

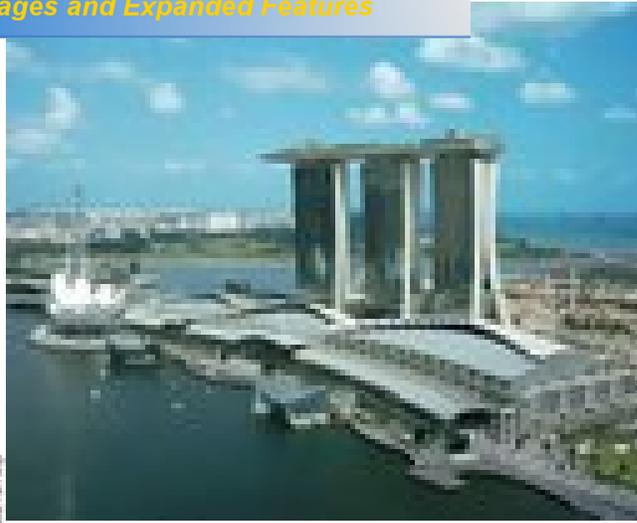


# Marina Bay Sands Integrated Resort, Singapore

Nomination for 2015 FIDIC Awards

# Integrated Resort, Singapore

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Arup provides a wide range of consultancy services for this 15.5ha integrated tourist resort, including, civil, structural and geotechnical engineering design together with traffic consultancy, project management, security, fire, façade, acoustics consultancy and site supervision. Totalling of 561,000m<sup>2</sup> the complex features three 55-storey hotels towers with over 2,600 rooms and suites topped with 1-hectare landscaped Sands SkyPark<sup>®</sup> which bridges across the towers, offering 360 degree views of the city and facilities such as swimming pool and restaurants.



The podium roof comprises long span roofs enclosing the casino, theatre and MICE facilities. They span up to 120m and exhibit highly-complex stepped, wave form surfaces. The retail arcade is sheltered by various lightweight canopy structures, some of which have plan dimensions of 45 by 90m, and are connected to pedestrian bridges spanning 60m. The canopies have a double curved geometry and are cable-stayed back to the podium concrete structure. The podium consists of approximate

120,000m<sup>2</sup> of Meetings, Incentives, Conventions and Exhibitions space which includes 54,000m<sup>2</sup> exhibition halls and a 5,900m<sup>2</sup> column free grand ballroom that can hold at least 6,000 diners for banquet, or 11,000 delegates for a convention. These facilities are vital components to the development of the tourism industry in the areas and propel itself as a leading business hub in Asia. Completed in 2010, the Marina Bay Sands had been providing one of a kind leisure experience to visitors in Singapore. In addition to 100,000m<sup>2</sup> of hotel, retail space and restaurants, the iconic lotus-like Artscentre Museum above also hosts a variety of international exhibitions, while two state-of-art 2,000-seat theatres stage Broadway shows and other special events.

## Innovation

Innovation made up every bit of the project. Located by the waterfront, the site geology generally comprised a layer of sand fill, overlaying a thick band of soft marine clay over old alluvium formation. The team had to come up with some very innovative types of excavation systems. The general excavation depth for the project is up to 18m below ground and 35m at maximum.



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Its ups to 120 meters in diameter and a fourth "peanut" with retention system allowed the construction of permanent basement to be in a prop-free environment.



The 38m wide and 340m long SkyPark is the world's longest habitable cantilevered observation deck, and has now become a symbolic icon for Singapore. To overcome the challenge of building one hectare of garden and extending the length of four and a half Airbus A380s in the sky, numerous options were considered. In the end, post-tensioned box girder is used to achieve the purpose. The maximum depth of the box girder is 10m at the end support from hotel tower and generally 3.55m deep.



The dynamic properties of a structure were particularly hard to predict as there were many structural elements and architectural finishes that contributed to this. To improve the response of the cantilever under dancing crowds, reducing the box girder taper near to tip of the cantilever was used. It stiffens the structure reducing the response due to dancing crowds. This modification resulted in a significant improvement in performance for dancing

crowds and some reduction in response due to wind loads. Large tuned mass dampers that act in a similar manner as shock absorbers were incorporated within the SkyPark's belly. Lastly, large scale vibration tests were also conducted to verify the design with over 150 participants involved.



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### Professional excellence

The design team members came from many offices including Boston, Brisbane, Melbourne, Hong Kong, Shenzhen and Singapore. For its work on the scheme design, the Boston office had the advantage of being close to Safdie Architects; while Arup Australia worked on the consultancy associated with risk, blast and security. Hong Kong office was responsible for the traffic consultancy and the dynamic behaviour of the structures, notably the SkyPark. At the same time, Hong Kong office also supervised the overall performance and the civil works design, while the detailed superstructure design was a collaboration between Singapore, Shenzhen and Hong Kong. Arup Singapore was involved in fire, acoustics and façade engineering designs, and together with representatives from Hong Kong, responsible for the day-to-day liaison with the client and contractors to ensure proper implementation of the designs. This project demonstrates how Arup's global resources respond to project design and management challenges, as in this project where the architect was in the US and the client and building site were in Singapore.



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The firm deployed expertise across four continents, and made a virtue of the different time zones to overcome geographical restraints and facilitate continuous design development through real-time co-ordination between the parties. Alongside its comprehensive civil and structural engineering experience, Arup also leveraged on its expertise in specialties such as materials, dynamics, risk engineering, bridge engineering, and frequently involved the range of skills within its Advanced Technology Group.

Construction sequencing was another big challenge; it included both top-down and bottom-up methods. Since the works involved many different disciplines and trades, the procurement packaging and interfacing between them required serious consideration so as to achieve and complete the works within the constrained time-frame. The heavy lifting operation for the construction was amongst the highest strand jacking operations ever undertaken in the world, and combined construction methods used in both buildings and bridges. It was a great achievement to the design and construction team for hoisting over 7,000 tonnes of steelwork 200m above ground in 13 weeks. Arup's cross-continental collaboration contributed significantly to the project's success, overcoming challenges related not only to construction issues but also the severe global financial crisis that happened during construction.



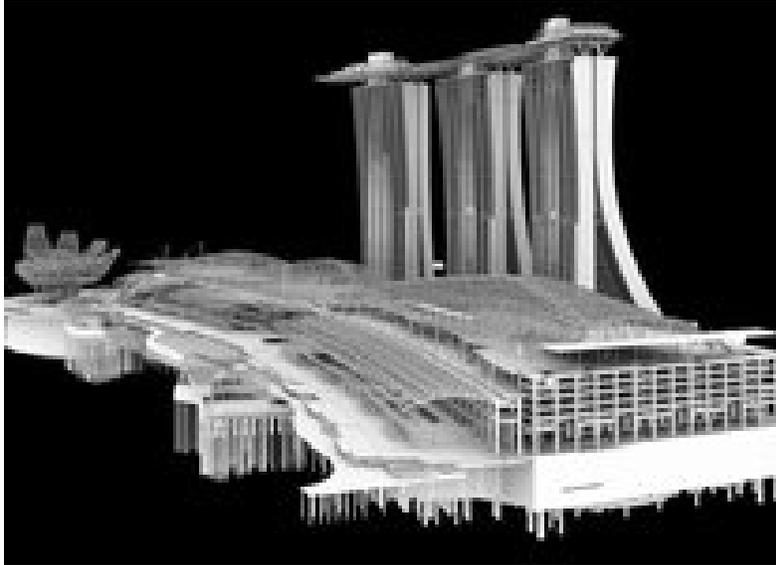
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### Principle of Transparency and Integrity

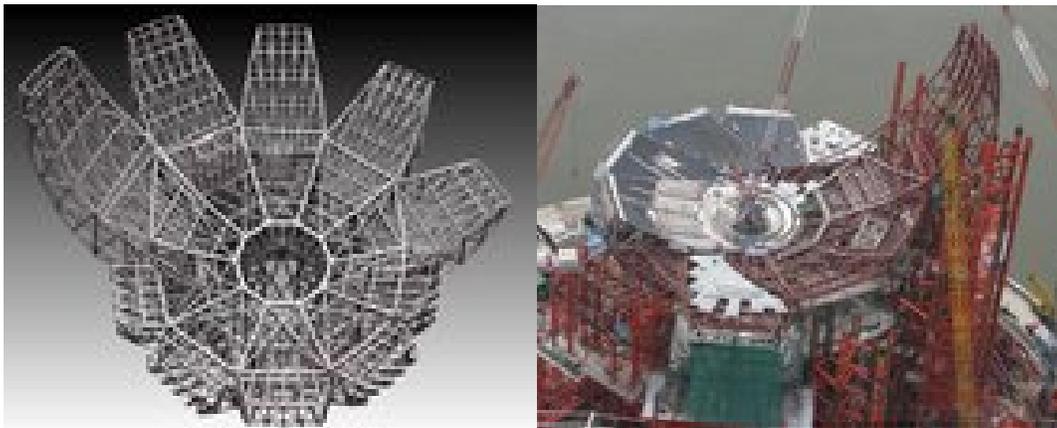
The entire design of the Marina Bay Sands Integrated Resort is an open book, especially with the help of Building Information Modelling (BIM). One can view every details of the project, from the grade of concrete used in a column to the dimension of the exhibition hall, with simply a few clicks. The integration of BIM model with structural analysis software also enhanced the overall design process for the project.

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of the three 55-storey hotel towers has a unique geometry, e of the hotel. This creates an open continuous space and atrium at ground level. BIM was extensively used to resolve complex coordination and documentation issues amongst designers and consultants arising from unique and complex geometry of the towers. The 3D structural analysis model was essential to create a realistic modelling capable of estimating the complex behaviour of the towers, deformation, wind induced movement, and elements stresses.



At the northern end of the development, with the appearance of a lotus flower, was the most geometrically complex structure in the development. The highly complex geometry of the museum required Arup to adopt innovative 3D parametric modeling technologies. The use of these techniques provided a significant reduction in modeling time, better coordination, visualisation of the complex steelwork and improved communication with the client. The conceptual and schematic design were carried out in our Boston office and developed in Melbourne office. Hong Kong office took up the role for detailed design and construction of the structure.



Advanced technology including X-Steel, Rhino models, Microstation Structural Triforma 3D model was used for the production of drawings and coordination with other parties. These software also enabled real-time interchange between analysis software and documentation

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design. As the design was well-presented to the contractor for their fabrication works, request for information from contractors was substantially reduced and it helped the overall construction programme of the Artscience Museum.



## Sustainability

The MICE facility is the single largest building in Singapore to be conferred the Green Mark Gold Award by the Building and Construction Authority in Singapore. Extensive precast elements were introduced by Arup in the design which aimed at achieving a more sustainable construction. It also significantly reduced wastage in concrete construction and the overall construction time was reduced.

A district cooling plant was integrated within the development, the second one within the Marina Bay Area. The district cooling system makes more efficient use of precious water and power resources, thus enhancing the green credentials of the development as well as improving the quality of the indoor environment. Comparing to the in-building chiller plants, the district cooling system is nearly 80 percent more efficient. Another distinct advantage of the system is that it saves money and space as conventional chiller plants and cooling towers are built on top of buildings. Rainwater is collected on the roof of Artscience Museum® in a rain harvesting system and cascades into a pool below. The water collected is recycled in the building's flush water toilet systems. Moreover, delayed-action, self-closing taps and constant flow regulators were installed in the bathrooms in the public areas to minimise water usage. Water consumption is reduced by more than 350 million litres of potable water annually in comparison to conventional fixtures and fittings. Overall, Marina Bay Sands Integrated Resort saves enough water to supply more than 800 households in Singapore every year.

To reduce the carbon foot print of the project, the team made an effort to reduce actual travelling for coordination meetings with external parties by using advanced technology for communication, such as video conferencing. See "N" Share facilities for sharing ideas and providing responses to particular problems to clients, architect and contractors.

## Conclusion

The project is technically challenging in almost every aspect and stretching the limit of engineering. In responding to this challenge, Arup adopted new and innovative technologies that push the boundaries of current software and systems. We pulled together a design team of global skills from four continents to communicate effectively and deliver outstanding outcomes to meet with the client's needs. At the same time, tremendous care was demonstrated to the surrounding community to achieve sustainability for the overall construction.

Today, Marina Bay Sands Integrated Resort is a remarkable icon in Singapore and act as a successful model for how construction project shall be delivered nowadays, ultimately it serves to revolutionize the practice of construction for the next decade.