CASE STUDY

PROJECT

JIZAN FLOOD CANAL

OVERVIEW

Jizan Flood Canal

Saudi Arabia

Saudi Aramco

The largest reinforced concrete structure using glass fibre reinforced polymer (GFRP) was completed recently in Saudi Arabia. The 21 km flood mitigation canal was built in Saudi Arabia.
This challenging construction was undertaken by the Jizan Complex Projects Department.

The hydraulic and structural design was carried out by AECOM. A concrete lining was decided as the best option considering hydraulic performance and optimal land use. The canal was designed using Eurocodes (EN standards), pre-EN standards revisions of the British Standards (BS), and other design standards and manuals.
For the original design a 200 mm concrete slab was determined to be the best option based on the following design and operation criteria:
The channel is fully loaded with a 2M water column; Maintenance vehicles with 10.5 tonne axle load.
Thermal and shrinkage crack width limited to 0.3 mm per BS 8007. The original design life was 50 years.
To minimize the risk of sulphate attack, the concrete mixture was designed to comprise 345 kg/m3 Type V Portland cement and 25 kg/m3 silica fume.
An assumption that 2.54 million standard traffic axles may be applied over the 50-year design life of the structure.
In January 2018 Saudi Aramco made the decision to commonly use non-metallic reinforcement in concrete structures in construction projects. In line with this vision, a major decision was taken to transform the Jizan canal from a structure reinforced with steel bars to a structure reinforced with GFRP bars. As a result, the project is now expected to provide a maintenance-free service life exceeding 100 years.

While thermal expansion and stiffness compatibility with concrete are quite good, GFRP bars have a relatively low elastic modulus, shear strength, and tensile creep rupture stress. The latter factors are not major considerations for ground-supported slabs.

The main criteria considered for the design with GFRP reinforcement included: Crack width limited to 0.7 mm as per ACI 440.1R-15 (AASHTO LRFD GFRP Guide Specification allows < 1 mm); and limiting tensile stress in GFRP bars to 30 to 40% of the guaranteed tensile strength. The design of the GFRP-reinforced concrete structure for canal was carried out as per ACI 440.1R-15.

The maximum crack width was based on aesthetics—the harsh environment has no impact on the GFRP bars, and the GFRP reinforced concrete can tolerate higher crack widths and lower cover. For crack control, the design called for the GFRP bars to be placed in the top one-third of the slab. Due to the change in crack width limitations from 0.3mm to 0.7mm the spacing for the GFRP bars was changed from 150mm grid to 200mm grid.
A minimum guaranteed tensile strength of 600 MPa was considered, with an environmental factor CE of 0.7. The guaranteed modulus of elasticity of the GFRP bars was 50 GPa. A soil-bearing capacity of 125 kN/m2 and a modulus of subgrade reaction of 30,000 kN/m3 were considered for the design of the slab. Based on thermal cracking computations, the spacing of the contraction joints in the base slab was changed from 7.5 m to 6 m in each direction.
Total GFRP bars 10 million Metres of 13mm between 3 suppliers. (tensile strength of 600MPa was used as other suppliers bar only achieved 900MPa)

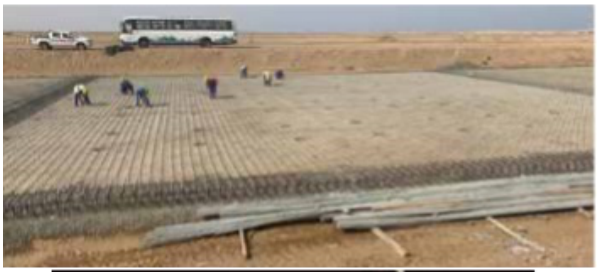
COSTS

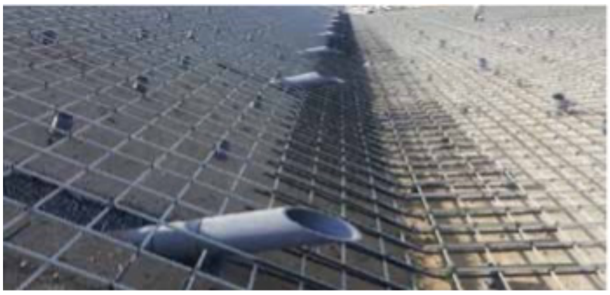
Based on a 30M x 30M x 0.2M bay

In the original design, 12 mm diameter bars were placed at 150 mm grid in both directions. A lap length of 600 mm was required, so the typical panel needed about 400 bars totalling 12,480 m in length and 11.1 Tonnes. In the revised design, 13 mm diameter GFRP bars were placed at 200 mm grid in both directions. A lap length of 750 mm was required, so the typical panel needed about 300 GFRP bars totalling 9450 m in length and 3.1 Tonnes.

Item / bay	Steel Bars	GFRP Bars	% difference
Reinforcing bars	12,480M	9,450M	-16%
Concrete	17,514	15,840	-10%
Labour	3,852	1,284	-65%
Crane	1068	0	-100%

The labour required for GFRP bar installation was significantly reduced compared with to installation of steel reinforcing bars, and no heavy equipment was needed for assembling the bars on the slab.





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