be dry and clean, with no obvious signs of moisture ingress.

Electrical enclosures are mounted directly on the internal wall of the housing. They were found to be clean and appeared in good order.

The enclosures themselves were not opened, so no opinion can be offered regarding the internal condition of the equipment.
The housing was fitted with an Emergency Stop switch to isolate the incoming power supply from the rest of the equipment.

The housing was fitted with an interlocking isolation switch mounted on the door aperture. This acts to isolate power to the equipment within the housing when the door is opened.

Photograph 19
General view within the motorised winch housing showing the interlocking door power isolation switch

The gate has a movement limit switch fitted to the front of the gate.

Photograph 20
General view of the gate movement limit switch

This switch is operated by a striker plate also mounted on the front face of the gate.
The position of many of the limit switches make them difficult to maintain safely.

Photograph 21 General view showing the limit switch striker plate with the gate in fully raised position.

4. ISSUES AND CONSTRAINTS

There were no issues raised by the EA staff whilst on site with regard to the operation of the gate. It is understood that the EA has some reservations of the use of the gate as a sluice from a number of viewpoints, including:
1. The gate is not currently suitable for sluicing
2. Using the gate as a sluice might cause damage to the adjacent civil works, which are listed structures
3. There may be Health and Safety implications for the public

Item 1 has been borne out by the survey, but could be made acceptable by modification.
Item 2 is a civil issue and is left to others.

Item 3 could be addressed by management and control modifications.

As it was not possible to obtain copies of the original gate installation drawings prior to the survey, the safety margin for the gate structure against the loads currently seen is indeterminate.

The effect of previously converting the gate to sliding operation will be to increase the loads in the winching system. It is unknown if this was taken into account. It is acknowledged that in general the gate is only operated under balanced head conditions.

Access to the original drawings would permit calculations to take place to substantiate the design load case for the original structure.

If no such drawings are available, it would still be possible to determine the approximate capacity of the existing gate by calculation based on the dimensions recorded during this survey. This work could be carried out, by agreement, if required.

Aspects of the previous gate modification to sliding operation are doubtful, however the risks associated with this appear to belong to the EA and surrounding properties which may be at increased flood risk.

It is not clear whether stop logs or other means of establishing dry working conditions around the gate are currently available. It is thought that there is no such existing provision. The elapsed time to remove and modify the gate would take it through at least one monthly tidal-cycle, this would expose Copperhouse Pool to some flood risk and would have to be carefully timed and coordinated. The EA may require temporary works to be put in place during this time. No cost allowance has been included in current estimates for such temporary works as they are unknown.

Should removal of the gate be required as part of any necessary remedial works, very careful planning will be needed as there are various site constraints such as the limited hard standing available within the existing EA site compound and also the close proximity of overhead cables. These issues would need to be addressed prior to any plan being made.

The gate is too large to be easily removed to another place for modification. It may be possible to place it directly onto a barge for removal via the harbour. Alternatively there is sufficient space in the adjacent car park to make modifications directly. All of the work envisaged to enable the gate to be capable of performing as a sluice could be undertaken under these conditions. Note that a tented, scaffold structure would be required, to contain painting contaminants.
5. RECOMMENDATIONS

5.1 Gate Structure

The existing gate structure itself appears to be in reasonable condition.

In order to continue to work effectively, some remedial work should be undertaken to curtail the spread of corrosion on the gate structure.

This would involve grit-blasting the gate in the areas affected by corrosion (namely below the tidal line) and re-coating the gate in accordance with the paint manufacturers instructions.

It may be possible to carry out painting works "in-situ", but it would be preferable to lift the gate out of its slot, lay it down somewhere close at hand and repair as required. By removing the gate and conducting the repairs off site it will aid the prevention of environmental pollution created by blasting and painting the gate.

The gate is not suitable for sluicing in its current form and structural modifications would be required along the bottom edge. Such modifications would require gate removal.

5.2 Civil Works Interfaces

The civil works interfaces generally appear to be in reasonable condition.

The exception is the two side gate guide slots.

In this area, there is significant loss of non-metallic gate bearing strips from both upstream and downstream faces of the side guides on both sides of the gate. This is probably due to the high friction forces developed when trying to move the gate when subject to hydrostatic loading. And, the poor mounting detail.

The conventional design for hydrostatically loaded vertical lift gates utilises rollers to allow the gate to move whilst under load without the detrimental effects of high rubbing friction. This obviously results in lower lifting forces, which will assist in keeping the operating loads applied to the lifting gear to a minimum. This in turn means that the equipment will probably operate reliably for longer as it is not overstressed.

It is not clear why the original design caused the rollers to seize, but for long term reliable operation of this gate the recommendation would be to return to the roller system.

In the light of the previous problems the axle, bearing and roller design should be considered in more detail prior to reinstatement.
In addition to the above, the bottom section of each of the side gate guide slots is suffering from excessive erosion of the concrete and also loss of section of the cast in steel guide. This would need to be repaired in any event.

Should the decision be taken to return to a roller design, it would be desirable to check the condition of the existing track faces within the side gate guide slots and make additional repairs (over and above those identified in the previous paragraph) if necessary to ensure a smooth and continuous running face for the rollers.

The real argument for returning to a roller design would be if the future use of the gate involved significant amounts of time acting as a sluice gate where the gate was moved regularly against a head differential.

The area of civil works immediately upstream of the cill could not be safely accessed. Whilst no obvious civil issue could be seen there is some element of unknown here.

5.3 Gate Sealing System

The gate sealing system appears to be intact with little damage evident.

There is, however, a gap within the seals at both bottom corners of the gate (probably exactly as originally installed) which is obviously a concern as these points are coincident with water at the maximum head.

Water spurting through these gaps will therefore travel at relatively high local velocities and will cause further damage to the built in parts and concrete surround over a period of time. For these reasons, it is recommended that this gap be filled or repaired as required to effect a continuous seal. Vulcanised corner seals are desirable.

The bottom seal detail requires modification if the gate is to act as a sluice.

5.4 Lateral Gate Guiding System

The lateral gate guide system appears to be working satisfactorily with no operational problems reported by the EA.

The rollers and mounting brackets were found to be in very good condition and do not require any remedial action.

5.5 Gate Lifting Gear

The gate lifting gear appears to be working satisfactorily with no operational problems reported by the EA.

The steel wire ropes appeared to have been changed recently and were in good order.
The motor and gearbox should, as a minimum, be inspected and subsequently overhauled to ensure that they remain in good working order. Should the equipment be found to be damaged, or irreparable, then replacement units will be required.

Wire rope drum bearings should be inspected and overhauled or replaced as required.

5.6  Electrical Equipment

The electrical equipment within the motor winch housing appears to be working satisfactorily with no operational problems reported by the EA.

A visual external examination of the electrical equipment revealed no obvious problems and all equipment appeared to be in good order.

However, in order to comply with current standards, it is strongly recommended that the electrical installation should be subjected to a Periodic Inspection Report (PIR) under the auspices of BS 7671 to ensure the safety of the equipment installed.

NB: No information has been made available to the surveyors to suggest that a current PIR has been issued for this site.

This inspection should be conducted by a competent NICEIC registered electrical inspector, who will issue a PIR (that remains valid for three years) to the Environment Agency.

The PIR generally assesses whether the installation is satisfactory or not by comparison to the requirements of BS 7671. It also recommends work that needs to be carried out to comply with the standard if the installation is deemed to be unsatisfactory.

5.7  Health and Safety

Items of a Health and Safety nature were outside the remit of the survey. However, it was noted that a number of issues are present at the site. These are obvious non compliances with handrail and access space requirements. There are also difficulties in maintaining much of the equipment by virtue of difficult access.

6.  CONCLUSIONS

The mechanical and electrical equipment installed at the Copperhouse Sluice vertical lifting gate is reported to be operating effectively and reliably by the local Environment Agency operations delivery staff.

However, it should be remembered that much of this equipment has not been changed since the original installation approximately 25 years ago. Most gate installations would be expected to have refurbishment intervals of around 25 years, hence it could be considered that refurbishment at this point was timely.
On this basis alone, it would be wise to plan for the systematic refurbishment of wearing parts within the equipment to ensure long-term reliable future operation. It is recommended that copies of the any existing record drawings should be sourced prior to any refurbishment work on site. Review of manufacturing data always assists in obtaining a better understanding of the aims of the original design.

The corrosion protection system for many parts of the equipment is now in need of refurbishment.

In terms of specific conclusions made for the equipment surveyed, the following notes are listed as applicable:

- The gate structure itself will require remedial action to refurbish the existing corrosion protection system. The use of sacrificial anodes on the gate to help prevent future degradation should be considered.

- The bottom section of each of the two side gate guide slots is in urgent need of repair. This will involve repair to the metallic section of the cast in guides and the local concrete as required. The use of sacrificial anodes on the metallic sections of the guide to prevent future degradation should be considered.

- The gap in the bottom corners of the seals should be filled or repaired as required to affect a continuous seal.

- Consideration should be given to the future possible usage of the gate. If the gate operation were to change to include sluicing, then there is a strong case for the re-instatement of the original roller design as this is the conventional design for a vertical lift sluice gate. It will be possible to achieve this with an improved design that is not prone to seizure.

- All elements of the electrical system associated with the operation of the gate should be covered separately by a dedicated Periodic Inspection Report for an Electrical Installation issued in accordance with BS 7671 — Requirements for Electrical Installations by an approved contractor or conforming body enrolled with the National Inspection Council for Electrical Installation Contracting (NICEIC).

- The bottom section of the gate will require reconstruction to enable sluicing/scouring.