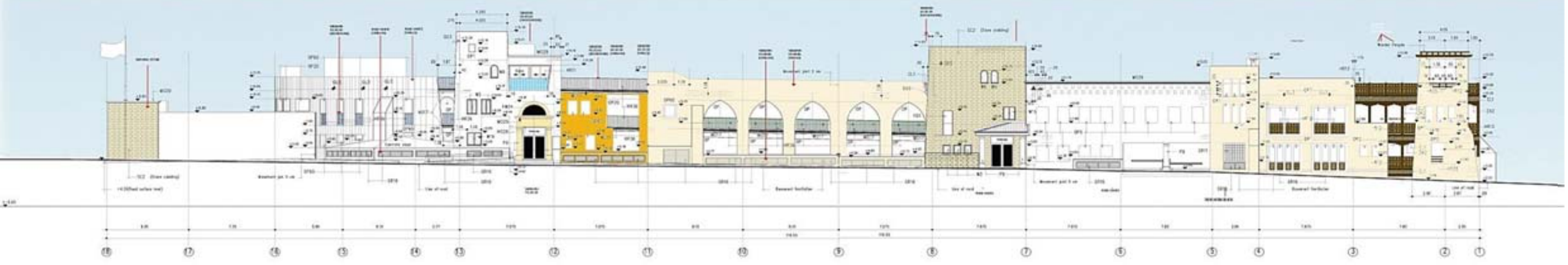


Limassol Marina, Cyprus
Multi-storey Car Park

Project Owner: Ministry of Energy, Commerce, Industry and Tourism
Project Developer: LIMASSOL MARINA LTD
Project Consultants: ATELIER XAVIER BOHL ● ARTELIA GROUP ● A. F. MODINOS & S. A. VRAHIMIS ● GEMAC
(Geotechnical Engineering by Alain YZIQUEL)
(Structural Engineering by Michael SHAFTACOLAS)
Project EPC Contractor: J&P – ATHENA – CYBARCO – MARINA LEMESOU JOINT VENTURE

Location and key facts about Limassol Marina

The featured multi storey car park is part of Limassol Marina in Cyprus, a prestigious marina of a total construction cost of 350 million euros, consisting of villas, apartments, shops, cafes, restaurants, boat and yacht berths, a marine training school and a cultural centre. It has 650 berths to accommodate yachts from 8m up to 110m at a basin area of approximately 170,000 square meters. It has a multi storey car park of a capacity of 746 cars that is founded 5m below water level. The scope of this article is to describe the design concept as well as the construction methods adopted specifically for this car park.

Key facts about Car Park

746 cars ● Total area of 25.000m^2 ● 2 underground storeys, ground level and 2 storeys above ground level ● All levels unfold as a continuous spiral with an average ramp slope of 1.5% ● Lowest foundation level is at -5.5m below mean sea level ● South edge of car park is built on reclaimed land ● 400 (A0, A1 size) construction drawings where prepared ● Reinforced concrete structure designed to EC2 / EC8 ● Earthquake acceleration Hg=0,25g ● 21.405m^3 of C30/37 and C35/45 of microsilica concrete used ● 2.021 tonnes of B500c reinforcement ● Design – Build – Operate – Transfer type of Contract enabled designers and contractor to provide a mutually agreed type of construction in advance

Basic Design Constraints

The location of the car park is partly in the sea. Therefore, the location and the required depth of excavation – 9m deep excavation, 5.5m below water level – troubled the designers as to what would be the best solution in order to provide a safe and dry construction site. The solution adopted, was to construct a perimeter secant pile wall. The piles would be reinforced concrete piles drilled down to a maximum depth of 14m as described below.

Figure 1 - Proximity with open sea

Basic Design Requirements

1. A high degree of water tightness
2. To protect the work force from sudden piping which could lead to fatalities
3. To provide adequate dewatering conditions whilst preventing depletion of a nearby river aquifer that would disturb nearby building foundations located within a radius of several metres
4. It would act as a retaining wall for the works
5. The secant pile wall would be a temporary structure to allow the construction of the car park and was not designed to give permanent support to the backfill or to resist seismic loads
6. It was not designed to insure the ultimate water tightness of the finished works

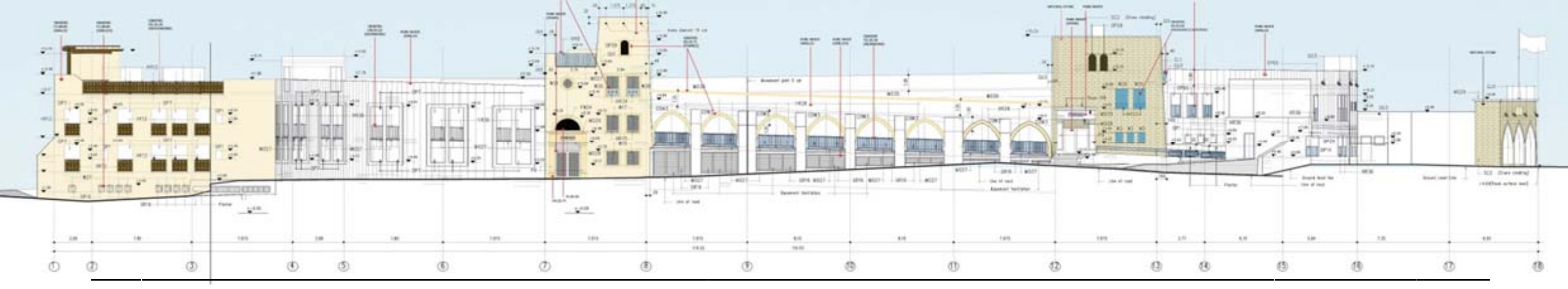
Basic Design Concept

The basic concept to achieve the required water tightness was to locate the end of the piles in the proper horizon i.e. clayey silt that was encountered at a depth of 12m. The dewatering would allow the control of both the seepage and the gradient of flows finding their path in more gravelly patches.

Foundation Conditions

The Geotechnical investigations consisted of three exploratory boreholes and three exploratory pits.

The following key data was extracted:



1. At the north side of the building the soil encountered at foundation level was gravel and cobbles and silty gravelly sand with SPT = 20.

2. At the south side of the building the soil encountered was unsuitable i.e. sea weeds and silty sand.

3. At -8.00m MSL the investigations revealed a layer of sandy and silty clay of very high plasticity and very low permeability.

The presence of the clay was the most important finding. It gave the designers the idea to design and construct the perimeter secant pile wall to penetrate this impermeable layer of clay. This meant that with the use of a number of dewatering pumps, the dewatering of the sea water would be achievable if the rate of dewatering would be equal to the rate of influent water.

Building overall possible settlement

The excavation of the car park would create an unloading of the foundation. The reloading by the weight of the car park and the cars would not compensate the stress reduction created by the excavation. Therefore general settlements were not expected and piling was therefore not necessary to prevent an overall settlement. In general the soil investigations revealed that the ground was suitable for raft foundation while at areas where sea weeds were located, the easiest solution was to excavate and replace them by a compacted backfill of gravels obtained during the bulk excavation.

Construction method stages

The proposed construction method was straightforward:

1. **Stage 1** – Excavate the footprint of the car park down to elevation 0,6m amsl

2. **Stage 2** – Discard the unsuitable material and select gravels to be dumped along the shore line in order to create working space

3. **Stage 3** – Construct a rock fill bund to protect the excavation from waves (See Fig 2, 3 and

4. **Stage 4** – Construct the secant pile wall from the platform at 0,6m above mean sea level. The piles were D880mm, 10m and 14m deep. Primary piles reinforcement was 13Ø22, Spiral Ø12/10.

5. **Stage 5** – Excavate the inside of the car park with dewatering

6. **Stage** 6 – Extend the platform towards the sea using selected gravels and sand material for construction of the secant piles of the quay wall.

7. **Stage 7 –** Construction of car park. Dewatering pumps were stopped once the structure weight was balanced with buoyancy forces.

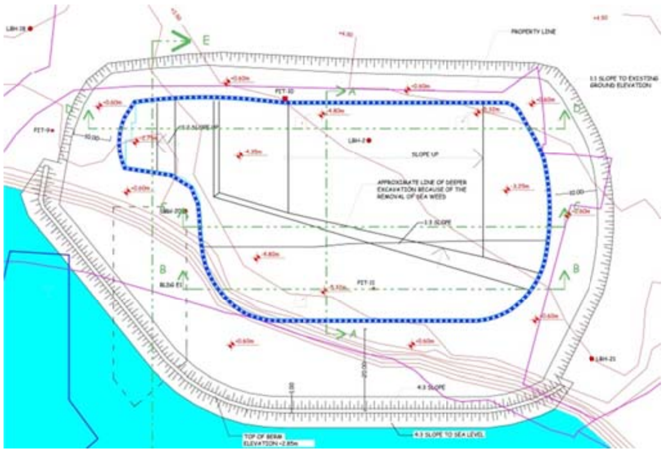


Figure 2 – Design layout of all stages of construction

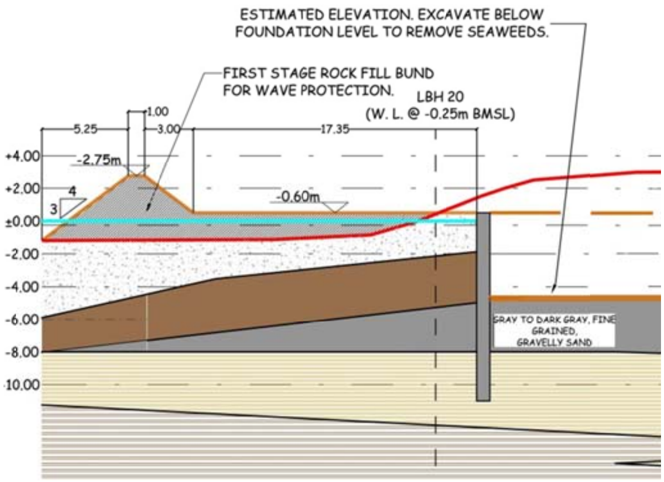


Figure 3 – South side of excavation

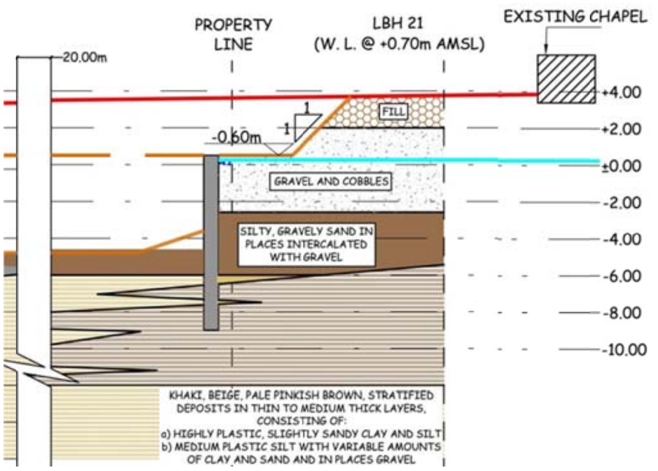
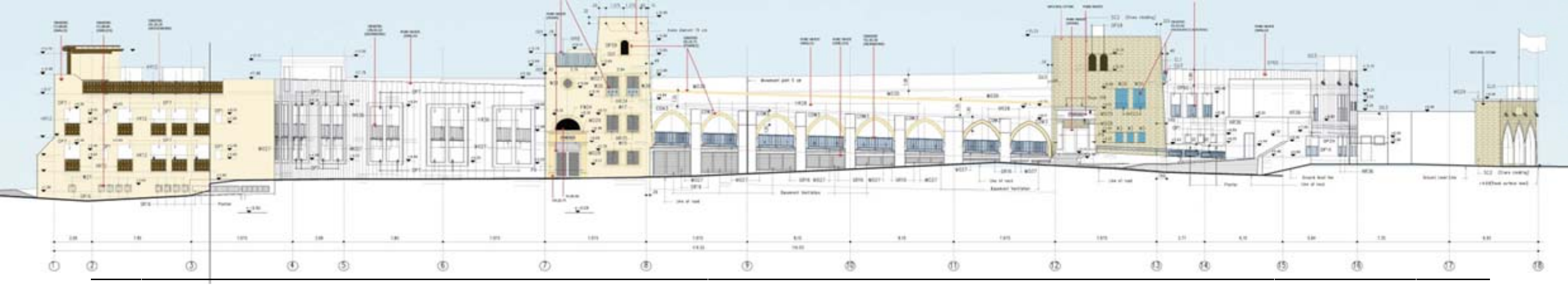


Figure 4 – North side of excavation



Construction timeline

Figure 5 – Construction Stages 1, 2 and 3 – Reclamation for working space and protection from sea waves

Figure 8 – Construction Stage 6 – Blinding concrete and permanent water proofing

Figure 6 – Construction Stage 4 – Construction of secant pile wall

Figure 9 – Construction Stage 6 – Construction of raft foundation

Figure 7 – Construction Stage 5 – Completion of excavation with dewatering

Figure 10 - Finished Car Park with surrounding buildings