Constructing Artificial Islands

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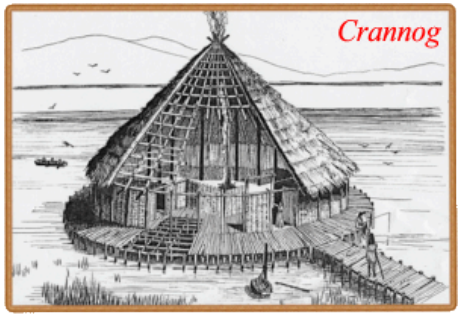
February, 2013

AECOM

Contents

Introduction

Ancient History of Artificial Islands



- Crannogs
  - Constructed in prehistoric Ireland and Scotland.
  - Wooden piles were driven into lakebed to form artificial islands.
- Nan Madol Stone Islands, West Pacific
  - Coral rubbles and stone boulders were piled on coral reefs.

Ancient History of Artificial Islands (Cont'd)

- Tenochtitlan, Mexico
  - Artificial Island founded on piles of canes covered by dirt and held in place by stakes.

- Uros Island, Peru
  - Supported by layers of floating reed anchored with ropes and sticks driven to bottom of lake.
  - The Uro Indians still live on the artificial islands nowadays.

Proposed Reclamation in Hong Kong

長遠增加土地儲備

政府考慮填海建人工島

20/2/2012 Hong Kong Economic Journal

土木處：填海增地不可缺

人工島影響最少

9/12/2011 Hong Kong Economic Journal

New land formed by reclamation offers resettlement option for residents

I refer to the editorial ("There's enough land already available", February 23), and the article ("Harbour 'cheaper route to gain land' ", February 20).

As the editorial rightly suggests, land supply is a complicated issue with complex environmental, political and social dimensions. Our goal is to strike a balance among the social, environmental and economic factors, so as to achieve a sustainable land supply model and address the political dimension through the public engagement process.

Your February 20 report highlights the cost-effectiveness element in considering land supply options. But, in all our dialogue with the public and media, we have also been discussing the impact on, for example, the local community, environmental aspects, accessibility and planning flexibility. The monetary cost is not the government's only or main concern in assessing different land supply options.

We have put forward a six-pronged proposal, with all present land supply options including rezoning, redevelopment, resumption, reuse of ex-quarry sites, rock cavern development and reclamation outside Victoria Harbour being deployed flexibly. However, all six options face their respective challenges.

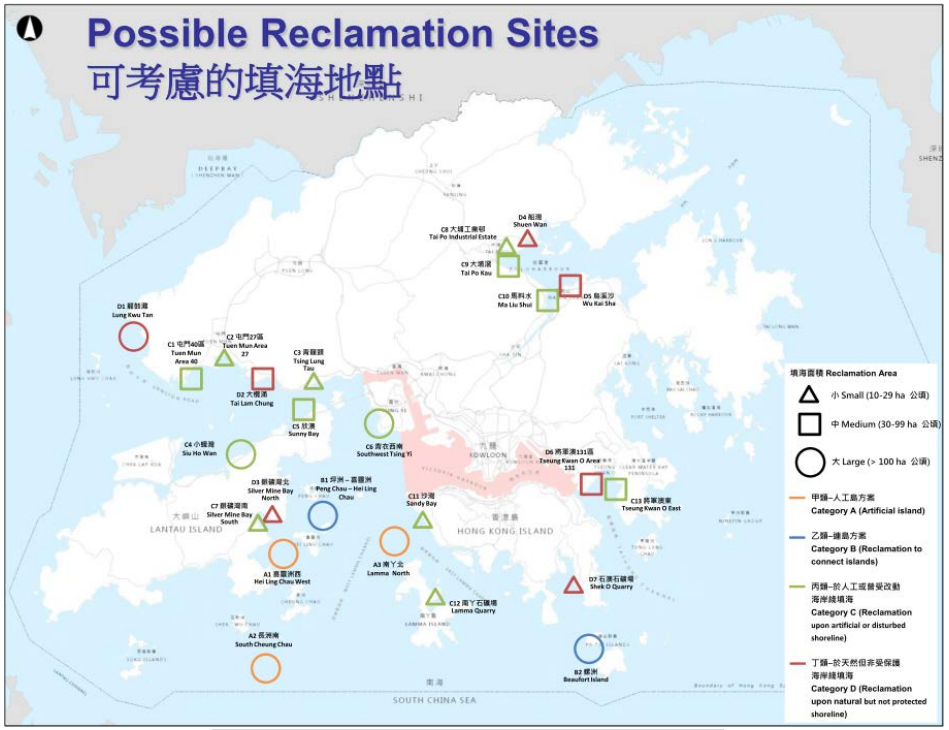
While reclamation may affect marine ecology, land development – including rezoning, redevelopment and resumption – may have an impact not only on the terrestrial ecology, but also on social aspects such as local culture, traditions and social networks. Land development is not necessarily better than reclamation from environmental and social perspectives. Rather, they are complementary. The new land formed by reclamation can provide an option for resettlement of residents and businesses displaced by land development. Public fill generated by land development can also be handled by reclamation. Reclamation should not be ruled out (the same goes for other options), nor should it be regarded as the last resort. We need all six options in play to meet our short-, medium- and long-term needs.

Moreover, the practical meaning of the notion of turning to reclamation as a last resort is hard to conceive. Shall we use up all agricultural land however environmentally sensitive or redevelop all rural and village land in the New Territories before resorting to reclamation? Timing wise, shall we start planning reclamation only when other options provide no further land? It will take 10 years or more to develop a piece of land, whatever its source. We must act now before it is too late.

Edwin K. H. Tong, head of the civil engineering office, Civil Engine

14/3/2012 South China Morning Post

Proposed Reclamation in Hong Kong – ranges from sizes of hectares to mega size of artificial islands



25 Suggested Reclamation Sites

- In order to increase land supply for the city, the government listed 25 possible sites for land reclamation.
- Public consultation has been launched in 2011 until March 2012.
- Five offshore reclamation sites include man-made islands near to Cheung Chau, Lamma and Hei Ling Chau islands as well as part of the sea between Po Toi Island and Beaufort Island to the south.

Recent HZMB Projects involving constructing Artificial Islands:

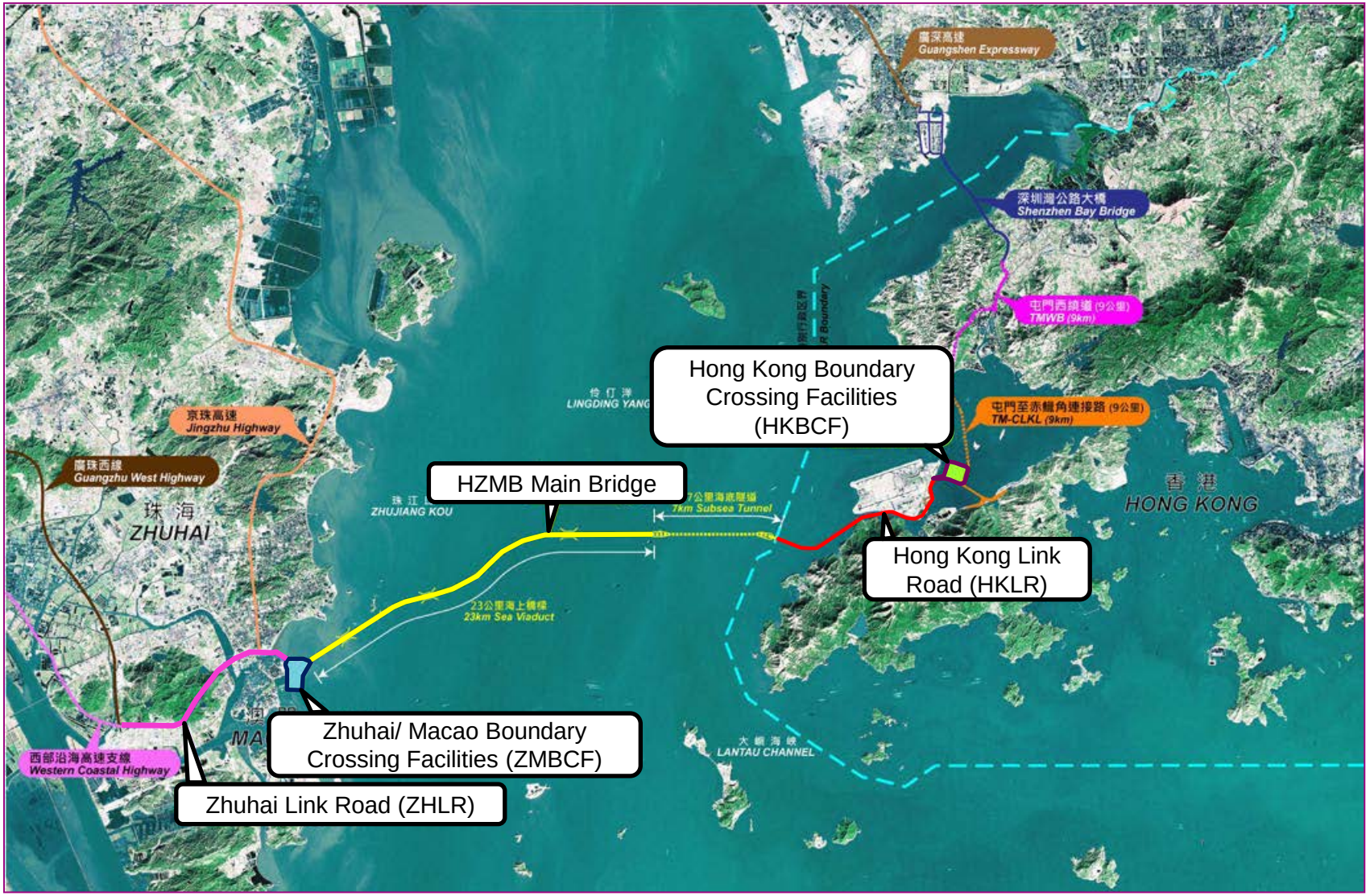
The HZMB project comprises three parts:

(1)The ZHLR starts from the artificial island off Gongbei of Zhuhai and A Perola of Macao, and connects with Guang-Zhu West Expressway under planning by passing through the developed area of Gongbei via a tunnel towards Zhuhai. The ZMBCF is located at the artificial island off Gongbei of Zhuhai and A Perola of Macao which is approx. 216ha in area.

(2) The HZMB Main Bridge runs from the artificial island off Gongbei of Zhuhai to the western artificial island and connect by an immersed tube tunnel with eastern artificial island just west of the HKSAR boundary. It includes a 29.6km dual 3-lane carriageway in the form of bridge-cum-tunnel structure comprising a subsea tunnel of about 6.7km connect by 2 manmade islands.

(3) The HKLR connects the HZMB Main Bridge and the HKBCF. It includes sea viaduct, tunnel and at-grade road section along the east coast of Airport Island, which will be approx. 12km long dual 3-lane carriageway. • The HKBCF is located at an artificial island at the waters off the northeast of the HKIA, connecting Zhuhai and Macao via the HKLR and HZMB Main Bridge. The HKBCF, which will be approx. 150ha in area [including approx. 20ha southern landfall of the Tuen Mun - Chek Lap Kok Link (TM-CLKL)].

The Hong Kong Zhuhai Macao Bridge (HKZMB) Project



Examples of Famous International Experience

Netherlands – Part of Zuiderzee Works
Eastern and Southern Flevopolder (1969)

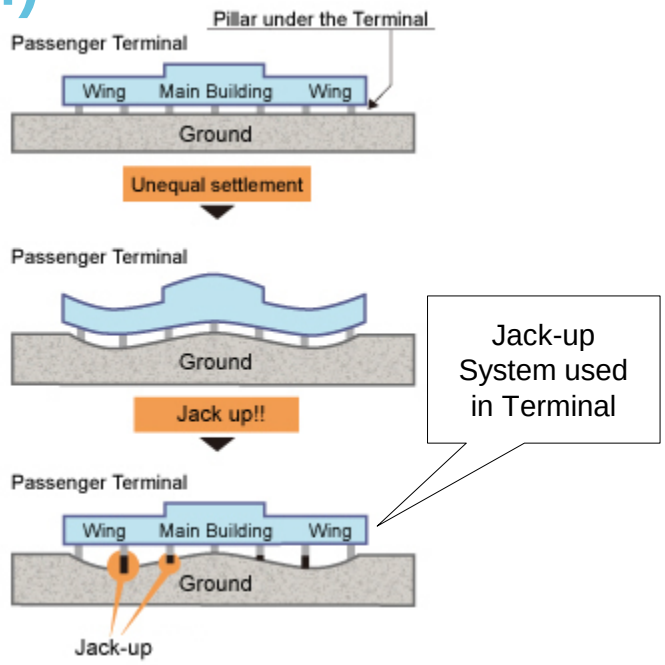
Aerial Photo of E & S Flevopolder

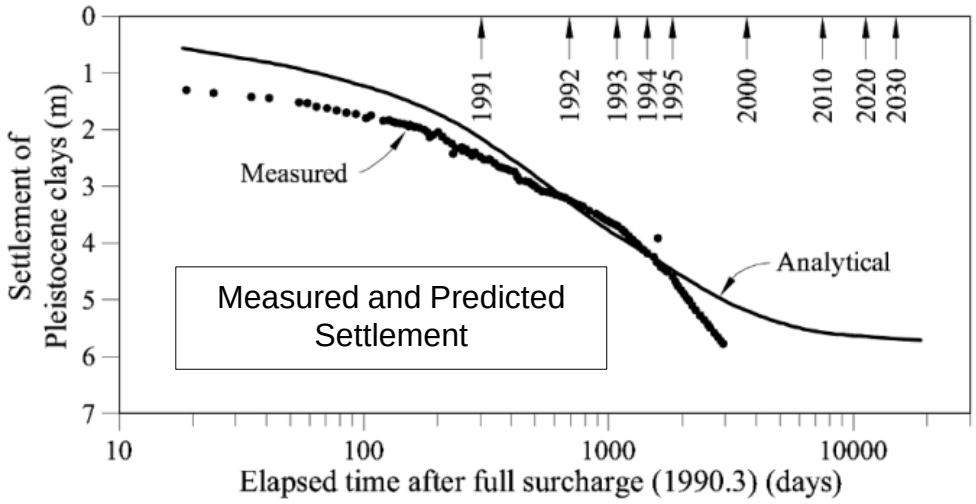
- Reclamation of Flevopolder finished in 1969.
- Total land surface of 970 km^2.
- Largest artificial Island in the world.
- A dividing dike, *Knardijk* in the middle would keep one polder safe if the other is flooded.

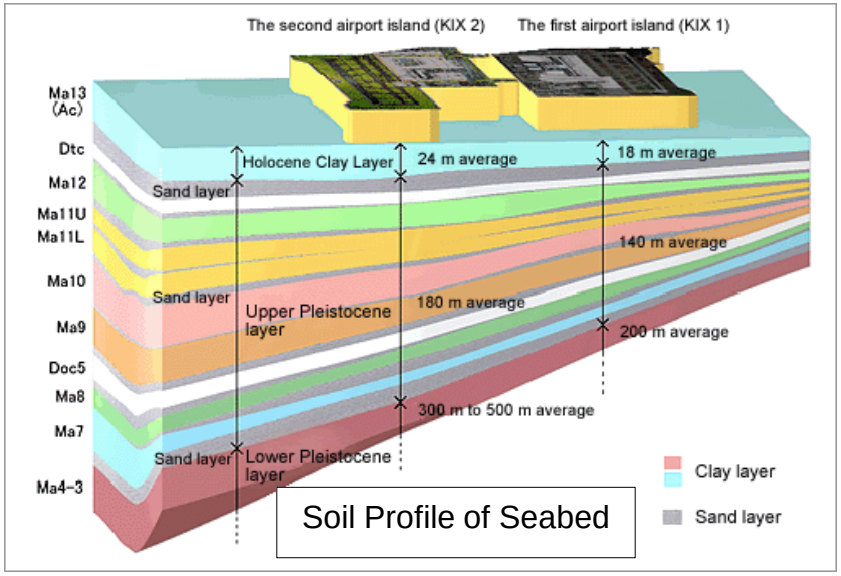
Japan – Kansai Airport, Osaka Bay (1994)

- Area of 4km x 2.5km.
- Constructed with measures to overcome the risks of earthquakes and typhoons.
- Settlement – Sinking of the island to be 8m more than expected. The settlement was caused in the deep Pleistoscene layers.
- Adjustable columns constructed to support terminal building for compensating settlement.
- Most expensive civil works project in modern history.
- "Civil Engineering Monument of the Millennium" award by ASCE in 2001.

Japan – Kansai Airport, Osaka Bay (1994)



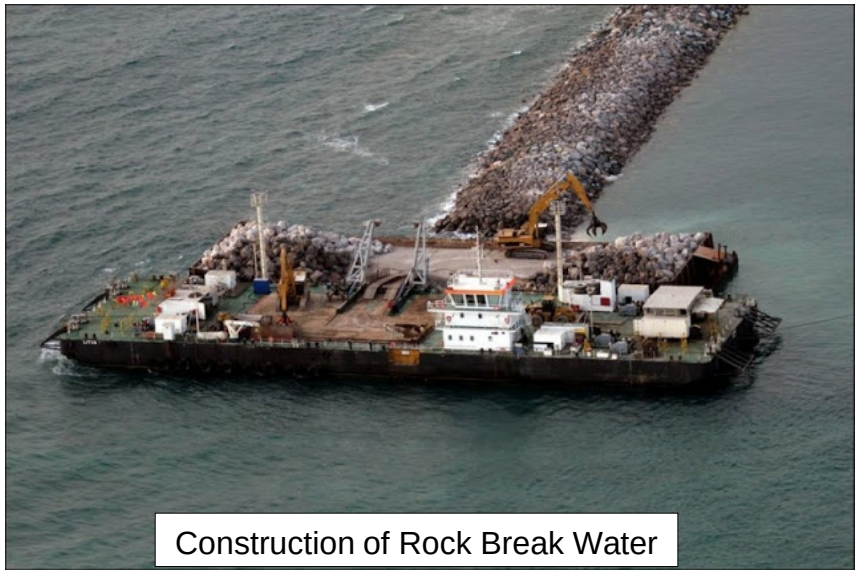




Dubai – The Palms (2001)

- Planned area of 50 km^2.
- Constructed by rainbowing technique with sand dredged from Persian Gulf.
- Risk of liquefaction eliminated during construction by vibro-compaction.
- Encircled by large rock breakwater.

Dubai – The Palms (2001)



Construction of Rock Break Water

Rainbowing

The Palms

The Palms – Closer View

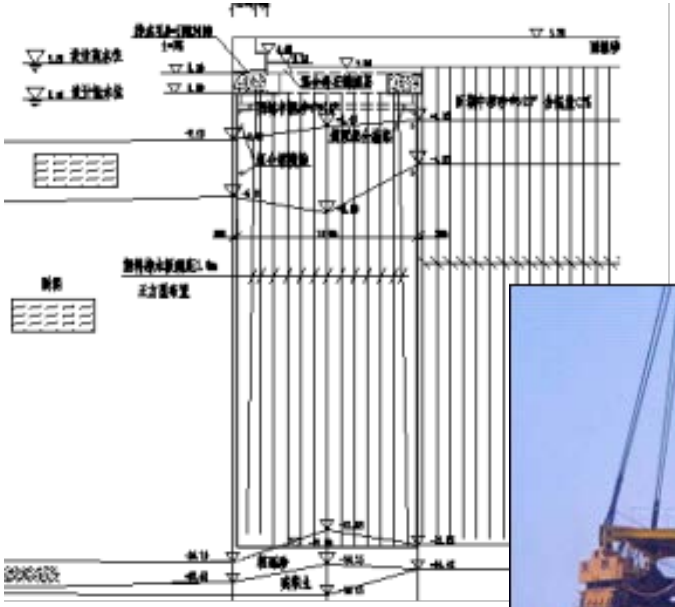
Innovative Construction Methods – AECOM Experiences

Large Diameter Steel Cellular Cofferdam

.

Large Diameter Steel Cellular Cofferdam – Nansha Development (2001-)

Nansha coastal work utilizing 39 nos of steel tube with 13.5m diameter and thickness of 12mm, penetrating 6m of alluvial sand to -32.5mPD.
It was installed using 4 nos of APE hydraulic Vibrator.
The structure is in good condition to-date.



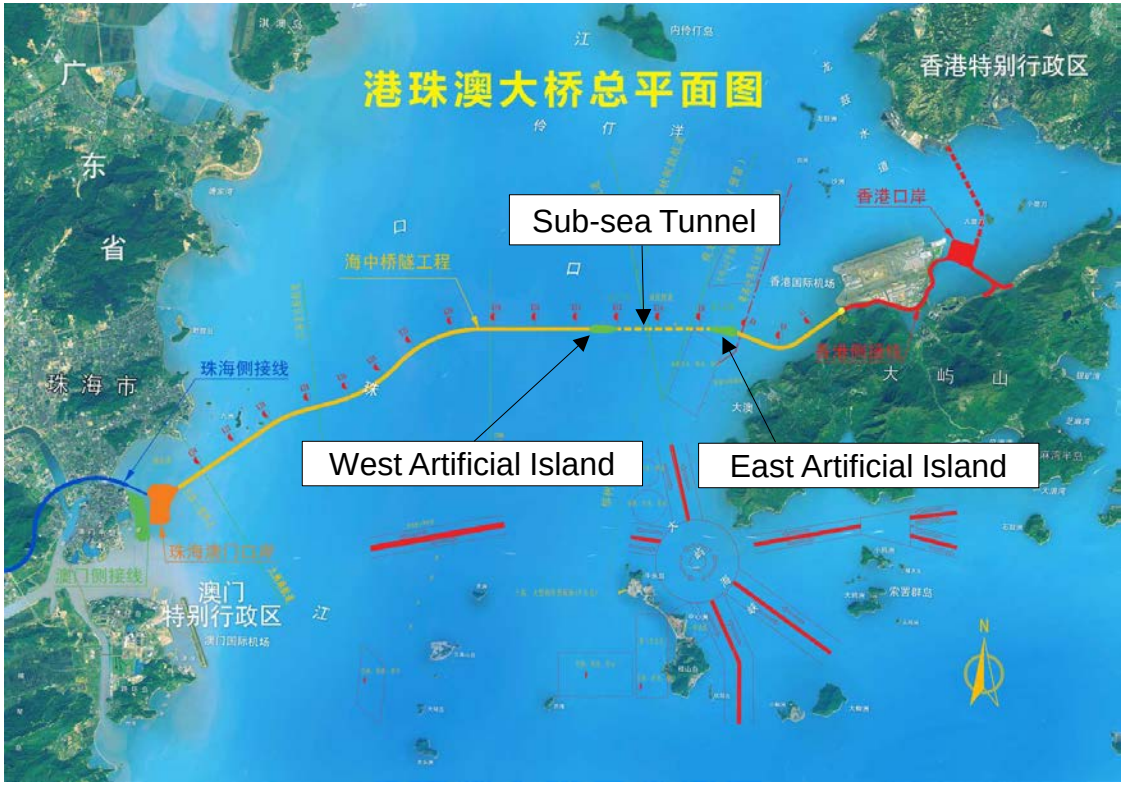
Large Diameter Steel Cellular Cofferdam

- West Artificial Island of Hong Kong Zhuhai Macao Bridge (HZMB)

Construction completed at October 2011.

Materials and photographs taken from www.cccchzmb.com are duly acknowledged.

The HZMB Project



- For construction of the HZMB Main Bridge, AECOM has been engaged by the JV Contractors to be responsible for the PMCM work comprising a Sub-sea Tunnel of about 6.7km connected by 2 man-made islands.

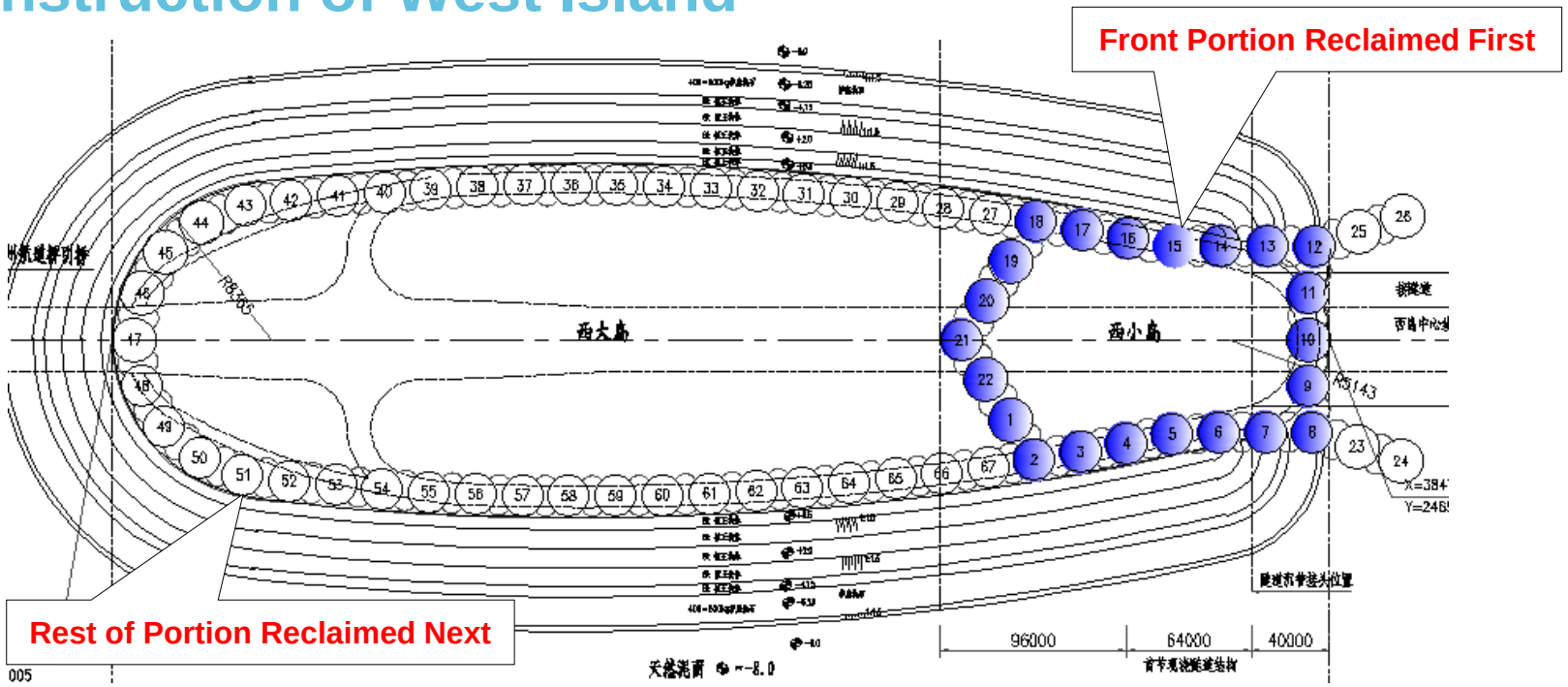
- The project commenced in mid-December 2010 by constructing west artificial island with the objective that island should be completed within 20 months or shorter so that the preparation work for the laying the first section of the IMT can be established.

Construction of West Island

Formation of West Island with Large Diameter Cofferdams

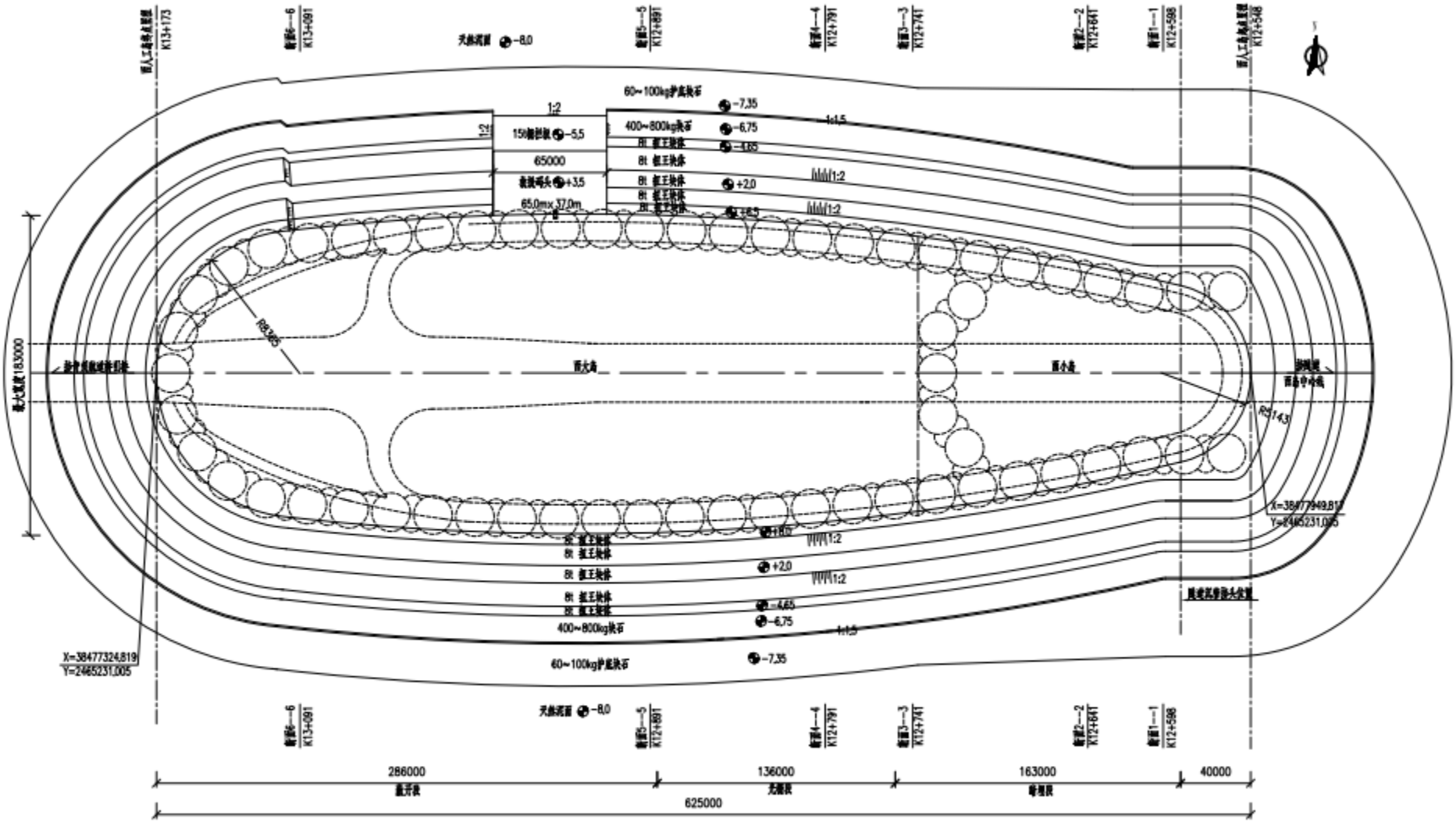
- The steel cofferdam has been designed to penetrate into an impermeable layer of alluvial silt layer with SPT N>8, which is estimated to be about 15m depth from seabed.

Construction of West Island



- The construction of west island is divided into two phases. The front portion where the IMT is connected to the cut and cover tunnel would be reclaimed first.
- The front portion has been reclaimed first by installing 22nos. of 22m diameter steel tubes.
- The rest of the portion is installed by 45 nos. of similar tubes.
- 67 nos. of tubes (of 16mm thickness) have been installed in total with average depth of 41.5m, and weigh 450 tonnes.

Construction of West Island (revised)



西岛结构平面图

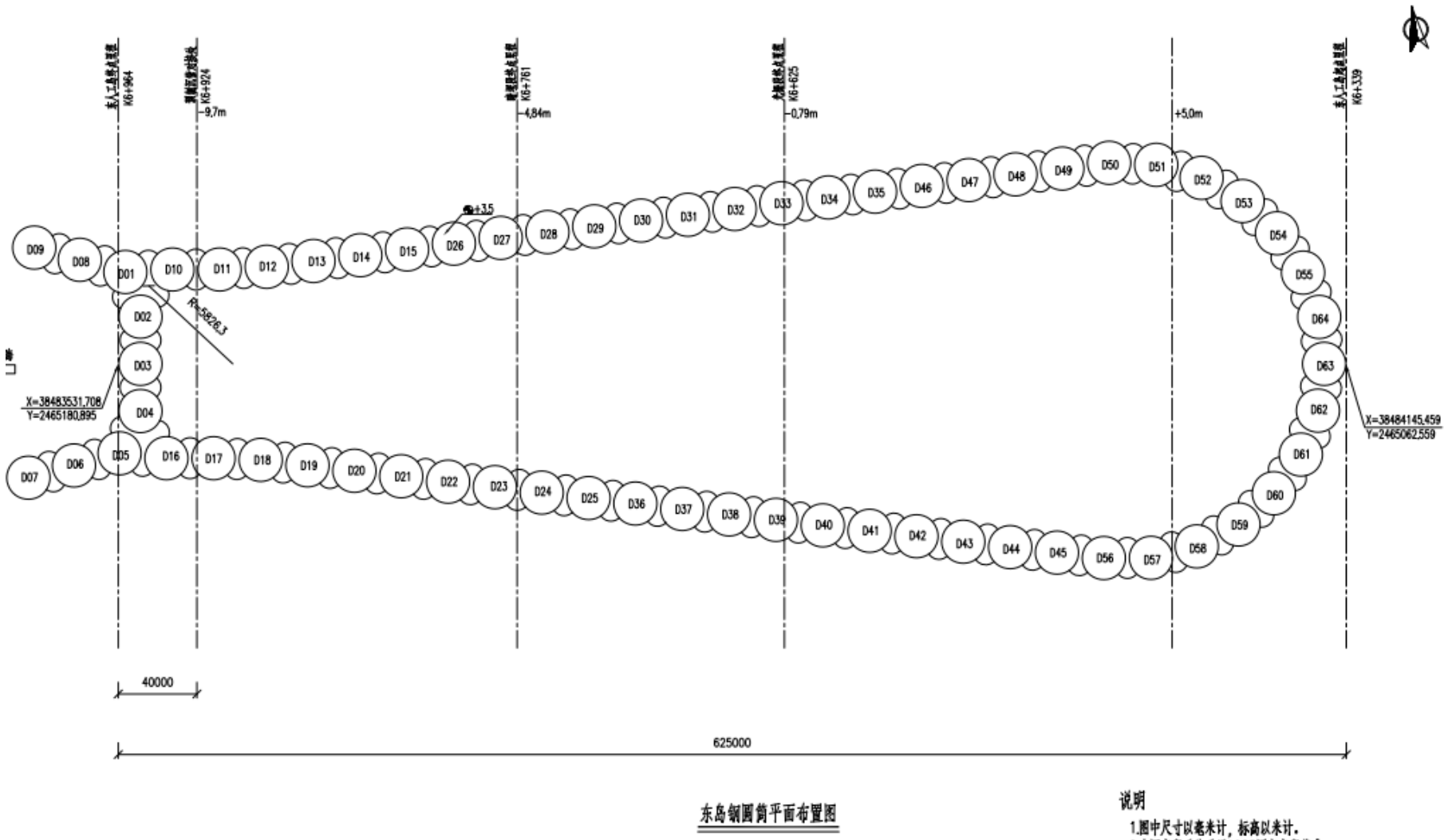
说明

1.图中尺寸以毫米计，标高以米计。

2.本图高程系统采用1985国家高程基准。

AECOM

Construction of East Island (revised)

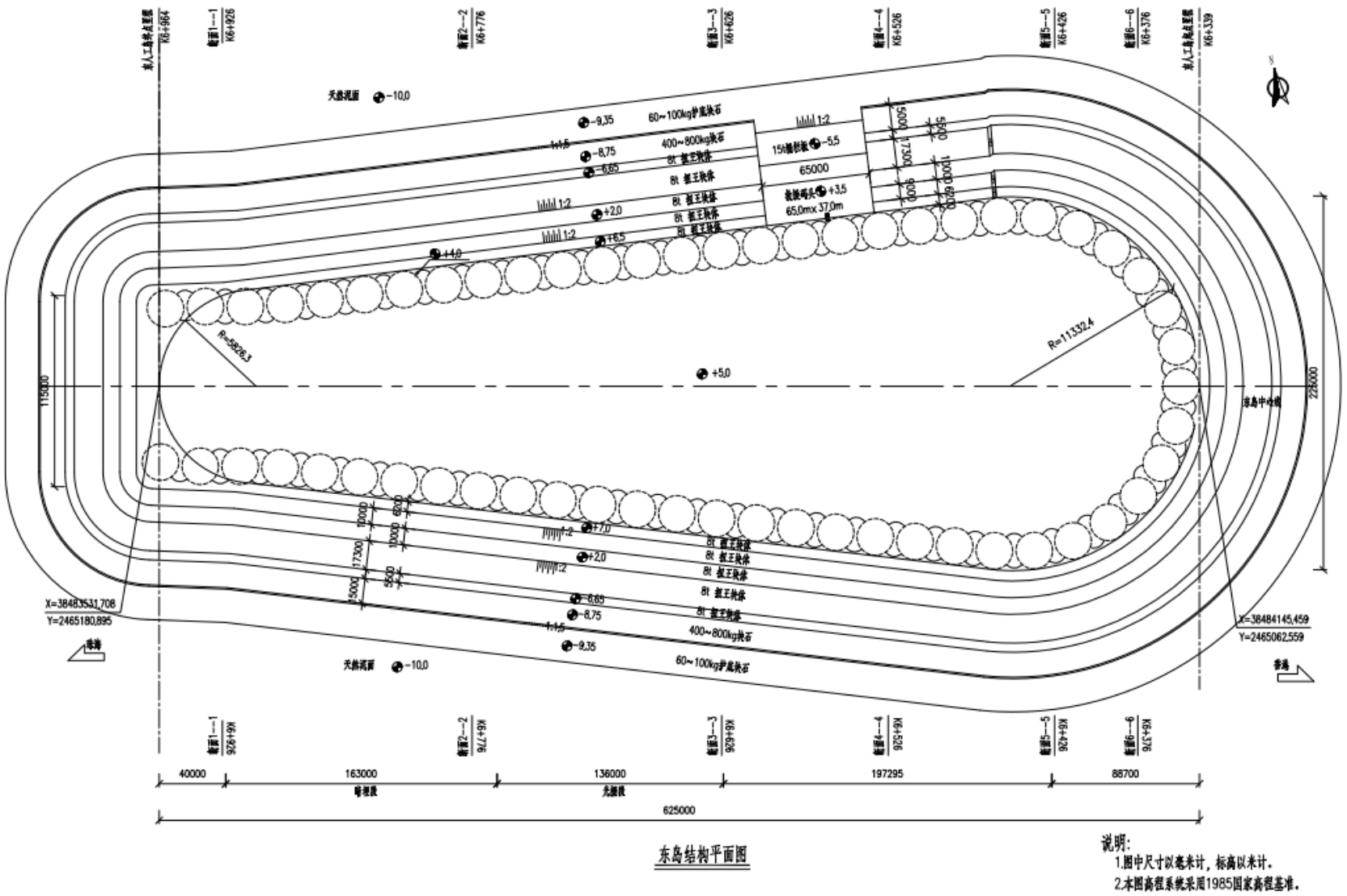


东岛钢圆筒平面布置图

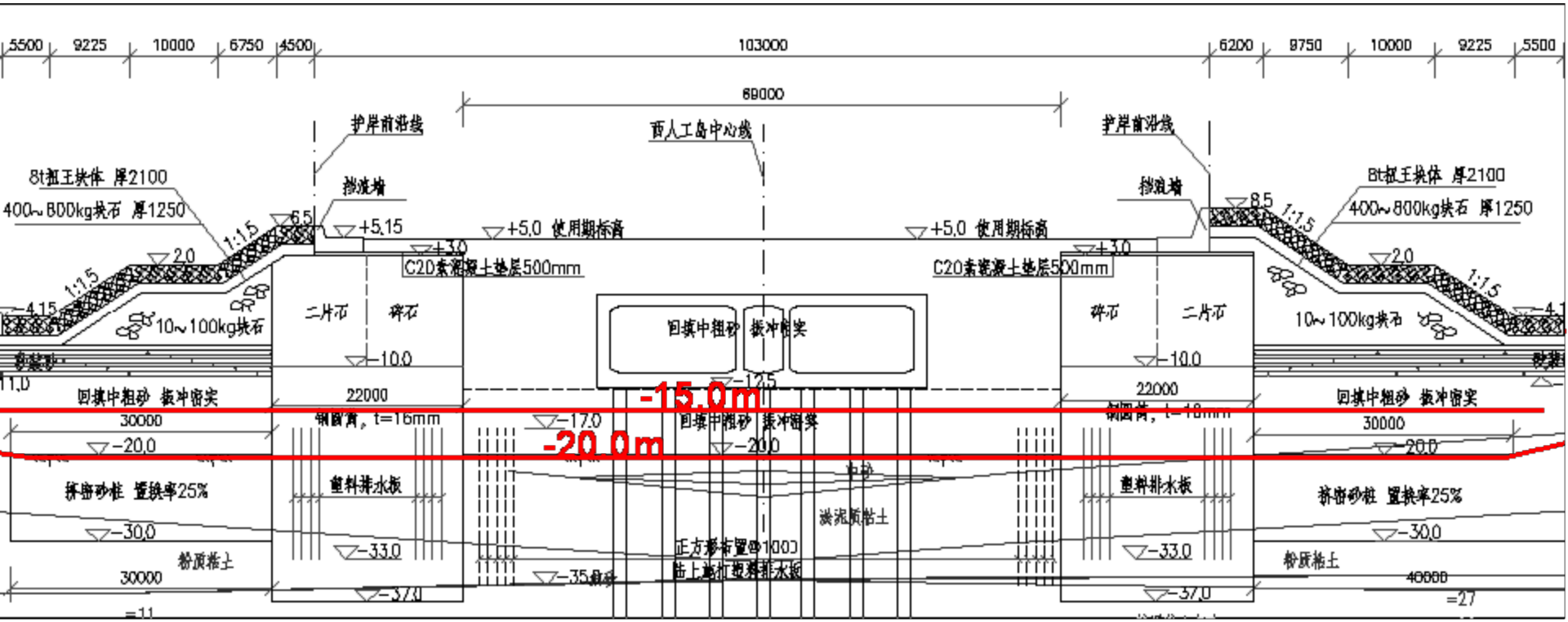
说明

1.图中尺寸以毫米计，标高以米计。
2.本图高程系统采用1985国家高程基准。
3.钢圆筒直径22.0m，筒间距2.0m，周21对直线型钢板桩连接.
4.东人工岛共64个圆筒。

Construction of East Island (revised)



Construction of West Artificial Island - Section

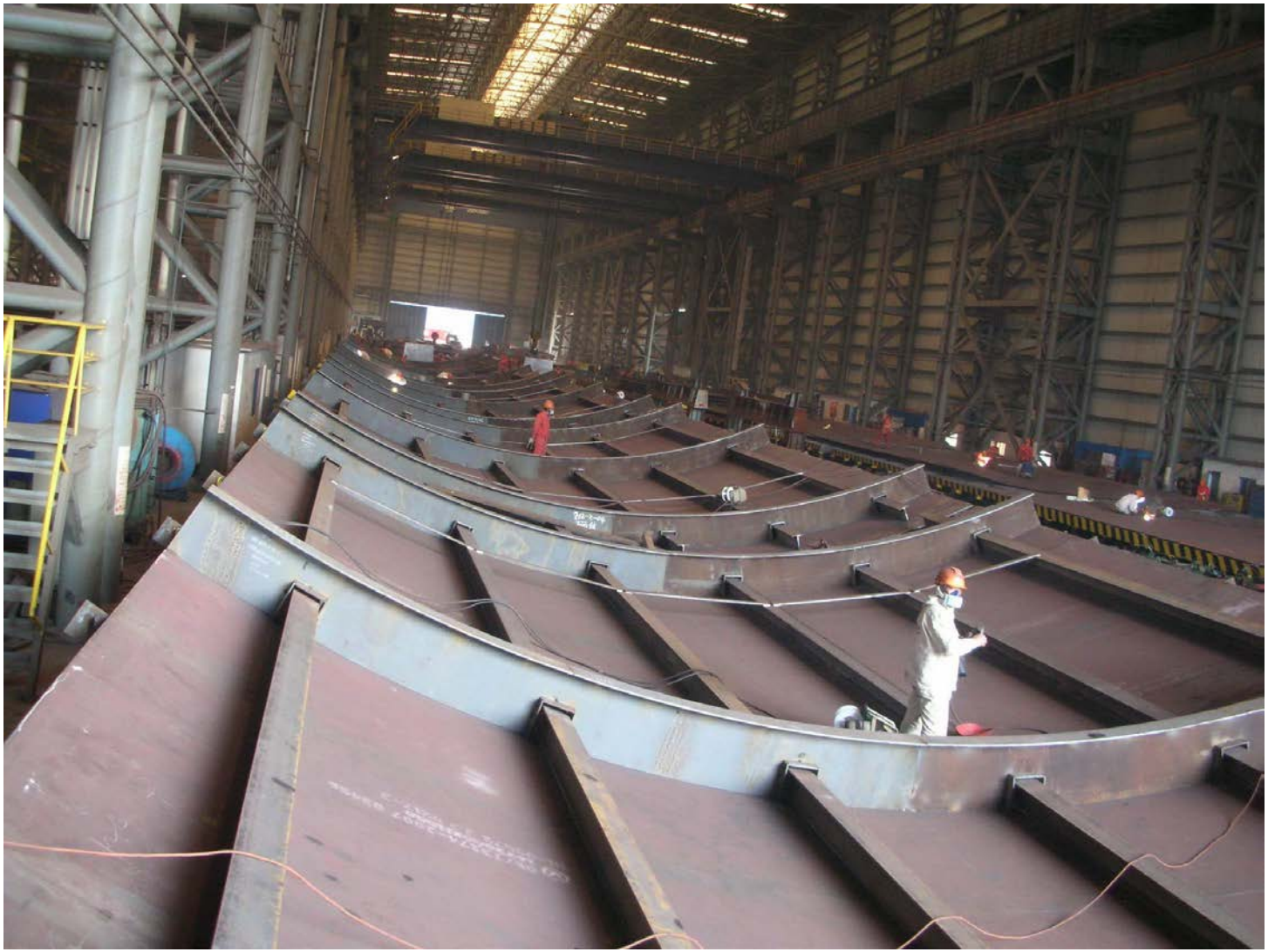


Construction Sequence for Front Portion of West Island

1) Excavate to -20m of the soft soils;
2) Back fill 5m of sandy materials (i.e. -15m);
3) Insert steel tubes;
4) Backfill the sand in the tube and later in the enclosure to +2m just above the sea level;
5) Install PVD and vacuum pipes;
6) Add surcharge load to +5m;
7) Lower the water bu high vacuum to -20m for 90 days;
8) Excavate to formation level for the C& C section;
9) back fill to +4.26m.
10) For portion outside the island, install SCP for improvement foundation, and build sloping seawall with rock fill .

Construction of West Artificial Island in progress

Making Large Diameter Steel Cofferdam



Making Large Diameter Steel Cofferdam

Making Large Diameter Steel Cofferdam

Transporting

Installing

Installing

Filling

Making Web

Installing Web

Installing Web

Forming

Forming

Installing PVDs within Cofferdam

Filling Island and Installing PVDs (far left)

Installing High Vacuum Dewatering Pipes

High Vacuum Dewatering in progress

Making Wave Barriers

Surcharging

Site Formation

Site Formation

Excavation for Cut and Cover Foundation

Installation of JGP

Installation of JGP

Installation of SCP

Installation of SCP along Alignment

Installation of SCP (interface with JCP)

Work Intensified

Making Progress

Making Progress

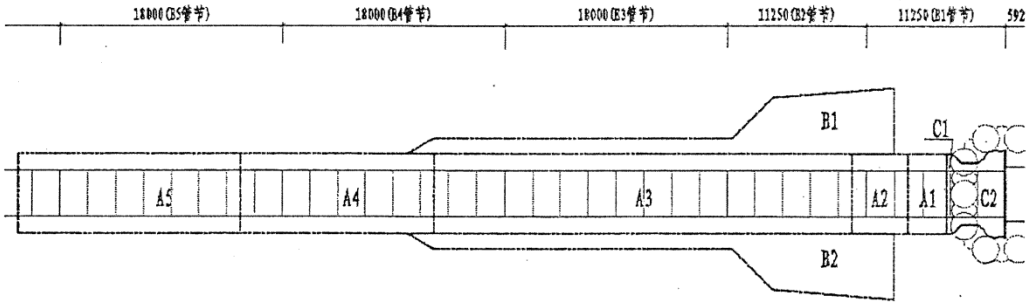
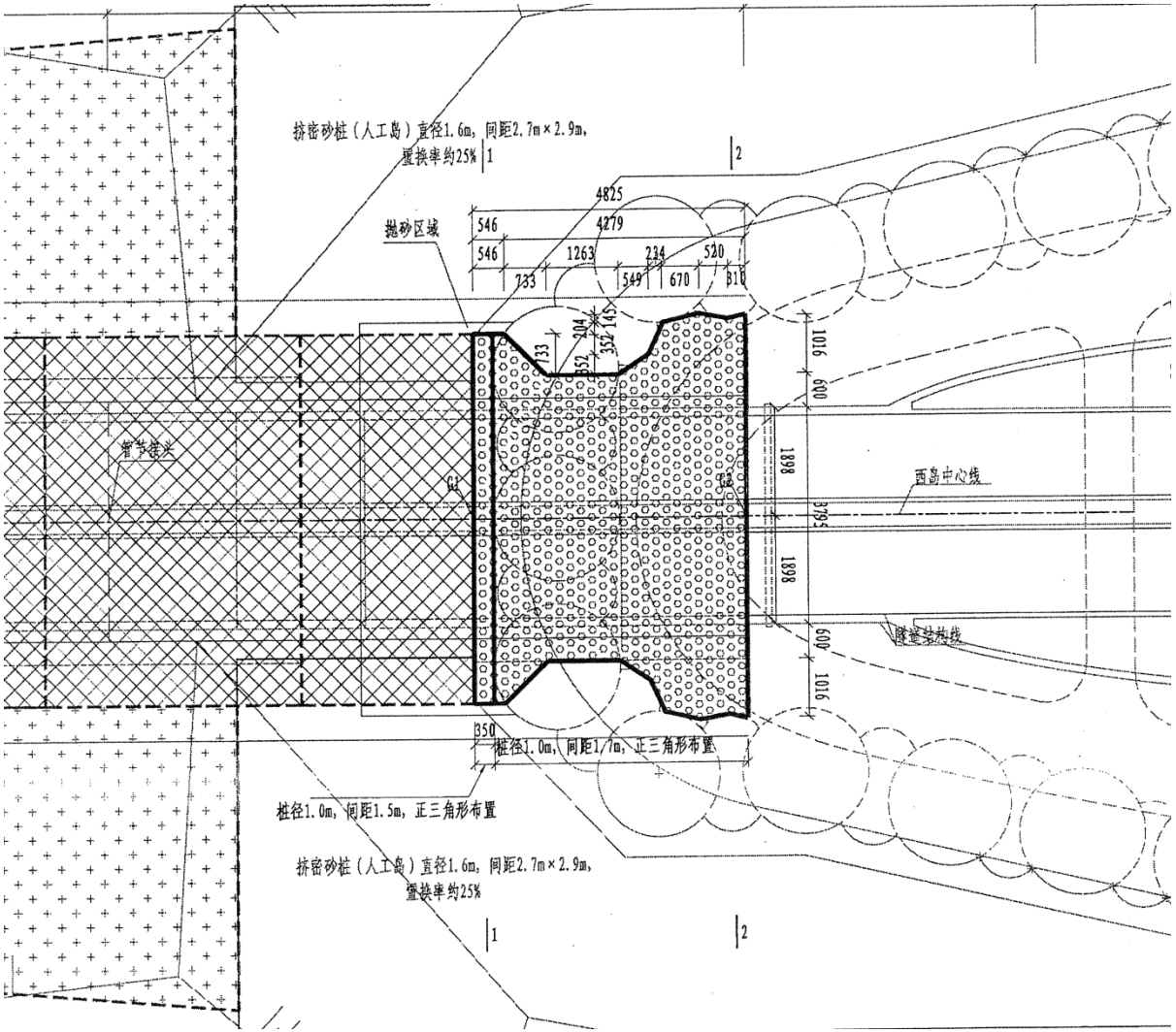


图 5.3-1 地基处理分区示意图

表 5.3-1 地基处理分区一览表

序号	区域	区块	面积（m^2）	处理方法	置换率	管节/里程
1	A	A1	1970.3	挤密砂桩+堆载预压	70%	E4-S2~E1-S3 K12+126.75~K12+539.75
2		A2	2907.0		55%	
3		A3	21802.5		42%	
4		A4	10174.5	挤密砂桩	62%	E6-S2~E4-S2 K11+789.75~K12+126.75
5		A5	11628.0		55%	
6	B	B1	8965.9	排水砂井+堆载预压	11%	E4-S2~E1-S4 K12+126.75~K12+498.0
7		B2	8965.9			
8	C	C1	226.1	高压旋喷桩	40.3%	E1-S3~E1-S1 K12+539.75~K12+588.0
9		C2	2662.4	高压旋喷桩	31.4%	
10	合计		69302.6			

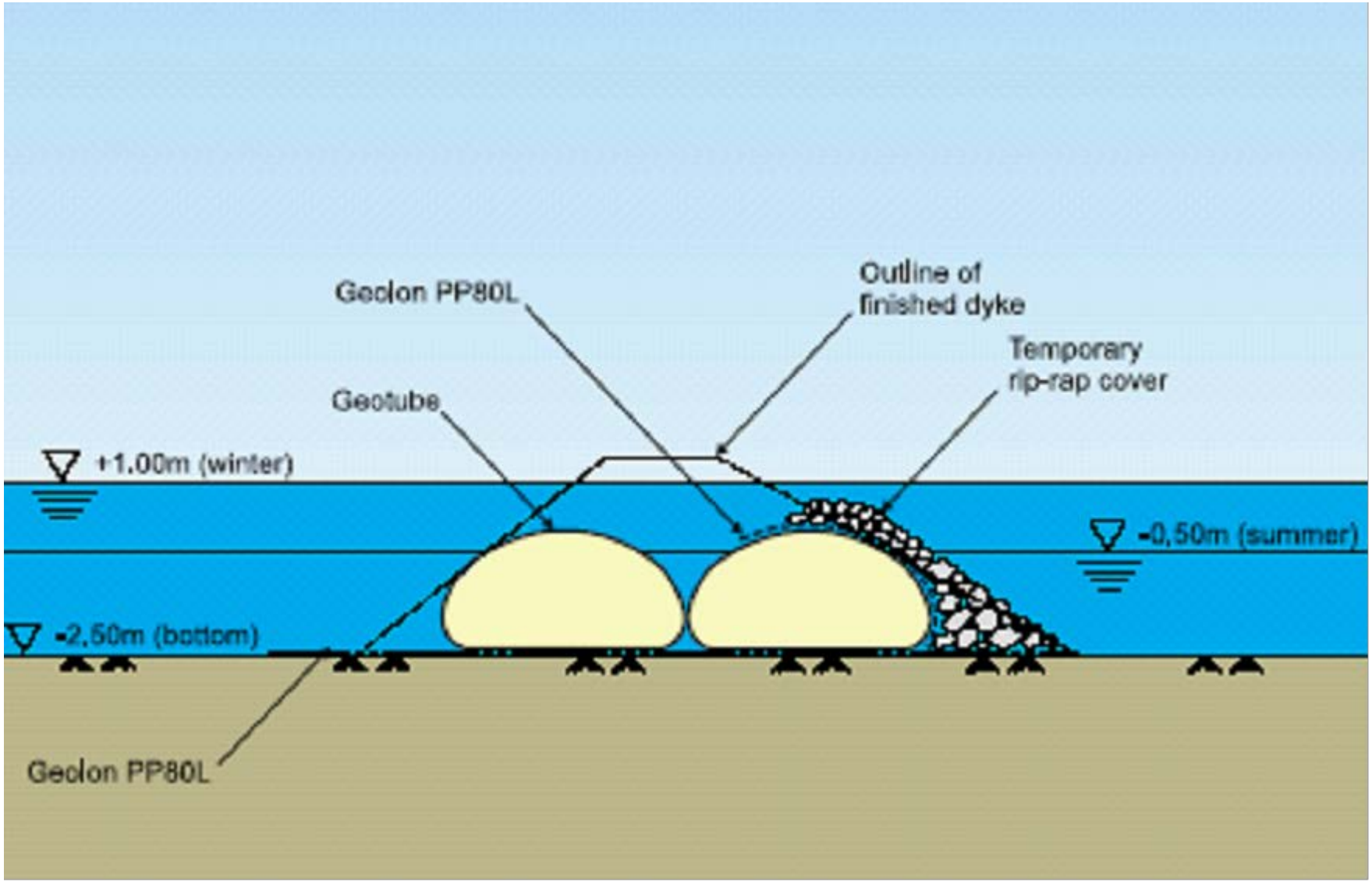
Making Progress



Making Progress

Geo-matress Revetment

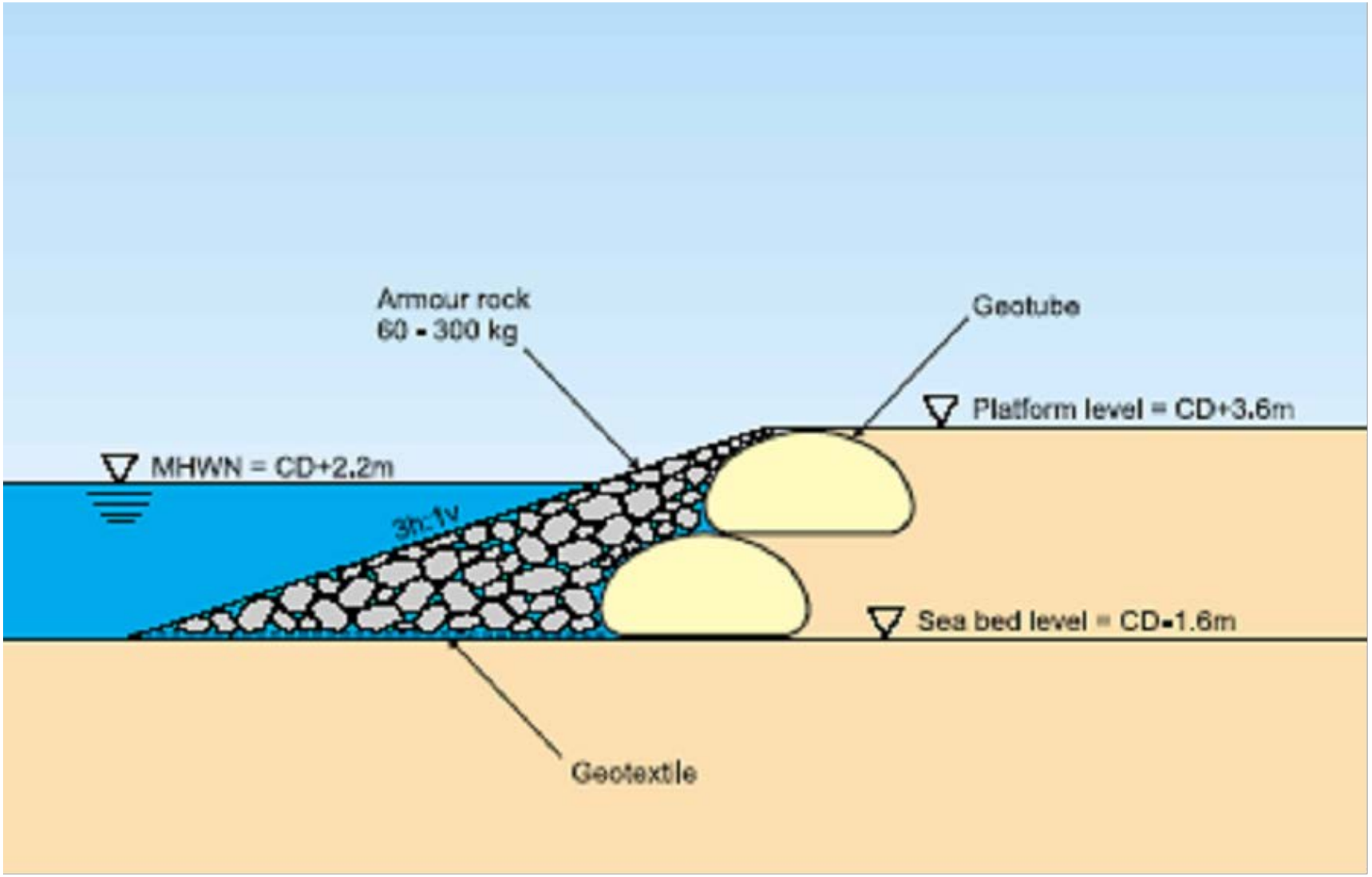
Containment Dyke



Naviduct, Lake Ijssel, The Netherlands
Geotube to retain dredged

Shamrock Island, Corpus Christi, Texas, USA
Geotube to reclaim wet land

Artificial Islands



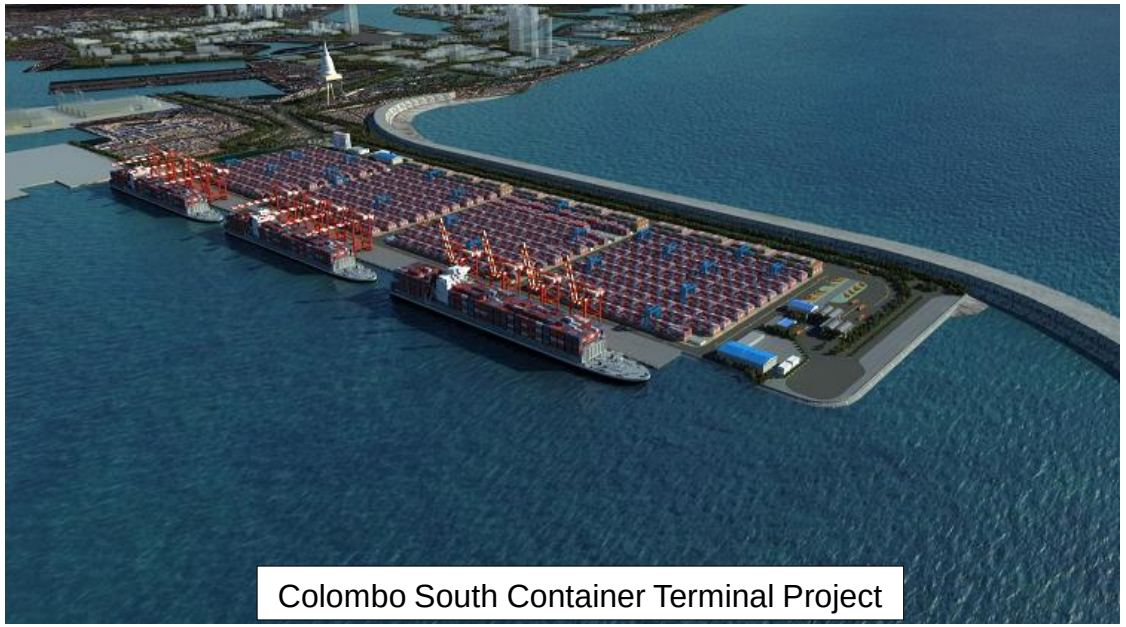
Temporary Cofferdam Formed by Geo-bags

Geo-matress Revetment

- Colombo South Container Terminal Project

Colombo South Container Terminal Project

- Works comprise of the following:
  - 1200m long quay wall with quay facilities
  - Revetment
  - Dredging
  - Reclamation of approx. 58 hectares
  - Roads and pavements
  - Buildings
  - Ducting
  - Lighting
  - Utilities and Services
  - Fencing, etc



Colombo South Container Terminal Project

Colombo South Container Terminal Project

- The works comprise of 1200m long quay wall with quay facilities, revetment, dredging, and reclamation of 58 hectare approximately.
- A temporary cofferdam retaining the fill material (i.e.dredged sand fill) prior to completion of quay wall.
- Top and bottom levels are proposed to be +2m and -7m respectively. Side slope is about 1 to 1.5.

Colombo South Container Terminal Project

- Each layer of the sand bag cofferdam was controlled to be approximately 0.5 m thick.
- Based on the designed size of the cofferdam, the dimensions of each sand bag were tailor-made.
- The largest sand bags—which were 23 m long, 19.7 m wide and 0.5 m thick—were used to form the bottom layer.
- The design tensile strength of the sand bag was 24 kN/m. The sand bags were equipped with special inlets, located at regular intervals.

Temporary Cofferdam Formed by Geo-bags

Heavy Duty Polypropylene Geo-bags (Vent)

Filled with sands

Temporary Cofferdam Formed by Geo-bags

Temporary Cofferdam Formed by Geo-bags

Forming Artificial Land

Filling

Filling

Performance Verification

Performance Verification

- The verification is to apply observational method using instrumentation.
- Inclinomter and settlement plates are installed to measure the lateral and vertical deformation for both cases.
- For selective location, piezometers are installed as option to monitor the excess pore pressure behaviour.
- After more than 6 months, the completed steel tube/ sand bag cofferdams are remained stable.

Discussion & Conclusion

Constraints for Construction Method

- Large Diameter Steel Cellular Cofferdams can be applied for deep water reclamation:

- Fast track (less tolerance)

- Expensive

- Geo-bags can be applied to about 10m, where water is less deep:

- Slow process (high tolerance)

- Cost effective

Typical risk & mitigation using large diameter cellular cofferdam

Risks

– Instability during construction
– Tilting during installation
– Jam at shallow depth

- Mitigation

– Filled asap
– Cut and erect
– Install additional element

Tilted Cofferdam

Tilted Cofferdam

Typical risk & mitigation using Geo-bags

Risks

– UV attack
– Broken during installation
– Vandalism

- Mitigation

– Installed asap
– Site repair
– Protect with armour rock

Pros and Cons of using Geo-bags

Pros and Cons of using Geo-bags

Future Recommendation

- Standardized with proper design and construction procedures
- By Design Code
- By Performance Specification
- By Material Specification
- By Verification

References

- *Technical Standards and Commentaries of Port and Harbour Facilities in Japan* (1999 edition),,published by Overseas Coastal Area Development Institute
- Geosynthetics and geosystem in hydraulic and coastal engineering, krystian W pilarczyk, AA Balkema, 2000.

Progress Photos of HKZMB – East Island

Progress Photos of HKZMB – East Island

Progress Photos of HKZMB – East Island

Progress Photos of HKZMB – East Island

Progress Photos of HKZMB – West Island

Progress Photos of HKZMB – Overview of West Island

Progress Photos of HKZMB – Deep Dock

Thank You

February, 2013