



Capability Statement

Immersed Tube Tunnels

Delta Marine Consultants

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Delta Marine Consultants (DMC) was founded in 1978 for the purpose of providing consultancy, project management and engineering design services to clients on a worldwide basis. The company has expertise in the fields of urban infrastructure, large-scale transport infrastructure, ports and harbour development and coastal engineering. DMC holds strong links with the construction industry through its parent company, the Royal BAM Group. This contributes to the ability to provide solutions to practical problems and to blend innovation with reliability in design.

DMC has been rebranded into 'BAM Infraconsult' and is working under that name in the home market. DMC is still used as a trade name for international projects and referred to as such in this Design Capability Statement.

DMC has well over 300 employees working in various offices worldwide. The head office is in Gouda (the Netherlands) and apart from several other offices in the Netherlands, local offices are also located in Singapore, Dubai, Jakarta and Perth. DMC is or has been active in a great number of other countries on project basis, often together with BAM contracting companies.

DMC and Immersed Tube tunnels

DMC's long tradition in designing immersed tube tunnels dates from the early days, well before it was formally founded as an independent design company. Originating from one of the few construction companies that are capable of building and immersing immersed tube tunnels, our engineers have been closely involved in many projects worldwide for more than half a century. Decade after decade, we have built a lifetime of experience, passing skills and knowledge through many generations of engineers, while simultaneously, continuously improving the technologies to keep up with the latest developments in the field.

DMC's long tradition in this field includes almost 50 projects worldwide, comprising both steel and concrete tube tunnels. Regardless of which phase of a project we are involved in, we always involve our in-depth knowledge of the whole design and construction cycle. Our services do not stop after the last drawing. During construction and marine operations our engineers are often part of the staff on site.

DMC is used to teaming up with construction companies for both Construct-only and Design-and-Construct immersed tube tunnel contracts. Working closely together with our sister companies such as BAM Civiel and BAM International, who are experts in concrete, infrastructural and maritime construction, we can ensure our designs are not only feasible, but also constructible and cost-effective. Our engineers are trained to understand the consequence of each design choice from a construction point of view. Having worked for owner-clients, DMC engineers are used to keeping an eye on the functionality and quality of the end product.



Client Orientated Approach

The often demanding projects related to infrastructure development require a genuine understanding of the clients' needs and strategies to support and facilitate decisions making on the most economic approach in view of capital investments and life cycle costs. DMC, through its close involvement in construction projects of its sister companies, is constantly challenged to develop the safest and most cost effective solutions. In that technical details are transferred to straight-forward solutions, striving to reduce construction risks to a minimum. Due to the wide experience and the interdisciplinary approach by DMC, valuable input can be provided from concept stage to construction design.

Design quality monitoring is carried out at various levels and includes expert panel meetings in particular for multifaceted projects and/or innovative designs.

DMC staff is familiar with the relevant international standards and guidelines, including the oil and gas industry and related classification societies. Lead engineers actively participate in national and international work groups of engineering associations.

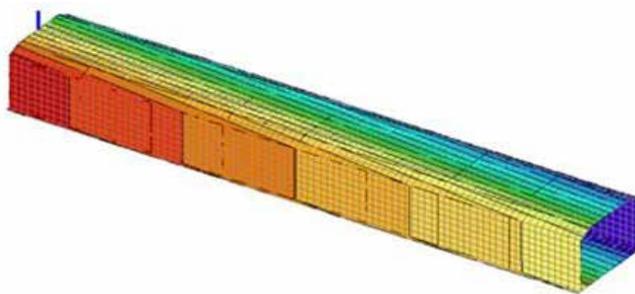
Regular advanced training is provided in-house, supplemented by external seminars to increase knowledge and expertise focussing on new standards and latest scientific developments.

Immersed tube tunnels, What We Offer

With its broad knowledge and detailed expertise of immersed tube tunnels, DMC is able to cover the whole project life cycle. Conceptual designs, feasibility studies or detailed designs: DMC can do it all. Working for a contractor or for the owner of the tunnel: DMC has done it before. Permanent tunnel design, temporary works design, immersion engineering: DMC has proven skills.

Civil Design, Maritime Structures and Geotechnical Engineering

Our departments for Civil design, Maritime structures and Geotechnical engineering can design to any code or standard. Our experience includes a.o. FEED, consultancy, detailed design and design review. The design of temporary works such as bulkheads and ballast tanks is also often part of our scope.



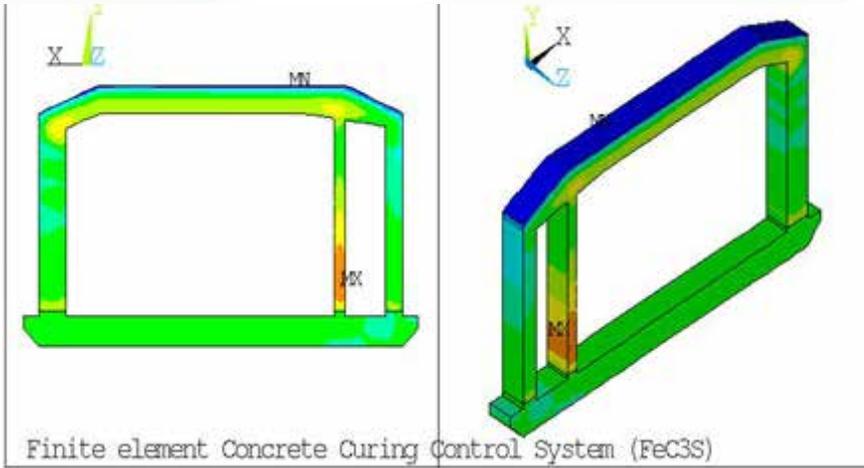
Roads Design, Rail Design and Technical Installations Design

By involving our Roads design, Rail design and Technical installations departments, we are able to make an integrated tunnel design, managing the interfaces between disciplines. To ensure an optimal and cost-effective design, while in parallel reducing client risk.



Concrete Technology

Our Concrete technology department designs fit-for-purpose concrete mixes, to ensure watertightness and meet any other project-specific requirements, taking into account local regulations and availability of materials. Special mixes can be tested in our “in-house” concrete laboratory. In-house developed software is used to model heat and strength development during concrete curing/hardening and to design cooling systems for the purpose of monitoring and controlling early age cracking. We are, in fact, one of the pioneers in concrete cooling and watertight concrete technology.



Steel- and Mechanical Engineering

Our Steel and mechanical engineering department is specialised in the design of temporary works and equipment such as immersion pontoons and access towers. We also provide support in the co-ordination of third-party equipment designers, the procurement process and supervision during fabrication.

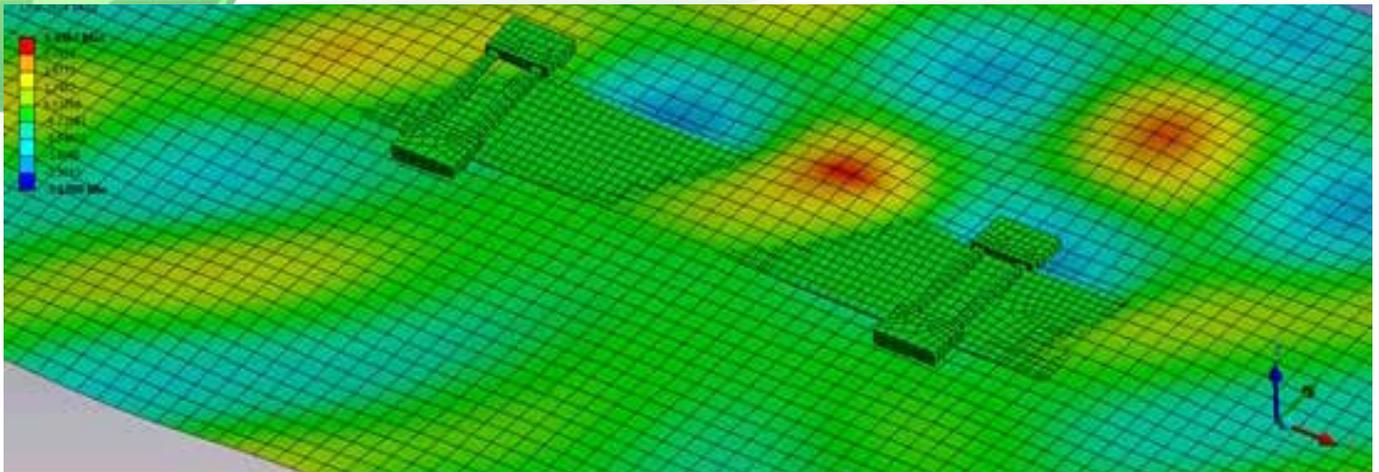
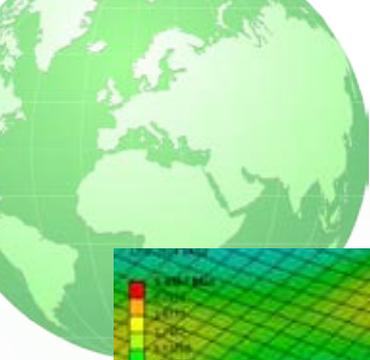


Draughting and visualisation

Our draughting department makes construction drawings, visualisations and animations in the 2D, 3D, 4D environment or higher. As one of the early users of this technology, BIM is used intensively for clash detection and preparation of marine operations. The models can then be used to provide the survey teams with the coordinates of each point of the tunnel element in the final position as well as at every moment during construction and marine operations. The 3D models can be linked to the construction schedule and cost estimates. Our office in Jakarta is specialised in 3D rebar drawings from which bar bending schedules are extracted.

Coastal engineering

Our Coastal engineering department provides specialist knowledge, e.g. design of the rock armour on top of the tunnel. During the preparation and execution of the marine operations, our coastal engineers advise on water related aspects such as tides, waves, currents, salinity and siltation. We have our own water laboratory in which we perform tests, for example to determine the wave response of a floating element. We are also able to investigate the behaviour of the tunnel element by numerical modelling. Other services include e.g. calculation of ship induced forces and design of temporary mooring and fenders for the tunnel elements.



Project Support

Our department for Tender strategy supports joint ventures to win construction contracts. During construction, our Infra management department minimises traffic congestion through optimisation of construction sequences. The interest and perception of stakeholders is managed by our Stakeholders communications department. The RAMS/Risk and Systems engineering departments manage risks, interfaces and requirements. Our Relatics system analyses, allocates and manages project requirements to control the process of compliance throughout the design and construction process.

Integrated Approach

An integrated approach is one of the key factors to successfully design, construct, operate and maintain a tunnel. More so than with other civil structures, all aspects are inter-related. The design requirements of all MEP-installations needs to be integrated with the civil works design from the start. Interfaces with construction equipment such as a TBM needs to be considered from early design.

Having all relevant design disciplines in-house, DMC is able to manage the full design scope, including the co-ordination of services by external specialists. Our experience is that the best way to control the interfaces between design, construction and all other disciplines is to have the design team embedded in the project team. DMC has been part of integrated teams for decades and has built up extensive experience and knowledge on how to structure, manage and execute multi-discipline designs within these teams. All disciplines are integrated into the design while the design is integrated with the construction operations.

International Experience

DMC has been involved in projects on all continents; regions include North and South America, Africa, Asia, Middle East, Australia and Europe. DMC maintains a steadily growing overseas office strategically located in Singapore, which efficiently cooperates with DMC branches in The Netherlands as well as servicing clients in the region independently. In 2013 a new DMC branch was opened in Jakarta to serve the increasing number of large projects in the area. Most recent branch openings are in Perth, Australia and Dubai, U.A.E. All DMC offices work closely together and facilitate the formation of international project teams to best suit specific project demands. DMC arranges for frequent exchange of staff throughout the organization for training purposes, to learn and benefit from each others work methods and to familiarize with colleagues.

We liaise with skilled partners to complement our expertise and use local knowledge as required to maximise the benefits for our clients.

DMC has been involved in immersed tube tunnel projects in The Netherlands, Germany, United Kingdom, USA, Ireland, Greece, Norway, Denmark, China, Turkey, Belgium, Sweden and Brazil.

Willems Rail Tunnel, Rotterdam

Client: Municipal of Rotterdam and Nederlandse Spoorweg Mij. (Dutch Railways)

Period of services: 1987-1995

The tunnel replaced an old bridge and established a main rail connection between the northern and southern part of The Netherlands. The four-track train tunnel runs under the bed of the river Nieuwe Maas, passes Noorder-eiland and Koningshaven, and goes 280 m into the southern bank of the river Maas. The closed section of the Willemsspoor Tunnel is 2,796 m in length, has an average width of 27 m and a height of nine metres. Eight 120-metre-long concrete elements for the closed part were cast in a construction dock in Barendrecht, towed to Rotterdam and submerged in a dredged trench. The rest of the tunnel was built using the open construction pit method. The technology used included diaphragm walls, cement-bentonite walls, combi walls and sheet pile walls, fitted with grout anchors on site.

DMC did the detailed engineering for both the immersed and the cut-and-cover part of the tunnel. Part of the engineering of the immersed tunnel was the immersion methods. The engineering of the cut-and-covered part included special ground stabilisation and complicated measurements to cope with noise and vibrations restrictions in the dense urban area with ancient buildings.



Third Harbor Tunnel, Boston

Period of services: 1993-1996

As part of the Boston's Central Artery project, the Interstate Highway 93 is diverted and the overhead roadway structures in the city centre are transferred to the underground. The Third harbour tunnel in Boston, later denoted the Ted Williams tunnel, was built under Boston Harbour, running from South Boston to East Boston / Logan Airport.

Interbeton (now BAM International) was part of the joint venture that won the contract for:

- Construction and installation of the 12 tunnel elements of typical American steel-shell design
- Design and construction of a cofferdam to connect the first element with the ventilation building.

The tunnel elements are designed in a binocular shape. Each tube comprises a steel shell with an interior concrete ring and outer pockets for concrete ballast. The steel and concrete rings form the structural parts of the element. In absence of a suitable shipyard near the tunnel location, the contractor decided to build the steel part of the tunnel elements in a VLCC dock in Baltimore and transport them to Boston, 700 miles over the Atlantic Ocean.

As part of the contractor's joint venture, DMC worked on the immersion engineering, sea transport and design of the extraordinary cofferdam. DMC initiated the successful transport of the tunnel elements on a modified submersible barge, and the alternative design of the unbraced cofferdam of 74 m in diameter and 27m depth (the largest ever built in the world).



Lee tunnel, Cork

Client: Tarmac Walls Joint Venture

Period of services: 1997

BAM Civiel was awarded the engineering and execution of the total immersing operations for the Lee Tunnel project. The works comprised the floating-up, transportation, immersing and sand flowing of five closed elements together with one open segment. DMC provided engineering support during the tender, preparations and execution, for the marine operations and sand flow.



High speed railway tunnels, the Netherlands

Client: Dutch ministry for traffic and water

Period of services: 2000-2005

The high speed railway link from Amsterdam to Paris passes the rivers Oude Maas and Dordtsche Kil by immersed tube tunnels. Each tunnel has a length of 3 km and consists of 7 immersed tubes (each 150 m long), closed cut-and-cover segments and open ramps. The joint venture was awarded a contract for the design, construction and installation of both immersed tube tunnels including the cut-and-cover parts and open ramps.

It took only 5 years for the design and construction of both tunnels. DMC played a key role in the joint venture. The design manager from DMC had the lead over the design team comprising 70 designers. Many DMC engineers contributed to the design, preparation of marine operations and site engineering.

The tunnels had to be designed on a differential settlement of 0.75 mm in very bad soil conditions and large surcharge loads. Special dowel structures (14 MN) were developed between the segments. Special aspects were: deep cofferdams, heavy combi-wall and bracing structures, large amounts of several types of steel and concrete piles, reduced thickness of underwater concrete, cut and cover sections, 150 m long immersed tunnel elements, air pressure reducing and ground shafts, temporary works for construction and marine operations, design of platforms and interior layout, architectural buildings, fire protection, finishing of the tunnels, interface management and technical cooperation between the design team and 5 construction teams, realisation in a very short time with complex contract conditions. All these activities were on site.



Bjørvika tunnel, Oslo

Client: Statens Vegvesen

Period of services: 2005-2008

As part of the redevelopment of Oslo, traffic is transferred to the newly built Bjørvika tunnel in order to make the space above ground available for housing and recreation. The tunnel is 700 m long and is the first immersed tube tunnel in Norway.

The six tunnel elements were constructed in a dock in Bergen. Due to the small sizes of the dock, only two tunnel elements could be built at the same time. The tunnel elements were 112 m long, 9 m high and 27-41 m wide. The weight of each tunnel element was 25,000 – 35,000 ton.

Spring is the favourable season for offshore towing. This means that before every spring, two tunnel elements had to be ready for towing, including temporary works. Each tow took five days (400 nautical miles) over sea before the port of Oslo was reached. For this purpose many physical model tests have been performed to determine the wave response of the tunnel elements.

BAM Civiil was part of the joint venture responsible for the construction and installation of the six tunnel elements, including the design of the temporary works. DMC designed the bulkheads and made the floating calculations.



New Tyne crossing, Newcastle

Client: TT2 (HSBC, HBOS, Bouygues)

Period of services: 2008-2010

With the New Tyne Crossing a new connection was realised to cope with the increasing traffic problems in and around Newcastle. Due to the choice for an immersed tube tunnel, the depth can be far less than the adjacent bored Tyne Tunnel. Consequently the ramps are much shorter and therefore the loops are not necessary anymore to develop sufficient length.

The tunnel has one traffic duct for two lanes and one escape / service duct. The immersed part consists of four tunnel elements, each 90 m long, 15 m wide and 8.5 m high. The weight of a tunnel element is 10,000 ton. Due to the asymmetric cross section, the eastern wall had to be extremely thin in order to have the tunnel elements float horizontally. This was a challenge for both the structural design and the construction.

The tunnel elements were built in an old dry dock with very limited dimensions. There was only 1 m available between the tunnel elements. Two tower cranes above the edges of the dock were used for the major part of the logistics. Due to the limited depth of the dock, the tunnel elements could only be towed out of the dock making use of the extreme tides of more than 5.5 m. Every two weeks there was a two hour window with a sufficiently high water level to get the tunnel elements out of the dock.

BAM Civiil was part of the joint venture responsible for the construction and immersion of the four tunnel elements, including sandflow. DMC had the lead over the site-based engineering team and was responsible for the design of the temporary works. DMC also advised the designer of the permanent tunnel on immersed tube tunnel related aspects. During preparation and execution of the marine operations DMC took part in the team as technical superintendent.



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