INNOVATIVE RAILWAY EMBANKMENT PROJECT
IN DIFFICULT ENVIRONMENT

Author:  Sylvain Laporte, Eng.
Regional Director – Rail – Canada East
AECOM
1010, de la Gauchetière St. West
Suite 1400, Place du Canada
Montreal (Quebec) H3B 2N2
Tel :  514.390.2600
Fax:  514.940.6868

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ABSTRACT

This paper relates to an innovative procedure devised by AECOM and CN engineers to reinforce a weakening railway embankment across a hydroelectric reservoir in Northern Quebec. Built some 70 years ago, the single-track main line embankment reached an advanced state of deterioration in 2006, as a result of systematic ice erosion caused by seasonal fluctuations in water level. There was an urgent need for widening the berm and stabilizing the slopes to prescribed standards, without traffic interruption. The steepness of the rake on both sides of the 4-mile pier made the use of conventional on-track side-dump equipment slow, expensive and treacherous. Sensitive fauna, exiguous site access and harsh winter working conditions were aggravating factors.

The task consisted of developing an alternate plan for sourcing, trucking and placing some 250,000 cubic yards of riprap while, at the same time, creating new alluvial to replace the existing fish spawning beds at the foot of the embankment. To gain access to pier, a new road and a new bridge were built, traversing a mountain on purpose to quarry the required fill material. For loaded trucks to run alongside the track clear of trains, it was decided to widen the berm on both sides. Circuits were established for articulated trucks to loop back and forth by turning around over level crossings, dumping in front of a backhoe used for placing the riprap along a 1:1.5 slope. A meticulous safety plan was implemented, involving training, signalling, communication, as well as ready access to barges, divers and helicopter rescue. In addition to restoring the embankment and its environment, the operation yielded new service roads for pier and track inspection and maintenance.
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1. INTRODUCTION

Carried out in a remote area with very limited access to the work site, the rehabilitation of CN's railway pier at Hydro Quebec's hydroelectric artificial lake at Reservoir Blanc has not had the visibility and public recognition of large infrastructure projects in urban areas. Notwithstanding, it provided a unique opportunity to showcase the skills and expertise of Canadian railway engineers in a highly specialized field of endeavour. In maintenance-of-way, track slopes subject to repeated wave wash are among the most difficult to rehabilitate and stabilize. The operation becomes traumatizing when these conditions are found on a long narrow pier traversing a critical body of water.

The CN main line (designated as the Saint-Maurice Subdivision) extends over a distance of 256 miles, from La Tuque in Upper Mauricie to Senneterre in Abitibi. It is the only rail line for passenger and freight transportation across this large and distant territory. At Mile 39, the single track is laid on a 4.0 mile embankment along the edge of the St. Maurice River, situated on the fringes of the hydroelectric reservoir which spreads over a surface area of 31.6 square miles.

The embankment, built at the same time as the reservoir in the early 1930’s, is made up of granular random fill material. Over the years, the original 1:2 slopes were strongly eroded by ice sheet abrasion and cyclical fluctuations in water level. In October 2005, topographic and bathymetric surveys carried out by CN revealed a condition of concern for efficient railway operations, which could entail service interruptions and temporary line closure. A project was immediately developed to widen and stabilize the embankment with rip rap.
Undertaken in the spring of 2007, the fieldwork was completed in the summer of 2009. In the opinion of all concerned, the project turned out to be a very successful initiative not only from a technical point of view but also from an environmental and social perspective.

2. PROJECT DESIGN

The originality of the method used to rehabilitate and improve the embankment is a source of pride for both CN and AECOM. Within the railway, it was acknowledged as a remarkable achievement worthy of consideration for award in the category engineering innovation. For AECOM, it gave a welcomed opportunity to participate in all phases of project development, thereby gaining valuable experience and recognition as a leading edge service provider in the railway business.

CN and AECOM engineers teamed up to identify the root causes of the problem, evaluate various corrective measures, determine the most cost effective approach, and develop a safe and efficient procedure for carrying out the works. The task consisted of restoring the side slopes of the embankment by adding a layer of riprap-run from the base up (16 to 60 inches) completed by a layer of riprap consolidation (30 to 48 inches) to widen the berm. In Figure 1 below, the slope before and after are depicted by the black and red lines respectfully. Figure 2 below gives an indication of the narrow width of berm and the advanced state of deterioration of the side slopes. Repair works may appear relatively simple at first glance. But put in the context of the site, it was quite otherwise.
Figure 1 Type cross-section of embankment showing slopes before (black arrows) and after (red arrows) the rehabilitation works.

Figure 2 Picture of the abutment before repair works, showing the narrowness of the berm and the steepness of the side slope.
Given the limited access to the site, consideration was first given to using on-track equipment for hauling and dumping the riprap along the slopes of the pier. This method was abandoned mainly for safety and economic reasons. In this particular case, the possibility of a tipper toppling over was deemed too risky. Given the weak berm and the waterlogged slopes, a sudden discharge could indeed cause a fracture of the shoulder. The use of side dump cars was also deemed inappropriate from a cost perspective, in view of the material waste envisaged during the dumping operation. With no means of placing the rip rap on the steep slopes, it was felt that the kinetic energy of the stones would cause considerable material to tumble outside the stabilization zone. Finally, delays and additional costs were expected as a result of mutual interference between the work trains, the passenger trains and the freight trains.

These unusual circumstances led the Project Team to devise a procedure for hauling the riprap by truck and placing it directly on the embankment slopes by backhoe. First, the track shoulders were widened and turnaround crossings were built for trucks to run back and forth, dumping the riprap along the edge of the pier. A backhoe loader operating from the other side was then used to put the riprap in place along the side slopes. This operation, which is shown in figure 3 below, entailed a rather sophisticated programming and signalling procedure to optimize productivity while ensuring safety. The oversized shoulders increased the width of track subgrade from 20 to 42 feet, while reducing from 1:2 to 1:1.5 the slope ratio. Hence, this feature did not increase the overall cost of the project while now providing CN maintenance gangs good access to the track on the full length of the pier.
3. PROJECT IMPLEMENTATION REQUIREMENTS

The choice of this construction method posed the challenge of locating an acceptable rock deposit to quarry the riprap within an economic hauling distance, as well as determining a suitable route for transporting it the work site. The latter comprised the construction of a bridge across the channel between the shore and the pier, in addition to a material and equipment storage area.
These requirements called for geological and topographical surveys in dense forest to carry out preliminary designs and secure the required certificates from the responsible authorities. They also called for extensive dialogue and consultation with the native population and the various Federal and Provincial Ministries concerned. The most extensive compensatory measures came from the Department of Fisheries and Oceans to offset the loss of fish habitat along the pier. These entailed the construction of 23 spawning on a surface area of 2,550 square yards along the pier, as well as a hatchery basin of 10,735 square yards inside the material and storage area.

4. SAFETY CONSIDERATIONS

The presence of a large water body on either side of a live track catering to both passenger and freight trains presented numerous risk factors. These called for the implementation from the outset of many safety measures which, in the opinion of all concerned, contributed the most to its success. Not a single accident or serious incident was reported at any of the work sites throughout the entire duration.

The safety management system put in place required the active participation and adherence of all involved, on a daily basis. Briefings were held each morning to raise, discuss and solve issues constituting potential hazards. The plan featured a single controlled access point to the track work site, and was based on effective communications using long-range radio and sentinels relays placed at strategic locations. Workers were always notified of imminent blasting and train passage. Two sentinel boats with qualified personnel in drowning first aid were always on site to provide timely rescue. Simulated rescue exercises were carried out at regular intervals
and results discussed in subsequent briefings. As explained previously, temporary road crossings were built every 1,000 feet to allow safe turns for dump trucks and one-way directional traffic on the pier. In addition, each truck was equipped with a camera for backup movements as well as safety equipment in case of fall in water (life jackets, masks, oxygen canister, mass, etc.). CN has always been particularly strict about safety precautions for all work performed over or near a watercourse. This project was no exception: all participants were required to take theoretical and practical training courses before given access to the work site.

5. ENVIRONMENTAL IMPACTS

In environmental terms, the Project Team was well aware of the precautions and measures necessary to protect the environment and offset the side effects. It follows that the Project Team was very concerned by all aspects related to sustainable development both at the design and construction stage.

In implementing this project, all steps were taken to obtain prior authorization certificates from regulatory agencies, including (1) the Department of Environment and Sustainable Development for the operation of a quarry and the execution of heavy civil engineering near water resources; (2) the Land Management Division of the Department of Natural Resources and Wildlife for the construction of a road in forestry environment; (3) the Department of Mines of the Ministry of Natural Resources and Wildlife for a request to exploit mineral substances at a quarry; (4) Transport Canada to carry out a project affecting of navigable waters; (5) the Department of Fisheries and Oceans to implement a project detrimental to the fish habitat with regard to the
compensatory works on the spawning grounds and nursery, a monitoring program was developed to verify the physical stability of the reconstructed zones, to check the vegetation and habitat diversity in the hatchery pond, and to verify the presence of fish in reconstructed zones. As specified in the DFO authorization, monitoring will be carried out on three occasions over a period of five years. Figure 4 below gives an aerial view of the hatchery basin. The abutment pier and railway track is seen in the background.

**Figure 4  Aerial view of the hatchery basin to compensate for the loss of fish habitat along the pier**
6. SOCIAL AND ECONOMIC FALLOUTS

From a social point of view, the project provided some opportunities to bring about infrastructure improvements to the benefit of the community in the region. To minimize construction costs, simplify approvals and authorizations, and provide direct access to the work site, the Project Team aligned the 10 mile project road from the village road at Rapide-des-Coeurs to the railway pier along the foothills of a mountain, where the riprap could be quarried by blasting. By so doing, acceptable fill material could be obtained within a short hauling distance. More importantly, the project contributed to improving the basic regional infrastructure by upgrading and extending an existing trail, building a new road through the quarry rock cut, then extending it to the pier across the channel. Throughout the construction, this road was used by contractors and other project participants. Today, it is used by tourists and local residents. Aligning the road through the quarry provided a less expensive source of material, given that the cut does not need recycling. It can be argued that by integrating the project infrastructure with the environment it traverses in a useful way, the project contributed to sustainable development.

7. CONCLUSION

Faced with significant technical, operational and environmental constraints, the CN-EACOM Project Team opted to reinforce the deteriorating railway pier using an unusual and technically challenging construction method. It relied on a combination of backhoe and articulated dump truck equipment for mechanical placement of riprap on the embankment slopes. It proved to be a cost effective way of correcting a most precarious operating condition, resulting from decades of relentless ice erosion. By creating new
alluvium for fish spawning beds, it contributed to the preservation of aquatic life. By implementing a rigorous safety plan, it prevented accidents and kept workers harmless throughout its entire duration. By improving the access roads, it contributed to enhancing local infrastructure and recreational facilities.

The project achieved its technical objectives with minimum disturbance to passenger and freight trains on the main line track. It was carried out with due regard and strict adherence to directives from the various authorities concerned. It was completed on time and within budget. It provides a good case study for practitioners in the railway discipline and a useful approach to project engineers faced with similar problems. All in all, it is deemed a success to the credit of both CN and AECOM.