Design of replacement vertical lift sluice gate for Kinloch Rannoch Weir

R. J. DIGBY, Kenneth Grubb Associates Ltd, Bournemouth, UK.
J. P. SELBIE, Enterprise Engineering Services Ltd, Aberdeen, UK.

SYNOPSIS. Kenneth Grubb Associates Ltd (KGAL) has been retained by Enterprise Engineering Services Ltd (EESL) of Aberdeen to design replacement vertical lift sluice gates for installation at Kinloch Rannoch Weir in Scotland on behalf of their ultimate client, Scottish and Southern Energy plc (SSE).

The design mimics the existing 1930s riveted gate construction using modern materials and joining methods. One of the challenges for the design team involves the need to design the gate to modern standards, whilst not exceeding the capacity of the existing dedicated lifting equipment on site.

Site load lifting limitations have also constrained the design of the gate to be a three part modular construction employing bolted seams to complete the construction. Further challenges have included the need to consider the effects of floods, waves and seismic loads on the structure.

INTRODUCTION

This paper describes the works undertaken by KGAL and EESL in the respective design and manufacture of the replacement gates at Kinloch Rannoch Weir on Loch Rannoch in Scotland. As part of the Tummel Valley hydroelectric scheme owned and operated by SSE, the three weir gates at Kinloch Rannoch Weir control the flow of water from Loch Rannoch. The gates are of the undershot design.

The gates themselves are around 78 years old and were originally designed, constructed and installed by Glenfield & Kennedy. Due to the age and condition of the existing gate structures, and issues relating to their capacity to withstand revised PMF and seismic loading requirements, SSE decided to instruct their term mechanical contractor EESL to design and install three replacement gate structures. EESL in turn retained the services of their chosen gate designer, KGAL.

Managing Dams: Challenges in a Time of Change. Thomas Telford, London, 2010

Figure 1. Photograph of Kinloch Rannoch Weir taken from downstream

PREVIOUS MAINTENANCE AND ENABLING WORKS

The gates and their operating systems have been maintained regularly by SSE over their life. Key items that have previously been refurbished are the headgear (original drive motors for the gearboxes replaced by Rotork Actuators circa 2006) and the roller trains, which have been replaced by stainless steel rollers and roller tracks (replaced circa 1985/6).

Figure 2. Photograph showing refurbished stainless steel roller train and fixed path.

In order to facilitate these current works, SSE separately commissioned KGAL to design stoplog guides to permit the installation of existing bespoke modular horizontal steel stoplogs on the upstream (and if required) downstream sides of the gates.

The bespoke modular horizontal steel stoplogs had previously been designed and manufactured by the KGAL/EESL team to enable SSE to utilise them across a wide range of different sites and different gate types.

The stoplog guides have since been fabricated and installed by SSE to enable the gate works to commence. A bespoke overhead gantry system has also been designed and installed by SSE to permit the installation of the stoplogs.

Figure 3. Photograph showing the bespoke stoplog installation frame

The SWL of the overhead gantry system, based on the maximum mass of a single stoplog, is 5 tonnes. It was agreed by the team that this overhead gantry system would also be used to install the replacement gates as separate craneage access to the site is difficult.

This has therefore provided the physical mass limitation for the design to enable the gate sections to be subsequently lifted into place.

Figure 4. Photograph showing the stoplogs installed on site

DESIGN OF EXISTING GATE

The existing gate follows a well-tried and trusted path in respect to the design of undershot water control gates of this vintage. The gate itself consists of a 7/16th of an inch (11 mm) thick rectangular steel skinplate (3m high x 10m wide) backed by a series of three horizontal stiffening truss assemblies formed from angles and rolled Tee sections. The gates are of a riveted and bolted construction.

The end posts of the gate incorporate a vertically pivoted rocking beam assembly on the downstream side that ensures even load distribution onto a roller train that is suspended from the rear of the gate end post. The rollers then run on a fixed steel path that is built into the cast iron support frame.

The mass of the gate and supporting fixings is counterbalanced by cast iron counterweights installed in the end piers of the civil work structure. Thus the torque required to lift and lower the gates is minimised.

The gate skinplate edges are sealed against the cast iron built-in frame using a “staunching tube” which is suspended from the upstream side of the end post.

Figure 5. Photograph showing the existing gate #1

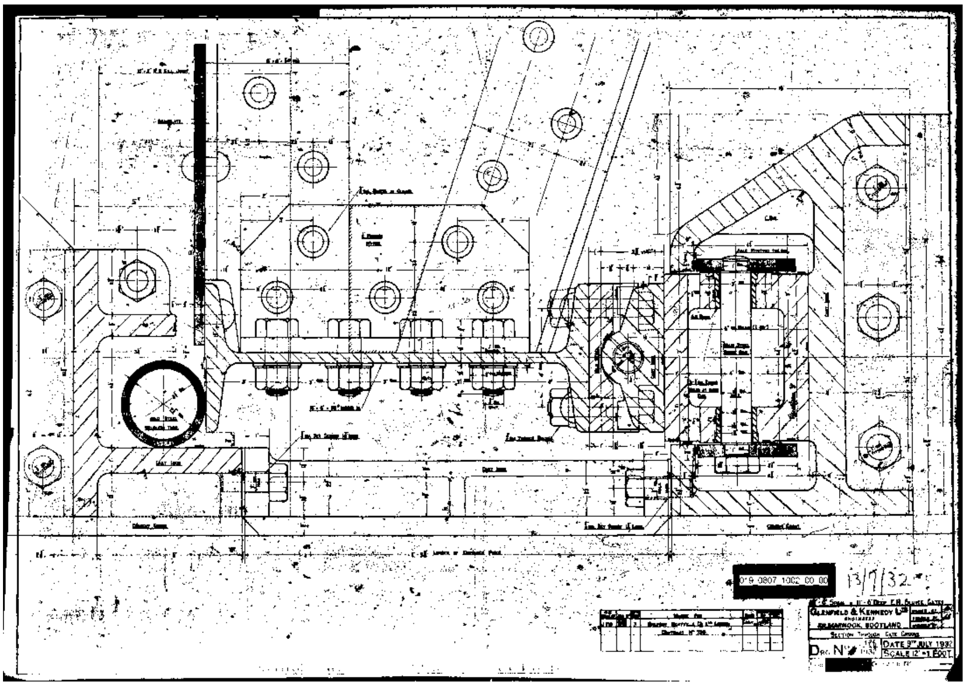

Figure 6. Original drawing showing the details of the guide frame and gate ends

DESIGN OF REPLACEMENT GATE

Several key issues were highlighted prior to the commencement of design, including:

- the requirement for the mass of new gate assembly to be no greater than that of the existing gate, as SSE wished to retain the existing refurbished lifting gear without modification;
- the requirement for the gate to be manufactured in several parts and subsequently re-assembled in situ, due to the SWL limitation on the overhead gantry system and the physical constraints of the existing civil works, as the existing gate had been installed prior to the fitment of the headgear, which was to remain for the new gate;
- the requirement for the gate to be designed to meet modern standards and provide an adequate design life based on the latest wave and flood modelling data available.

A design brief detailing the primary loads acting on the gate (including hydrostatic, self weight, impact, wave, friction and installation) and all required combinations of the primary loads was then prepared and agreed.

Appropriate partial load factors were derived from relevant standards including BS 5950 and included within the design brief. This document then formed the basis of the design intent.

Latterly during the design process, SSE specified an additional requirement for the gate with regard to the ability of the structure to withstand seismically generated forces. This resulted in changes to both the design brief document and the substantially completed design works.

The basic premise for the new gate design was to split the gate into three separate sections at the trusses, bolt them together and attach them to the retained end posts. This effectively meant taking the original Tee sections and splitting them at their centreline into back-to-back bolted angles.

For ease of identification, the sections have been designated Top, Centre and Bottom. The Top section has been modified to change the original trash / ice deflectors from flat strips to angle section in order to provide more robust support for the top edge of the gate.

Due to the physical limitations on size of section capable of installation (in the cross-weir direction) and the inability to guarantee the long-term performance of the existing end posts, it was decided to design and manufacture replacement end posts.

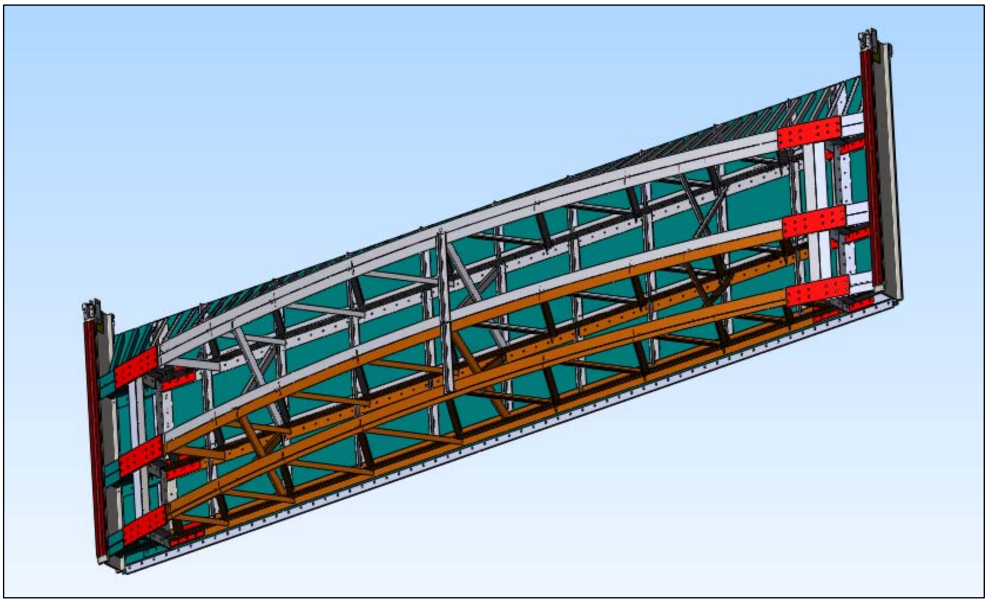

Figure 7. Three dimensional model of replacement gate design

Each of the two new stiffened end posts are attached to the ends of the three horizontal gate sections via a new vertical bolted joint, which utilises a percentage of fitted bolts to act as both dowel locators and shear load resistance.

The vertical joint faces are bolted directly together and are also supported by additional horizontal fishplates across each joint secured using fitted bolts on both the back and front of the gate for additional stability. The horizontal section joints also utilise a percentage of fitted bolts to act as both dowel locators and to provide shear load resistance.

The skinplate thickness has been designed at 10mm. Whilst this is a slight decrease in thickness compared with the existing gate, it enables the overall mass of the gate to be maintained within the design limits, given the necessity for the additional skinplate support required to adequately stabilise the structure under the specified loadings.

Structural calculations to underwrite the design have been undertaken generally in accordance with the relevant parts of applicable design codes including BS 6349, BS 5950 and DIN 19704 as required.

The relevant seismic loads utilised in the design have been calculated using the methodology proposed by C. N. Zangar [1].

Additional work to provide the fundamental frequency of the gate has been carried out using the finite element method. The frequency has been determined as approximately 6 Hertz.

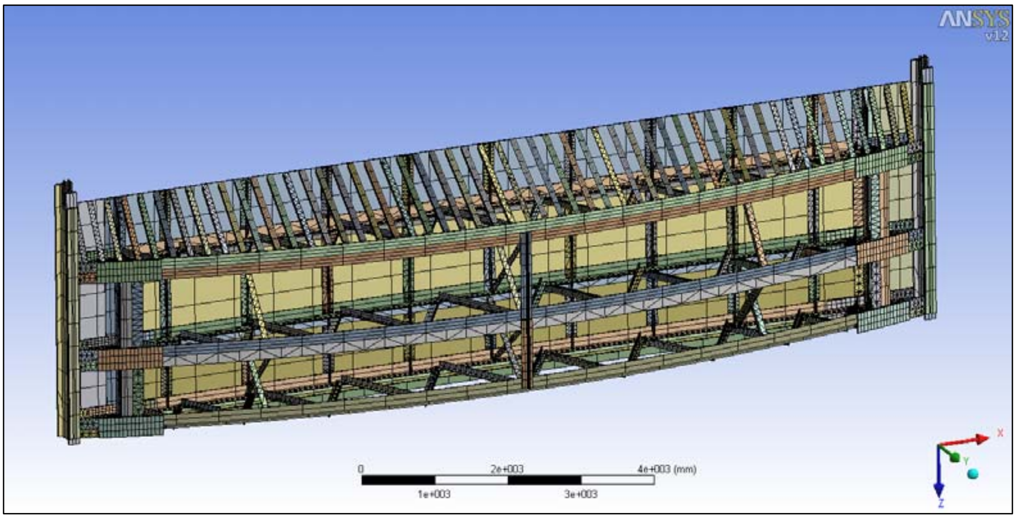

Figure 8. Finite Element Mesh of replacement gate design

CONSTRUCTION AND INSTALLATION OF REPLACEMENT GATE

The construction of the replacement gate #1 has begun and EESL is well advanced in the process at the time of writing. It is anticipated that construction of gate #1 will be completed by the end of January 2010 with installation following soon after.

Figure 9. Photograph showing construction progress on gate #1

It is intended to cover the construction and site installation issues in a later paper.

REFERENCES

[1] Zangar, C. N. (1952). *Hydrodynamic Pressures on Dams due to Horizontal Earthquake Effects*. Engineering Monograph No.11, United States Department of the Interior, Bureau of Reclamation, Denver, Colorado.