Unconventional Excavation and Lateral Support System near Seashore in Lamma Power Station Extension

K.T. Hung[1], John Lai[1], Michael W.L. Ng[2*]

[1]The Hongkong Electric Company Limited
[2]AECOM Asia Company Limited

*Corresponding author
doi: https://doi.org/10.21467/proceedings.159.10

ABSTRACT

Nowadays in Hong Kong, the maritime construction is becoming more common for the infrastructure projects especially on the increasing demand of the land use for those residential and housing supply. Those civil infrastructure works would normally be completed in reclamation projects prior to the land grant to a private developer. For the developments under private and quasi-government sectors, the projects are required to execute under the land lease allocated conditions and controlled under Buildings Ordinance CAP123. The nature of this project in Lamma Power Station Extension (LMX) contains both characteristics in buildings and infrastructures, including reclamation and seawall construction. Under this circumstance, the excavation and lateral support would have considered the merits between both requirements and advancing to an out of conventional land construction method. The subjected site is situated at the southern-east of the LMX reclaimed platform facing to the incipient Lamma Island. The project required to construct a No. 5 C.W. Intake adjacent to the existing seawall. Under a fast-track programme, an Excavation and Lateral Support (ELS) system with submerged excavation was adopted for tow-in of the precast caisson chamber. This paper summaries the key features for the design and construction of the ELS for the project.

Keywords: Excavation, Submerged, GFRP

1 Introduction

1.1 Background

Hong Kong is being one of the most developed urban regions and global financial centre. An uninterrupted world-class electricity supply is one of the key attributed factors for this success. The Hongkong Electric Company Limited (HEC) provides a safe and highly reliable electricity for those financial centers / commercial & industrial buildings as well as those residential buildings in Hong Kong Island and Lamma Island through the century. In order to provide a clean, more sustainable and environmental friendly power supply, HEC has developed its own gas-fired combined-cycle unit that uses liquefied natural gas (LNG) since year 2006 at the newly reclaimed Island next to the operating Lamma Power Station. Committed to meet a long-term green energy need, this extends the LNG gas-fired stations to be further developed to achieve less carbon emission target. AECOM has been appointed to provide a design and supervision consultancy services for the No. 5 C.W. Intake Chamber which would supply seawater intake for cooling system of the newly constructed gas-fired station Unit L12 as well as future Unit L13.

1.2 Project Particular

The location for No. 5 C.W. Intake situated at the southern-east of the 22-hectare newly reclaimed platform, Figure 1. A planned new intake chamber would be adopted as the current No. 4 C.W. Intake is reaching its capacity for the commissioned gas-fired stations Unit L9 to L11. The proposed new intake

Proceedings DOI: 10.21467/proceedings.159; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-965621-6-8

chamber was constructed and connected to the adjacent 3 nos. existing reserved intake culverts which were integrated as part of the existing vertical seawall back in earlier stage of reclamation. The marine deposit at the footprint of No. 5 C.W. Intake and the vertical seawall were dredged away and backfilled by layered rockfill and sand filling upto the ground level of +5.5mPD between year 2001~2004 forming the current reclamation platform. Therefore, excavation to the formation of the new intake was required for the construction.

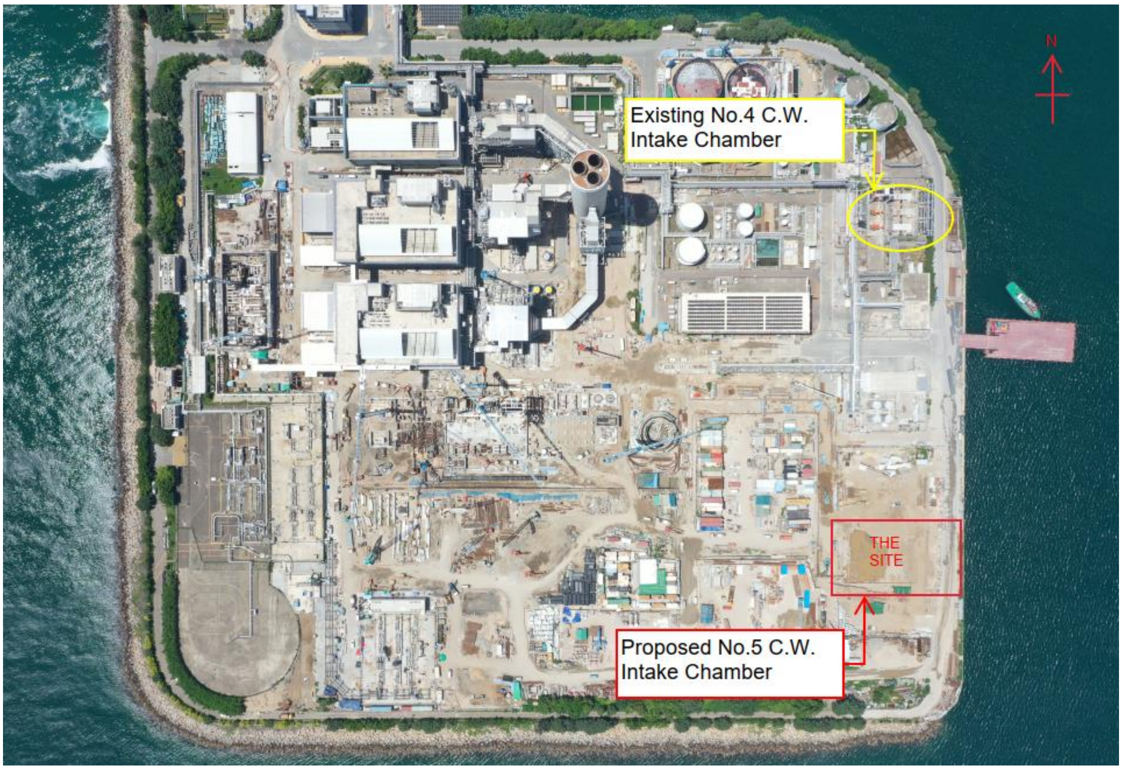


Figure 1: *Site Layout Plan*

2 Design Scheme and Options

Based on the general arrangement, Figure 2 &3, the proposed intake chamber would be as deep as the invert level of the existing intake culvert and down to -7.5mPD. The plan size of the intake chamber would be 30m x 45m including the chamber for bar-screen and penstock, drum mesh screen, main

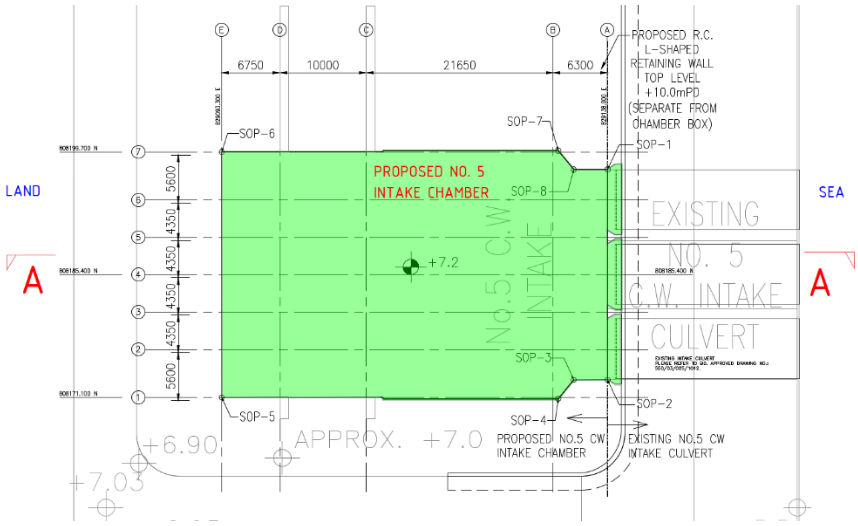


Figure 2: *Layout for Proposed No. 5 Intake Chamber*

Proceedings DOI: 10.21467/proceedings.159
ISBN: 978-81-965621-6-8

Series: AIJR Proceedings
ISSN: 2582-3922

reaction pump and discharge valve. Hence, the proposed excavation would be as large as 35m x 50m x 13m deep from the existing ground level. The construction sequence is always one of the most contributing factor for the design of Excavation and Lateral Support System and the options are discussed in the following sub-section.

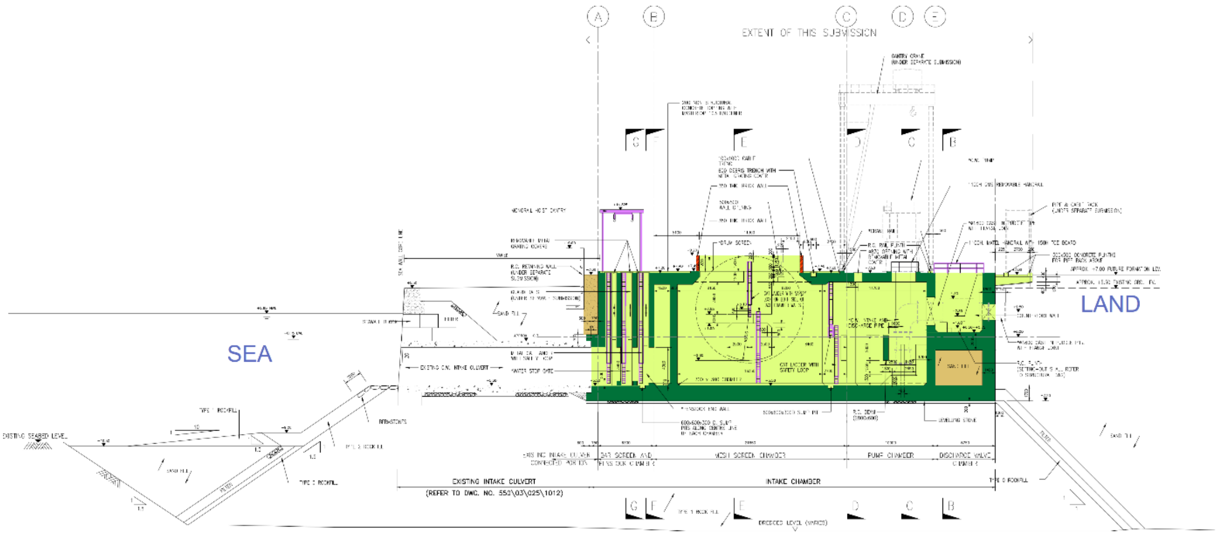


Figure 3: *Section A-A for Proposed No. 5 Intake Chamber*

2.1 Typical Land Base Option – Cast-in-situ

For the private developments in Hong Kong, it is very common to adopt vertical elements using sheet pile or pipe pile with cross flying strut for the ELS works. The curtain grouting might be necessary to provide an effective water cut-off for dewatering within the cofferdam using cast-in situ concrete construction method. When dealing with the situation near the seashore, sometime might need to adopt double hydraulic cut-off wall system to safe-guard the seepage conditions against the sea. It is always difficult and not environmentally welcome for grouting close to the seawall. In this project, the intake chamber required to form connection to the existing culvert, therefore an opening to the pre-installed ELS vertical elements was inevitable which would complicate the situation. Experiences told that it would be very time consuming to form successive water cutoff against the sea and might involve several stages of grouting and re-grouting works. Moreover, the flying struts would pose numerous restrictions to the subsequent in-situ reinforced concrete construction for the chamber. Therefore, this option was not pursued for this project.

2.2 Adopted Design Scheme

In order to meet the operation target for the new power generating unit, it was planned to have the on-site excavation as well as off-site precast construction working simultaneously and thereafter the permanent precast structure could be shipped from the Mainland China as a floating caisson. Hence, the ELS design had to consider the tow-in operation of the precast structure and the opening of the existing seawall. The time management, logistic, weather forecast with tidal effect shall be well planned throughout the design and construction stage. For the vertical element of ELS works, interlocking pipe pile was deployed to control the loss of fine material during the submerged excavation. While the lateral support, tie-back system was adopted to allow maneuvering of the tow-in operation for the precast structure installation. Once the lateral ties were installed layer by layer above the water level, further excavation was carried out under-water until reaching to the formation level of the structure. The general arrangement of the ELS works is shown in Figure 4.

After the completion to the excavated formation, the existing seawall and intake culverts would be temporary removed in the remaining phase of construction. It was necessary to check the partial stability of the seawall during construction against the tidal effect. The seawall blocks and existing culverts were removed in stages and temporary stored for reinstatement after the installation of the precast intake chamber. When the opening of seawall was completed, the precast caisson would be tow-in to position. The backfilling and reinstatement works could be carried out concurrently with the culvert connection work as well as further construction of internal structural elements and M&E installations.

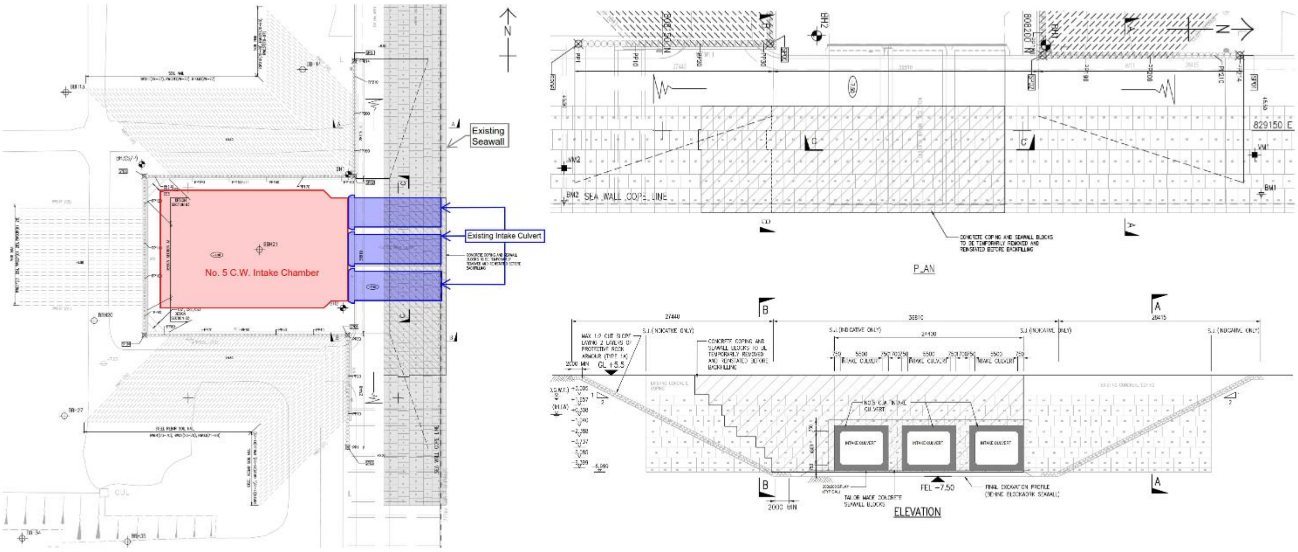


Figure 4: *General Arrangement for the ELS Design Layout and Sewall Opening*

Since the excavation was carried out in submerged conditions, the overall water pressure tended to be balanced at both retaining side and excavation side. Nevertheless, as the seawall would be opened up during the construction, the ELS works would therefore be subjected to the wave action and suctional force. Reference was therefore made to the nearest tide station in Chi Ma Wan from the Port Works Design Manuel (PWDM, 2002) to allow the effect on tidal water level in the design, Figure 5.

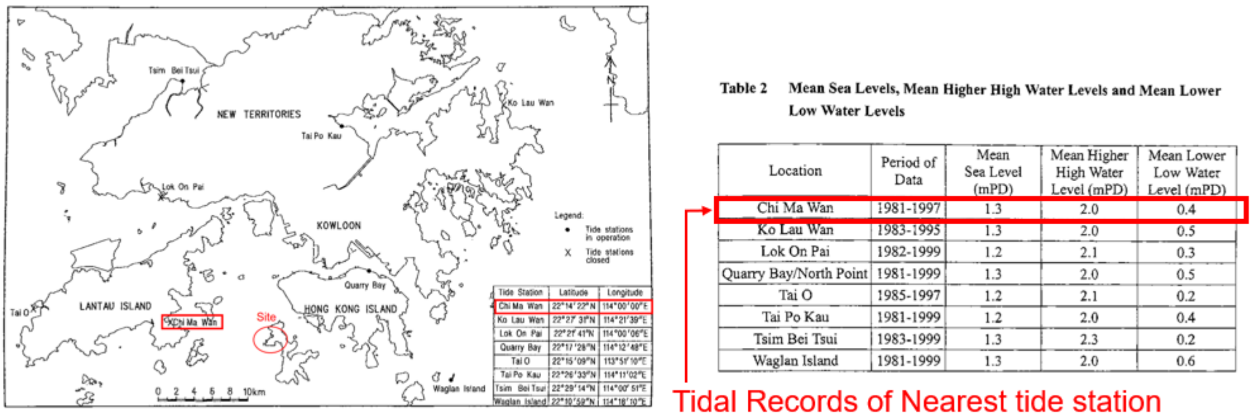


Table 2 Mean Sea Levels, Mean Higher High Water Levels and Mean Lower Low Water Levels

Location	Period of Data	Mean Sea Level (mPD)	Mean Higher High Water Level (mPD)	Mean Lower Low Water Level (mPD)
Chi Ma Wan	1981-1997	1.3	2.0	0.4
Ko Lau Wan	1983-1995	1.3	2.0	0.5
Lok On Pai	1982-1999	1.2	2.1	0.3
Quarry Bay/North Point	1981-1999	1.3	2.0	0.5
Tai O	1985-1997	1.2	2.1	0.2
Tai Po Kau	1981-1999	1.2	2.0	0.4
Tsim Bei Tsui	1983-1999	1.3	2.3	0.2
Waglan Island	1981-1999	1.3	2.0	0.6

Figure 5: *Reference on the Tidal Water Level near seashore, PWDM (2002)*

Based on the monitoring record and the G.I. from the Lamma Island Extension, which had been recorded more than 2 years covering the rainstorm periods, the highest measured ground water level

Proceedings DOI: 10.21467/proceedings.159
ISBN: 978-81-965621-6-8

Series: AIJR Proceedings
ISSN: 2582-3922

was +1.7mPD. As the Site was relatively close and surrounded by the Sea, the ground water response and recharge on this reclaimed platform would likely be influenced by tidal fluctuation. As the excavation was designed to be carried out underwater, i.e. submerged excavation, therefore the following two scenarios of water level was considered:-

In **Case 1**, the design groundwater level at the retained side was +2.65mPD while at submerged excavation side was MLLW = +0.40mPD.

In **Case 2**, the design groundwater level at the retained side was +1.70mPD while at submerged excavation side was MSL = +1.30mPD.

While Case 1 was adopted for the structural capacity checking and Case 2 was adopted for estimating the wall deflection and ground movement in serviceability conditions.

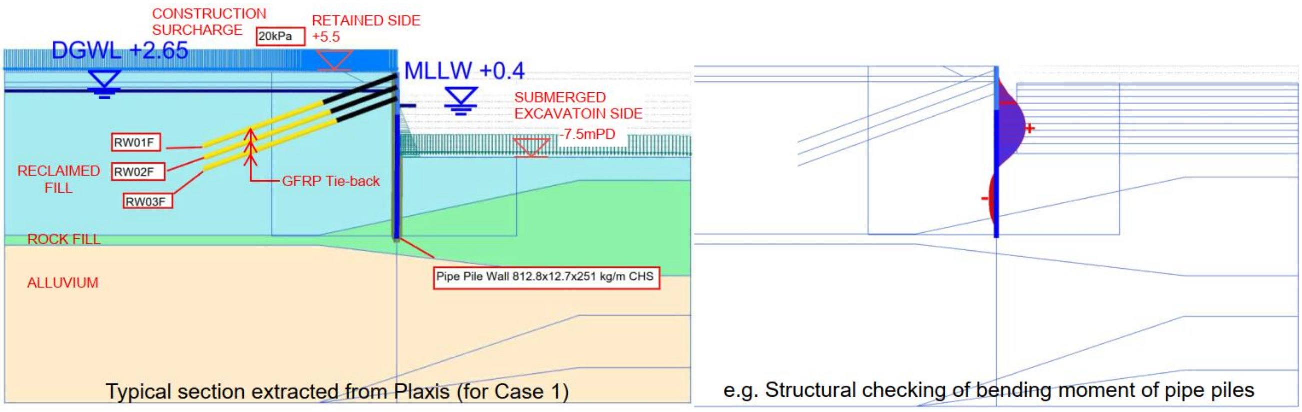


Figure 6: *Design Condition Case 1 (for Structural Design Checking)*

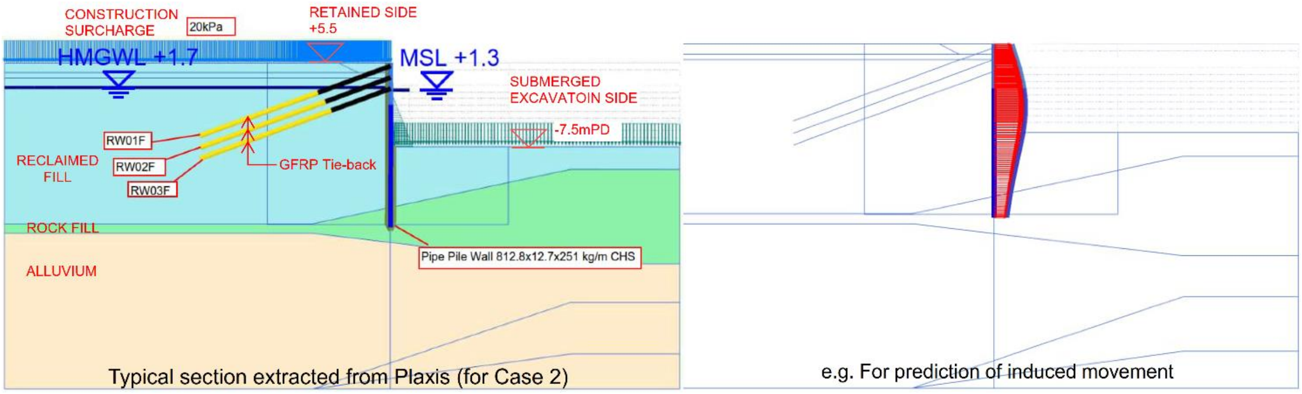


Figure 7: *Design Condition Case 2 (for Serviceability Design Checking)*

3 Use of Glass Fibre Reinforced Polymer (GFRP) for Tie Back System

Glass fibre-reinforced polymer (GFRP) is a composite material made of glass fibres embedded in a polymeric resin matrix. This material composition results high strength primarily along the length of the bar in tension while it can be easily abraded or "consumed" by boring machinery. This unique "anisotropic" property offers many benefits in temporary construction. It has been widely adopted for diaphragm wall nowadays with soft eye opening for the receiving tunnel boring machine cutting through as well as tie-back system for excavation, Figure 8.

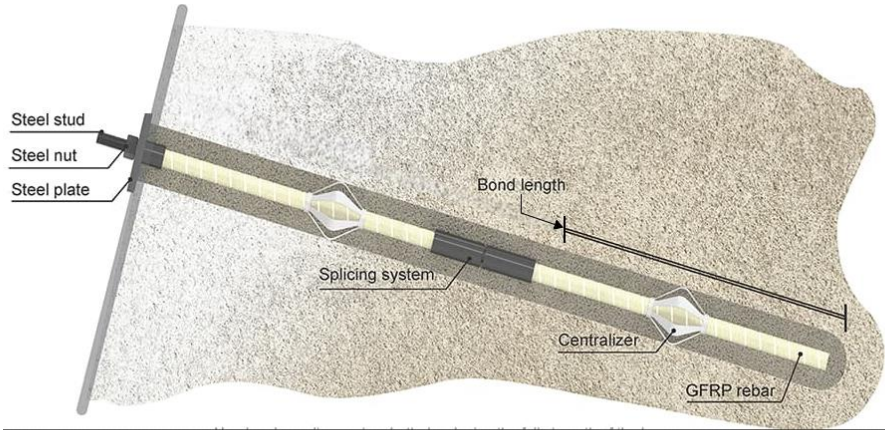


Figure 8: *GFRP Tie-Back System*

3.1 Project Benefits to be Adopted

The Lamma Power Station extension (LMX) had been planned and designed full house of the M&E installation. Adjacent to the No. 5 C.W. intake, there would be development for Chlorinators Areas, C.W. Pump Equipment Room, Crane Rail Foundation, 275kV cable Landing Point as well as other facilities for the coming LMX 12 to 13 which all require their foundation system. It was therefore proposed to adopt GFRP tie-back system within the future foundation footprint to enable further developments. The GFRP reinforcement is an alternative to the steel reinforcing bar. Its performance is much better when exposes to aggressive environment such as marine for which bare steel would have corrosion deterioration. Besides, it is non-magnetic and would not have electromagnetic interference problem against the plant and machinery operations. The high tensile strength performance helps to achieving the tension forces for the lateral support and stabilize the overall ground action. Also, the cuttability enhances its temporary usage, with strong action in main axis but can be easily machine bored and abraded away by excavation equipment later on.

3.2 Design Standard

There was no specific British Standard / Hong Kong Standard or Code of Practice addressing the design and the usage for reinforcement with GFRP bars. The American Concrete Institute Manual of Concrete Practice ACI 440.1R-06 was considered to provide the most up-to-date methodology for undertaking design of the reinforcement with Fibre Reinforced Polymer (FRP) and this code was adopted for the design of the GFRP bars. This ACI guide was based on the knowledge gained form worldwide experimental research, analytical works and field applications of GFRP.

The physical and mechanical properties of GFRP bars were dependent on the technology and processes employed by the manufacturer's making of the bars. For the tie-back system adopted in the ELS works, the following mechanical properties was used for the design and are summarized in the Table 1 below for easy reference:-

Table 1: *GFRP Mechanical Property adopted for Design, Dextra (2020)*

Bar Dia. (mm)	Nominal Area (mm^2)	Guarantee Tensile Strength, f^*_{fu} (N/mm^2)	Ultimate Tensile Load (kN)	Tensile Modulus of Elasticity, E_f (GPa)	Ultimate Strain (%)
41	1339	>460 (672)	900.0	>40.8 (50)	>1.13% (1.48%)

For GFRP design, the ACI 440.1R-06 applied a "strength design approach" based on limit state design philosophy consistent with the relevant provisions in ACI318-05 "Building Code Requirement for Structural Concrete". Whereas the soil nail and tie-back system would follow the recommendation given in Geoguide 7 which had been commonly adopted in Hong Kong practices. In comparison of the factor of safety, the onerous approach was adopted in the design to cater for the uncertainty.

The ACI 440.1R-06 recommended that GFRP bars were not be relied upon to resist compression. Justification calculations therefore ignore any contribution of GFRP bars in the compression stress block to the section. The tie-back system in Lamma Island was not required to resist compression. From the analysis, the tie-bars were all in tension at all stages of excavation process. The adopted of the tie-back system was mainly for the control of the wall deformation and hence the servicing settlement. Moreover, GFRP bars should be formed into the required shape during fabrication in factory and field bending was not allowed. The bending in GRFP bars for the tie-back system would not be required.

3.3 Testing and Verification

In section 11 of ACI440.1R-06 identifies two testing regimes with respect to the performance of GFRP bars:

- Product Certification of guaranteed and nominal values (denoted "C" in the "test regime" column in table 2 below). Product Certification was to be based on testing prior to the delivery of the product.
- Manufacturer's quality control tests / purchaser's quality assurance tests on the production lots of the bars incorporated into the specific works (denote "Q" in the "test regime" column in table 2 below).

The Quality Assurance / Quality Control (QA/QC) were based on testing of a minimum of five samples taken from each production lot of bars delivered to site. Test Certificates to show Product Certification for the specified properties were to be provided by the manufacturer prior to the works. QA/QC test certificates for the production lots were required for properties that were critical to the performance of GFRP bars in the specific application in the Tie-back System of Lamma Island. The properties of the GFRP reinforcing bars for 41mm dia. are specified in Table 2 below:-

Table 2: *Mechanical Property for testing or certification of GFRP, DEXTRA (2020)*

Manufacturer recommendation

Ref	Property	Unit	Requirement	Standard Test Method	Test Regime
1	Nominal area	mm^2	1339	ACI440.3R-04/B.1	C
2	Fibre content	%	>55 (73)	ASTM D2584-08	C
3	Guaranteed tensile strength f*fu	N/mm^2	>460 (672)	ACI440.3R-04/B.2	C, Q
5	Ultimate tensile strain, ε*fu	%	>1.13 (1.48)	ACI440.3R-04/B.2	C, Q
6	Modulus of elasticity, ef	kN/mm^2	>40.8 (50)	ACI440.3R-04/B.2	C, Q
7	Transverse shear strength	N/mm^2	>115	ASTM D4475-02	C, Q
8	Bond strength (pull-out strength)	N/mm^2	>1.1 (3.0)	ACI440.3R-04/B.3	C, Q
9	Longitudinal wicking for void	Presence of voids	Report results only	ASTM D5117-09	C
10	Barcol Hardness	--	Report results only	ASTM D2583-07	C

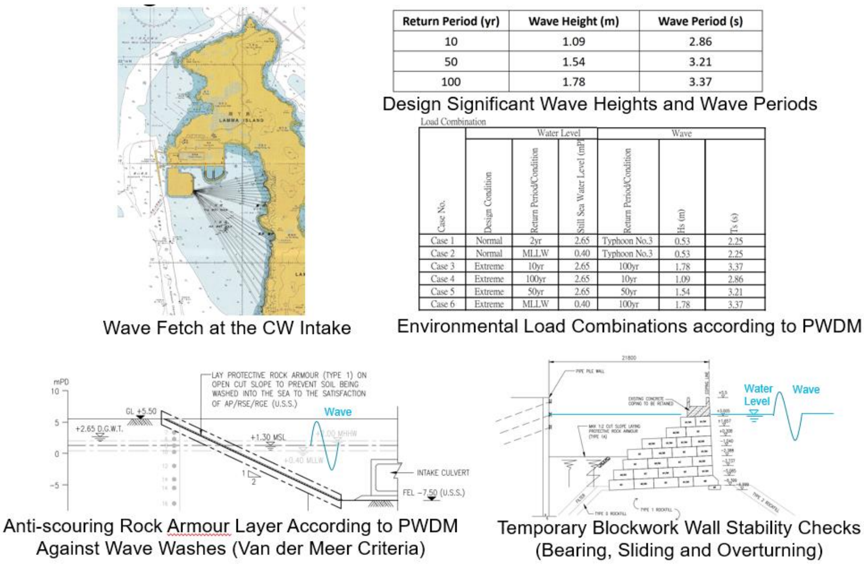
During installation progress, 8 nos. of site trial with pull-out testing were carried out before working nail installation. Besides, 10 nos. of the working nail were selected for further performance testing. It was reviewed that both results from site trial and performance test were well agreed with the design assumption prior to the further excavation, Figure 9.

Figure 9: *Set up of Pull out test on Site*

4 Maritime Design and Construction

4.1 Design

The opening of the existing vertical seawall was located at the east of the reclaimed platform where the fetch length was shielded by the incipient Lamma Island. Therefore, the tidal effect would not be significant comparing to the shoreline facing to the South China Sea. The vertical seawall with pre-constructed intake culverts would be temporarily removed until the installation of the intake chamber. Hence, the temporary stability of seawall should be checked according to the Port Works Design Manual (2002), Figure 10. Besides, protective rock armour was proposed to be laid over the excavation face with max. 1:2 temporary slope to resist wave wash.



Return Period (yr)	Wave Height (m)	Wave Period (s)
10	1.09	2.86
50	1.54	3.21
100	1.78	3.37

Load Combination

Case No.	Water Level: Design Condition	Water Level: Return Period/Condition	Water Level: Still Sea Water Level (mPD)	Wave: Return Period/Condition	Wave: Hs (m)	Wave: Ts (s)
Case 1	Normal	2yr	2.65	Typhoon No.3	0.53	2.25
Case 2	Normal	MLLW	0.40	Typhoon No.3	0.53	2.25
Case 3	Extreme	10yr	2.65	100yr	1.78	3.37
Case 4	Extreme	100yr	2.65	10yr	1.09	2.86
Case 5	Extreme	50yr	2.65	50yr	1.54	3.21
Case 6	Extreme	MLLW	0.40	100yr	1.78	3.37

Figure 10: *Design Consideration with PWDM (2002).*

4.2 Maritime Construction

Due to the limitation of loading capacity of the semi-submersible barge and to avoid future in-situ works to be affected by tidal action, only the bottom part of the chamber without internal walls was constructed on the semi-submersible barge in one of the pre-cast factory yards at Mainland China in Xinhui. The pre-cast portion of the intake chamber was of size approximate 30m x 45m x 10m in height. Careful planning was needed for the transportation of this huge structure including the weather forecast, geometry of the routing, suitable marine vessel and equipment. Since the construction involved the marine works within the Hongkong Waters, Marine Department Notice should be arranged prior to the construction works. It was planned to have 1 main tug, 2 auxiliary tugs, 1 crane barge and 1 semi-submersible barge for the installation of the precast caisson. The depth of the seabed nearby the site only have 6m ~ 8m and would not be suitable for the semi-submersible barge to be submerged for unloading the precast caisson. The South West Lamma Anchorage was selected as the sinking area with water depth of approximate 20 metres which met the sinking depth requirements for off-loading.

Figure 11: *15000DWT Semi-submersible Barge (ZHONG REN 1500)*

The loading capacity of the semi-submersible barge could be reached upto 14387.50 ton and the deck submersion to a maximum of 6.0m, Figure 11. That allowed the off-loading of the precast caisson at the designated sinking area by floatation. Suitable time window taking into account the high tide cycle and installation time was carefully planned to ensure there would be sufficient water depth for chamber floatation to facilitate the pulling in of the pre-cast chamber into position. The removed seawall blocks and intake culverts were temporary stored on barges such that these elements could be reinstated in the later stage after installation of the pre-cast chamber in position. Besides, some site safety and environmental precautionary measures were deployed for the marine operation including silt curtains, floating wave breaker against the sea front of predominant wave direction, monitoring of floating level marked on the pre-cast chamber, early alarm for loading/lifting winch operation, subscription of long weather forecast (over a month) and contingency plan for the barges to vacate in case of typhoon…etc. so as to minimize the risk throughout the delivery of the pre-cast chamber from the casting yard all the way to Lamma site for installation.

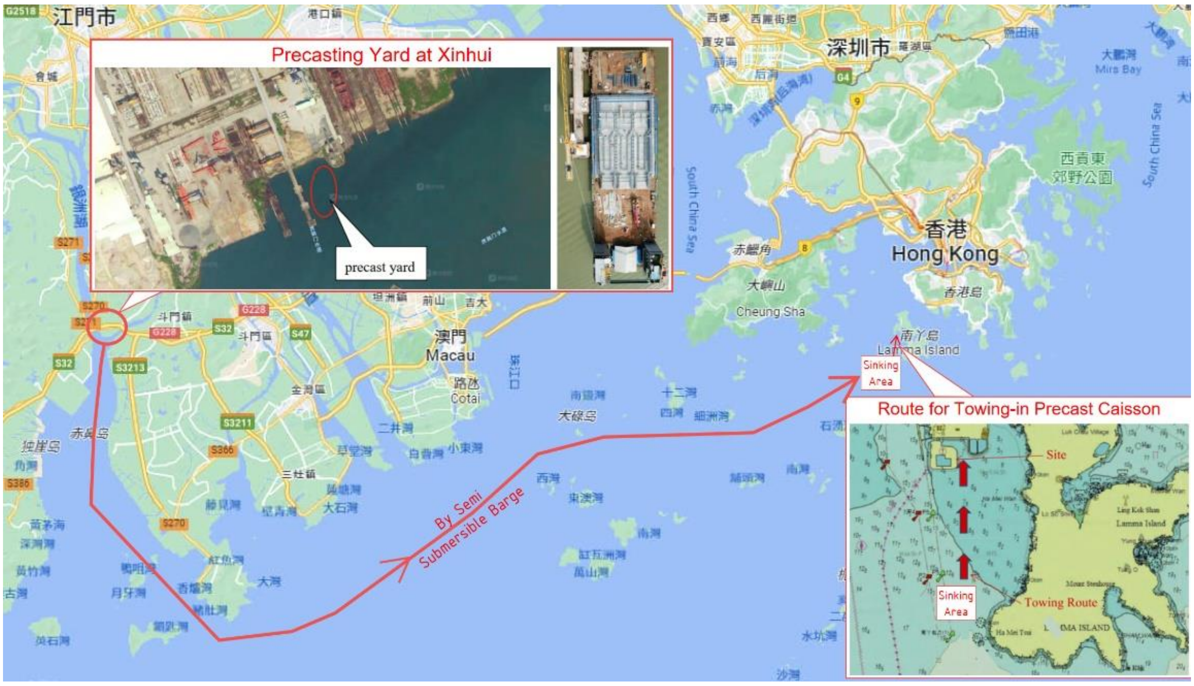


Figure 12: *Transport Routing from Mainland to the Site*

After the precast chamber had completed in the Mainland China, it would then deliver to the Sinking Area within the Hongkong Waters, Figure 12. It was necessary to plan for the transportation date, to avoid the towing operation at bad weather from the forecast. The Intake Chamber would then be winched out with mooring cable and act as floating caisson by itself when reached to the sinking area. Finally, the precast intake chamber would be installed and offload onto position of the excavated formation level, Figure 13.

Figure 13: *The ELS with seawall opening for receiving the floating caisson*

5 Design To Suit Statutory Requirements and Standard

Unlike the government, railway and other civil infrastructure projects, this project was a private development and shall be controlled under the Buildings Ordinance. The following sub-sections discuss the approach to fulfill the relevant regulations and administrative requirements for the design of ELS works especially for those uncommon material.

5.1 GFRP

Under the regulation 54 of previous Cap. 123B (1990) , the reinforcement for concrete should be hot rolled steel bars, cold reduced steel wire or steel fabric of suitable composition, manufacture, and chemical and physical properties. The proposed use of GFRP bars for soil nailing tie-back would constitute the standard and code commonly adopted for reinforcing bar as stipulated in CAP 123B not being applicable. Therefore, a specified form BA16 for the modification of and/or exemption from the provisions of the regulation was required to submitted to the Buildings Authority. Currently, the regulation CAP123B had been obsoleted and replaced by newly enforced CAP123Q in 2021 which regulates the use of material in a performance base. This would promote the use of new material under the Buildings Ordinance including GFRP.

Safety Factors

ACI 440.1R-06 applied limit state philosophy whereas the guaranteed tensile strength by the manufacturer was the initial properties that did not include the effects of long-term exposure to the environment. Therefore, a reduction factor that specific to the use of FRP in order to take into account the impact of environmental and the exposure conditions. This factor was time dependent and hence would be more onerous for longer design life periods. Since the factor developed in the logarithm relationship to the design life and hence the factors were significant even after relatively short periods. In the case of the tie-back system of Lamma Power Station, the approximately design life would be 18 months (1.5 years), and hence the application factor the Environment factor CE (for concrete exposed to earth and weather) was 0.70 [Refer to ACI 440.1R-06 Table 7.1]. Besides, a strength reduction factor Φ from 0.55 to 0.65 was recommended by the ACI 440.1R-06 in design for the account of the GFRP bars exhibited low modulus of elasticity and ductility. Since the design of the tie-back system was subjected to the axial tension loading in principle and its temporary use for less than 1.5 years, the FoS of 2.0 (i.e equivalent to 0.5 reduction) was taken for the global factor of safety in design of the tensile capacity correlated to the adopted guarantee tensile strength.

Bond Resistance between GFRP and grout

The requirements for development length and splices in GFRP bars were addressed in section 11. The design methodology was based on experimental testing, mostly of spiral wrap and helical lug patterned bars. No notable difference in bond with concrete was found for these alternative bars. The bond strength between concrete(grout) and GFRP rebar was tested by the manufacturer in accordance with ACI440.3R-04. Based on the testing results, the maximum bond stress could be as high as 7.1MPa. However, based on experimental data, ACI440.1R-06 proposed an empirical method for calculating the development length of a GFRP bar (which is dictated by the concrete strength, the bar diameter and the concrete cover to the bar i.e. ACI440.1R-06 equation 11-2 and 11-3). The design approach on average “bond stress” for the bar/concrete interface along the bars can therefore be deduced with the account for equivalent factor of safety comparable with Geoguide 7.

5.2 Foundation

The intake chamber was designed to sit on top of the pre-dredged reclamation. Therefore, the settlement of the structure would not be significant. Since the internal chamber was hollow structure for receiving seawater and M&E facilities, the floatation stability of this underground structure would normally be critical. Unlike those private development with limit extent in the urban area, the base slab of the raft structure could be slightly enlarged such that the soil within the zone of influence would help to balance the uplifting force. Under the cl. 4.2.2(2) in Code of Practice for the Foundations, BD (2017), plate loading test would be necessary to verify the design bearing capacity in submerged condition if the bearing pressure fell within one of the criteria specified. In order to comply with the code requirements, the design of the net increase in bearing pressure was controlled to be less than 50kPa. This was done by the iteration on the extent of footing enlargement, Figure14.

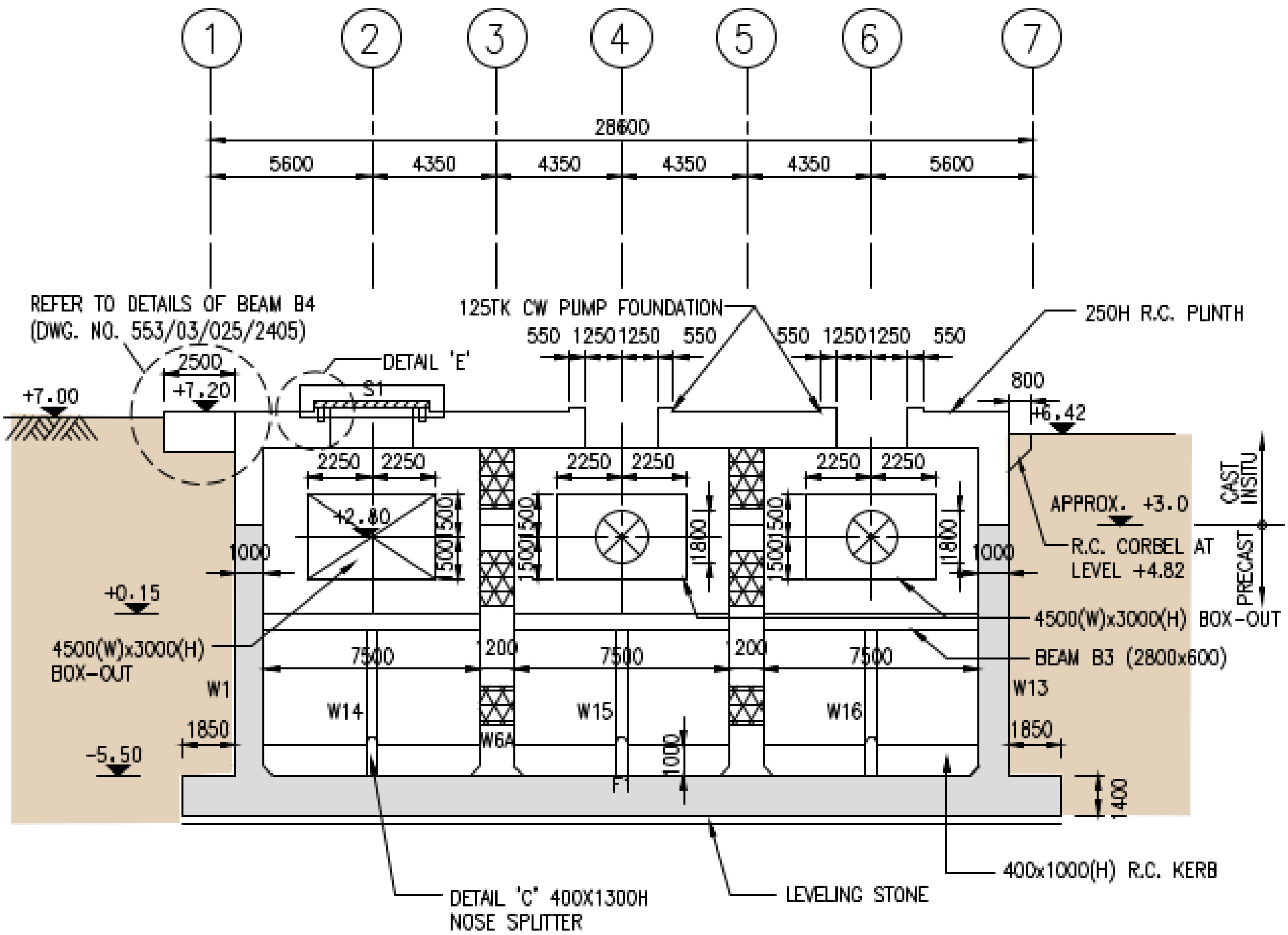


Figure 14: *Typical Section for the Intake Structure*

For the site supervision, BD (2009), inspection of bearing stratum was classified as one of the critical stage of works for raft and spread footing. In order to have inspection properly, chain sound survey on the completed excavation level and independent diver inspection was necessary to confirm the foundation of the bearing stratum with the present of Technical Competent Persons. The survey was carried out in grid manner such that it could be recorded the inspection properly, Figure15.

Figure 15: *Confirmation of the Founding Level*

6 Conclusion

The ELS design in this Lamma Island project had taken the merits between both characteristics in infrastructure and private development. Although it was common to have the marine construction and new material tie-back system for those infrastructure and rail projects, we as the Engineer responsible would advance more with hybrid consideration according to the codes and international standards. During the construction, the ELS works had faced against several typhoon attacks (such as Chaba, Mulan & Ma-on with highest typhoon signal no. 8) and remained intact when the seawall was opened. It was no doubt that the ELS was an effective and robust solution for this project. The recent update on legislative requirements in Cap. 123Q (2021) allowed the use of material in performance based. This would encourage the innovative and new material design to have simplified administration to fulfill those requirements such that we would deliver a more safe and reliable design to face the new engineering challenges.

7 Declarations

7.1 Acknowledgements

This paper is published with the kind support and permissions of The Hongkong Electric Company Limited and the hard-work from the site supervision team as well as the contributing effort from Paul Y Construction Limited.

7.2 Publisher's Note

AIJR remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

How to Cite

Hung *et al.* (2023). Unconventional Excavation and Lateral Support System near Seashore in Lamma Power Station Extension. *AIJR Proceedings*, 109-122. https://doi.org/10.21467/proceedings.159.10

References

ACI 440.1R-06. (2006). *Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars*. http://www.iranfrp.ir/wp-content/uploads/2018/12/13.pdf

BD. (2009). *CODE OF PRACTICE FOR SITE SUPERVISION*. Buildings Department, The Government of Hong Kong SAR. https://www.bd.gov.hk/doc/en/resources/codes-and-references/code-and-design-manuals/SS2009_e.pdf

Buildings Department. (2017). *Code of Practice for Foundations 2017*. http://www.bd.gov.hk.

Cap. 123. (2021, February). *Building (Construction) Regulation*. https://www.elegislation.gov.hk/hk/cap123Q

Cap. 123B. (1990). *Building (Construction) Regulations*. https://www.elegislation.gov.hk/hk/cap123B!en@2011-08-01T00:00:00

CEO. (2002). *PORT WORKS DESIGN MANUAL PART 4 Guide to Design of Seawalls and Breakwaters*.

Dextra (2019). ASTEC Soil-Nail Submission File for BD Submission. Dextra Group
https://aecom-my.sharepoint.com/:f:/p/michael_ng/Ek3C28psftBGvEHMc2OOXvwBcAOKF8FZF7X5hMldKuphaw

GEO. (2008). *Geoguide 7 Guide to Soil Nail Design and Construction*. https://www.cedd.gov.hk/filemanager/eng/content_117/eg7_20170918.pdf

ACI318-05. (2005). *Building Code Requirements for Structural Concrete and Commentary*. https://www.oaxaca.gob.mx/sinfra/wp-content/uploads/sites/14/2016/02/aci_318-05_building_code_requirements_for_structural_concrete_and_commentary_aci_318r-05.pdf