Inclined Elevator
for Bulgari Resort

by Mark Galvin

Overview of Resort Project

Bali, Indonesia, located on the southwestern tip of the Jimbaran peninsular atop a plateau 170 m above the Indian Ocean, is the site of a cliff-top resort. The resort has around 60 villas, and the overall design reflects a mix of traditional Balinese combined with sophisticated contemporary Italian architecture.

Main access to the resort is via road, but the cliff-top location also provides a physical barrier to the sandy beach and surf below. The rugged limestone cliff plunges almost vertically for about 40 m before the grade steadily reduces to about 20° over a slope length of about 200 m. The challenge for Access Automation Ltd. was to design, construct and install an inclined elevator that could provide the link between the resort and beach. The job required a design incorporating a self-leveling system for the cab as it traverses the three rail gradients at 1 mps. The client's specification demanded a high level of smoothness and car stability so that guests feel at ease when riding the elevator.

During construction, rope access was the only option. In addition, the volcanic rock of the cliff face is difficult to work with due to its voids and porosity. All foundation excavation work was carried out by hand by local laborers. Furthermore, the site is adjacent to the ocean, making for a prime marine environment for corrosion. All mechanisms and electrical controls need to be able to cope with this. Due to the height of the cliff, using a crane onsite was not possible. The entire installation was carried out by hand with the aid of some "Kiwi ingenuity." The elevator was designed and assembled from the top (winch end) down. In this way, the rail formed the main access way, and the cab chassis was

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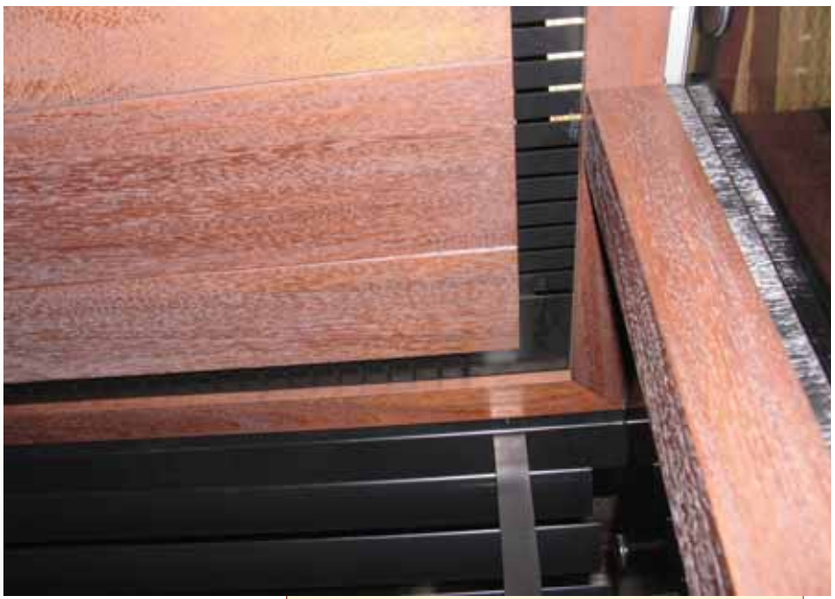
Opposite page:
Top: A view of the sea from the top landing
Bottom: The cab at its bottom terminus

This page:
Top: The rock conditions on the site
Middle: An aerial view of the cliff and site before construction began



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initially fitted with a purpose-built crane so that the elevator could "build itself" down the hill. The entire 170-m-long structure was assembled in this manner over a five-week installation period.

Once Access Automation obtained accurate topographical data from the project surveyor, the detailed design was carried out using the SolidWorks 3D design package to ensure that the structure would fit in the site. These computer-aided-design (CAD) models are also used to generate the laser-cutting files for the prefabricated rail transition sections. Next, the entire rail structure was manufactured in New Zealand as a kit that could be bro-

Top left: A sheave assembly and bogie cutout
Top right: Detail of the cab's roof venting
Bottom: A close-up of the rail structure

Inclined Elevator Specifications

Rail geometry:
32 m X 59°
84 m X 43°
55 m X 25°

Total rail length:
171 m

Total gradient change:
34°

Cab payload:
500 kg

Cab bogie system:
Auto-leveling design by Access Automation

Design speed:
1 mps

Cab design:
Custom glass and hardwood cab design by client's architect; manual sliding door with interlock

Winch system diameter:
760-mm drum; 16-mm rope; 6-X-19 construction

Motor:
18.5-kW induction with inverter drive

The view from the resort

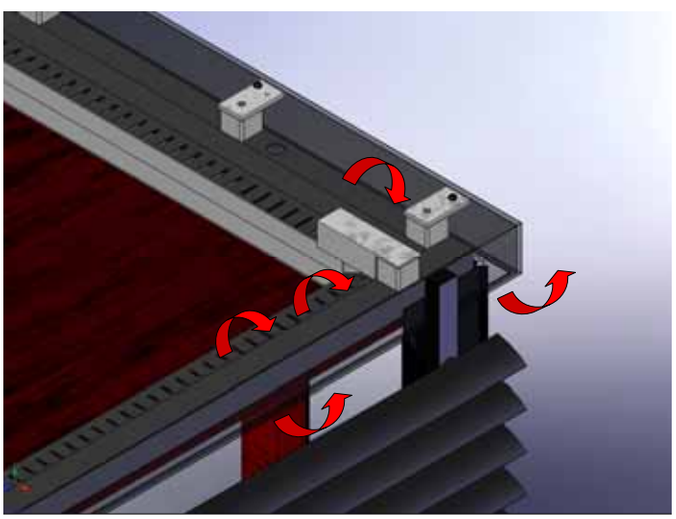
The machine room

ken down into 5-m-long modules for sea freighting. These modules were bolted together on site.

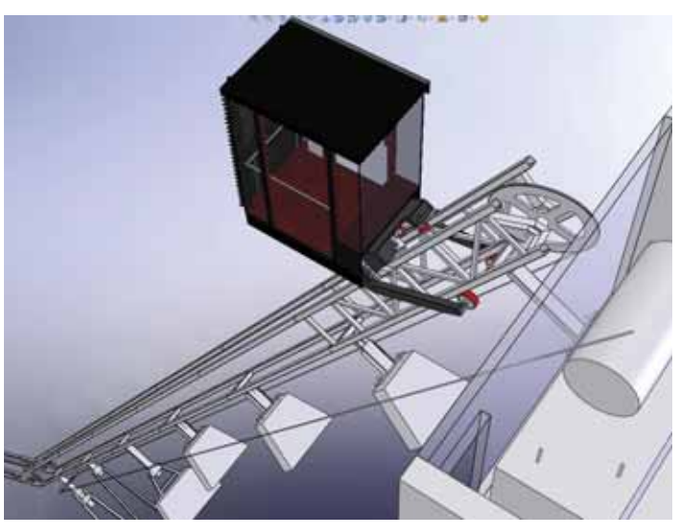
Elevator Technical Innovations

Access Automation has developed a system for keeping the cab level as it travels over changing rail gradients. Based on a simple failsafe mechanical system, the car can travel at its full design speed of 1 mps around a bend without causing any tilting or feelings of acceleration to the passengers. As a backup safety system, a tilt switch is installed inside the cab to safely shut the elevator down if the cab should ever go out of level.

Unlike vertical elevators, inclined elevators can generate high lateral accelerations if the safety gear or an emergency stop is activated. Lateral accelerations can be hazardous to standing passengers, as they are more likely to fall over. In a multi-gradient installation like this one, special design attention had to be given to controlling these lateral accelerations. To achieve this, the cab was mounted on a horizontal sliding frame, the motion of which is controlled by hydraulic dampers.



How the cab's cavity roof with ventilation works



A section of the CAD model

As the cab passes over the concave bends in the rails, the rope is threaded under capture sheave rollers to keep it parallel to the rail line. The mechanical design of this detail is complex, as there was very little room to mount these sheaves between the floor of the car and the rail. The sheave assemblies are monitored by a safety switch to check for correct rope engagement

Because of the complexity of the rope management system, it was more practical to use a single rope with a high factor of safety (about 14:1). Even so, when the car is at the bottom, there is about 210 meters of rope deployed. To prevent the cab level from creeping up or down as passengers enter or leave, an active control system is used to keep the car level. A closed-loop control system is used on the motor inverter so that subtle

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changes in motor/winch drum position are possible while the car is being loaded.

Since the site is exposed and subject to wind-blown debris, and considering the complex rail geometry utilized, the use of a separate trailing electrical cable was considered inappropriate. Instead, in-car controls are achieved with a combination of a failsafe radio link and power cables installed inside the main wire rope.

The project specification called for natural ventilation inside the cab. Because of the high ambient temperatures in Bali, a number of special design features were used on the cab. These included a cavity roof with ventilation, tinted glass, louvers to provide shading and large cutouts in some window sections.

The style and finishing details of the cab were specified by the project architect, Antonio Citterio and Partners S.r.l., while Access Automation was responsible for its construction details and manufacture. The cab is constructed from toughened glass and finished internally with hardwood.

Left: The cab at its bottom terminus
Top right: Sunset over the resort

Mark Galvin is director of Access Automation (www.accessauto.co.nz).

Credits

Hotel operator: Bulgari Resorts and Hotels – Bali
Owner: P.T. Jimbaran Villas
Project managers and construction cost consultant: Davis Langdon and Seah Indonesia pt
Project architects: Antonio Citterio amd Partners S.r.l
Contractor: PT. Nusa Raya Cipta
Project engineers: PT Meinhardt Indonesia