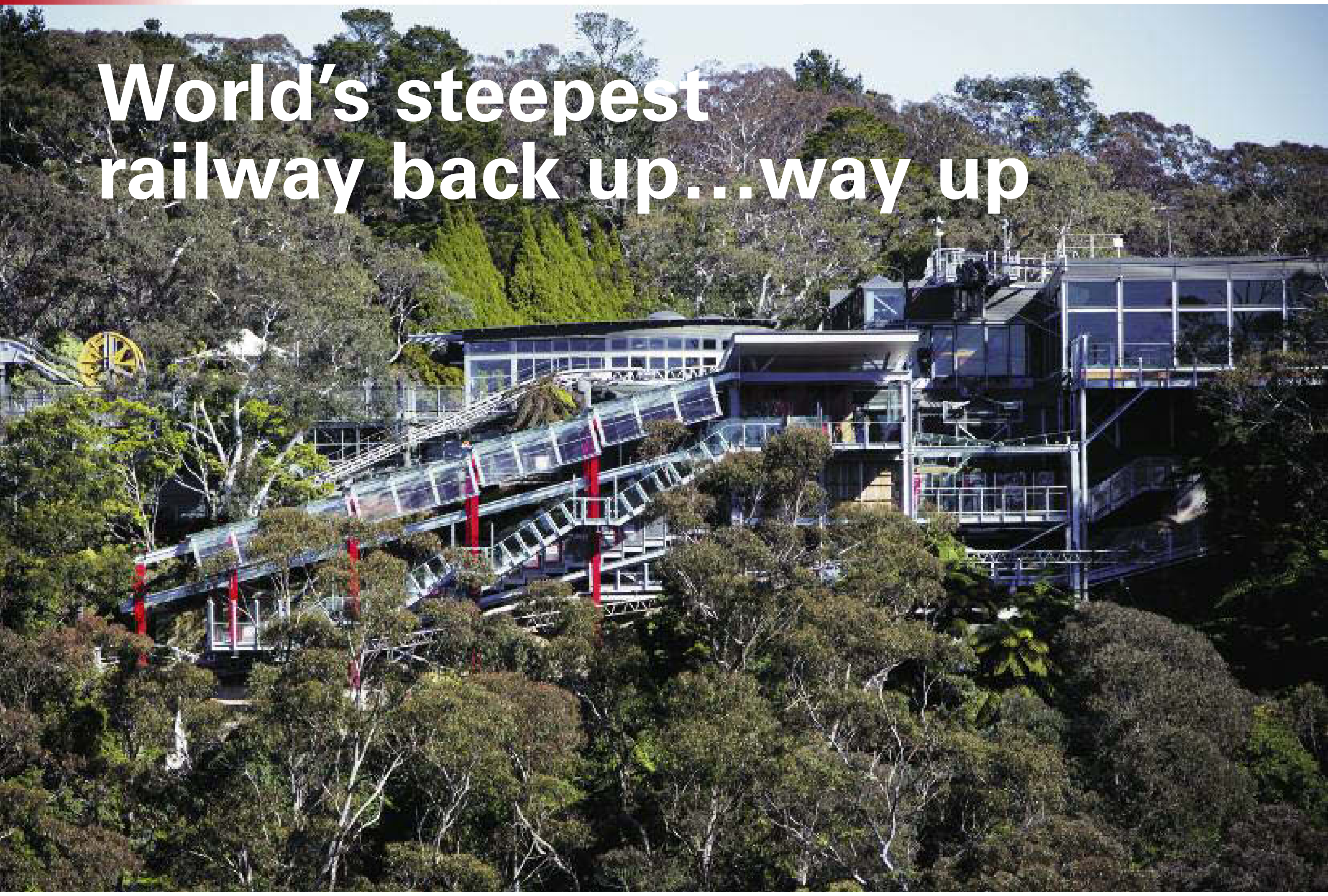
World's steepest railway back up...way up



The world's steepest incline railway at Katoomba in NSW's Blue Mountains underwent an extensive redevelopment recently to accommodate new train carriages and upgrade facilities at its top and bottom stations as part of an overall site master plan originally developed in 1996.

The railway at its steepest is 52 degrees on its journey down to the Jamison Valley floor 310 metres below. It is the last of the three major Scenic World attractions to be totally revamped with the Cableway aerial cable car completed in 2000 and Skyway suspended cable car upgraded in 2005.

Located on the edge of an escarpment adjacent to a national park, the railway travels through a 70 metre-long inclined tunnel and rainforest capable of carrying 84 passengers.

Joint Managing Director of Scenic World, **Anthea Hammon** said the upgrade was timely.

"We were in a situation where we needed to rebuild nearly most of the train as its mechanical design life was nearing completion," she said.

"To further improve visitor enjoyment and functionality of the ride we decided to undertake this major upgrade of the railway equipment and railway infrastructure together with a complete overhaul of the Top and Bottom Stations."

The upgrade involved replacing all foundations and track, stabilising the existing rail tunnel, constructing new top and bottom stations, modifying the existing workshop/winch room, upgrading power supply and replacing winder equipment and rail cars.

All up, the project called for the fabricator, Combell Steelfab to supply 205 tonnes of structural steelwork for the loading and unloading platforms and stairs for the top and bottom stations, service walkways, bottom station towers, module walkways, equipment platforms and a balcony extension, totalling 17,855 individual steel components.

But what really complicated the task was the client's requirement to minimise disruptions to operations and allow Scenic World to continually operate during construction. Not only was this a requirement to ensure continuity of operations to the site's two other existing rides, but it was also required that the railway be constructed while the existing structure remained largely operational.

Sinclair Knight Merz (SKM) contributed to both previous projects and was engaged as overall Project Manager for the new work.

"The need to provide business continuity for the client in terms of suitable staging solutions was very important," said SKM Project Manager, **Arnold Cheng**.

"In order to achieve this goal with due consideration to the terrain, materials handling and existing brownfields structures of the site, the staging logistics and construction methodologies had to be integrated right from the beginning of the design process."

He said that as the railway was to be constructed in the same alignment as the original structure, maintaining operational continuity required installing the foundations for the track directly adjacent to the existing railway foundations that remained operational throughout most of the redevelopment, whilst the construction team navigated steep, rugged and loose terrain.

SKM led Safety by Design workshops prior to construction using the NSW Workcover CHAIR Workshop process to facilitate and streamline designs for staging, constructability, operations and maintenance. During the workshops the design, construction and operations teams were brought together to identify the design issues and risks and to develop integrated solutions.

Mr Cheng said that overcoming creep loads associated with the presence of thick loose colluvium in the top soil layer of the slope observed by SKM geotechnical engineers presented further challenges. Such soil moves slowly down slope over time causing an additional load (creep load) to the proposed foundations.

"This caused some concern for the proposed use of micro-piles since these slender concrete piles are usually chosen for their ability to take compression but have a low capacity in bending," he said.

SKM worked with the piling contractor to develop designs using circular hollow sections (CHS) to sleeve the concrete piles for increased bending capacity. Many iterations of the design were considered using various combinations of diameter widths, available strength grades, CHS tubing wall thicknesses and double sleeving to optimise manoeuvrability and handling of materials.

The design allowed for additional sacrificial thickness for corrosion as well as specification for galvanizing as the CHS steel was to be installed into soil.

The track support structure consists of approximately 300 metres of preassembled steel sections. While a long list of load cases were considered, they fell into four main groups being In-Service Ultimate Loads, In-Service Working Loads, Maintenance Ultimate Loads and Maintenance Working Loads. In each category, all combinations of a subset of load cases were assessed including downhill operation, uphill operation, emergency braking and wind loading.

The programming of structural steel supply was staged through regular planning between the steel fabricator and detailers to achieve two to three day turnarounds. The provision of 3D models from the architect and engineer in drawing interchange format (DXF) enabled the supplier to fast track processing. An anti-clash checking facility used was critical to de-risk the fast tracked steelwork to service the difficult location. In coordination with the consultant's design intent, Southline Drafting also used Building Information Modelling (BIM) Software.

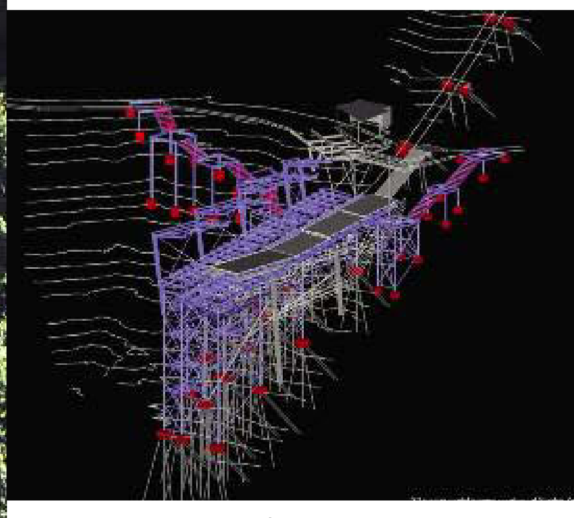
General Manager of the project's prime steel contractor Combell Steelfab, **Paul Comin** said fabrication accuracy was most crucial where the steelwork needed to precisely match up with timber decking on loading platforms and treads on stair rungs.

Fabrication accuracy was also important for the construction of tower supports at the bottom station. A series of nine modular tower sections were initially fabricated as individual items, sent for galvanizing, then returned back to Combell's workshop. Each tower module was preassembled with aluminium floor grating, handrails, caged ladders, weighed and tagged for delivery to site.

In considering options for installing steel for the bottom station, crane installation was deemed incompatible with the client's requirement to minimise downtime to the existing railway as it would impose higher costs and longer times for trades working onsite.

A Bell UH1H helicopter was selected with a maximum lifting capacity of 1200kg to handle the installation with some sections having to be lowered into place weaving through the complex web of the existing steel support structure. This required the structural engineers to carefully design the modules within strict weight limits in close liaison with the steel fabricator and shop detailer. The complexity of the installation onsite by helicopter required high 3D accuracy especially for the bottom station's eastern platform columns.

A staged approach to design and construction was undertaken to allow safe public access to parts of the existing platforms. Lacking 'As Built' records in some of the existing structure, SKM utilised 3D laser scanning technology to survey the top and bottom stations and the railway tunnel to allow more accurate modelling of existing features.



3D design modelling of bottom station structure

The 3D point cloud data was also used to create TruView files allowing users to scan a 360 degree field of view onscreen.

Mr Cheng said that these tools not only aided design, but also enabled SKM to consider staging implications in workshops with the contractor and client during the ECI design phase and again throughout the construction phase. This allowed the overlay of existing terrain and structures with the proposed designs.

Careful consideration was given to access walkways for each stage of the modules' installation, connection details with guides to receiving members, draw/guide cables and tolerance considerations to allow for the difficulty of precise lifting with a helicopter. SKM was able to borrow a technique from the Swiss railway supplier that used an extra metre of each cable to be available on the ground to thread through holes at the base to help guide installation as each section was lowered into position.

The top station consists of three levels; service, viewing and queuing platform plus an architecturally distinctive roof structure. The main feature columns supporting the top station were mill ordered 400WC212. The loading and unloading platforms consist of fabricated channel frames. Workshop drawing coordination was critical due to the timber decking system.

In keeping with the pre-existing architectural language of the site, the design is dominated by the use of exposed steel members which give an industrial feel to the facility. To achieve the architect's vision, a higher than normal level of structural and architectural coordination was undertaken.

"The architectural language of the site reinforces the unique location and man's attempt at taming nature," Director of PMDL Architecture & Design, **Peter Doddrell** said.

"Expressing the structural engineering and mechanics componentry of the rides reinforces the sense of this unique tourist attraction."

Together the architect and structural engineers came up with sizing of key members and design of connection details that met both the structural performance requirements and suited the architect's design intent. An example of this can be seen in the use of visually 'light' elements in supporting the glass roof to give it the effect of floating over the structure. The design utilises angles rather than more conventional sections in supporting this glass.

"One of the most rewarding things about this project was to actually go through that process of looking at the entire engineering infrastructure and thinking about solutions that really worked for our client," Mr Cheng said.

"We did this by using the knowledge of our entire consultant team to come up with well considered designs and construction methodologies suitable for the difficult terrain and access to construct safely and provide solutions that work for our client to maintain its continued operations whilst considering its future operations and maintenance."

Project Team

Client: Scenic World

Project Management: Sinclair Knight Merz

Architecture: PMDL Architecture & Design

Railway Equipment: Garaventa Doppelmayr

Managing Contractor: Grindley Construction

Project Engineering (Structural, Geotechnical, Electrical): Sinclair Knight Merz

Steel Fabrication: Combell Steelfab

Steel Detailing: Southline Design and Drafting

Galvanizing: Galvanising Services (Nepean Group)

Aluminium Handrail/Grating: Webforge

ASI Steel Distributor: Southern Steel

ASI Steel Manufacturer: OneSteel

Project Photography: Brett Boardman Photography