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Siltation Control Of The Immersed Tunnel For Hong Kong-Zhuhai-Macao Bridge Project

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Communication for connecting the world and construction for a boundless world

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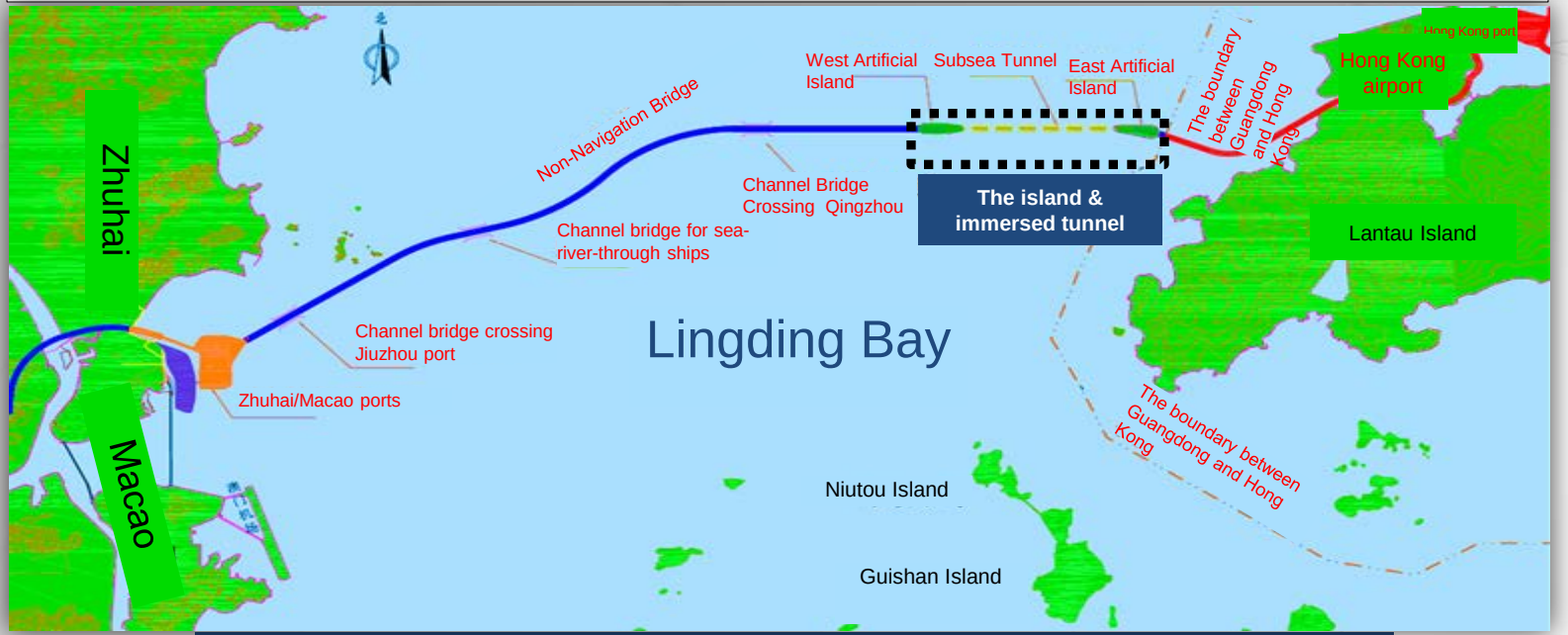
1. HZM-Bridge Project Profile

HZM-Bridge, connecting Hong Kong, Zhuhai and Macau, by about 30km bridge and 6km island & immersed tunnel, a large-scale lane crossing Lingding Bay (Pearl River marine outfall), with the construction period for over 7 years, now still on construction, to be completed at the end of 2017.

The subsea immersed tunnel, with the maximum depth(50m) and the longest span one in the world, being undertaken by a CCCC-led Joint Venture, as the design–build contractor . The engineering is subject to rigorous quality requirements, complex technology and high comprehensive difficulties.



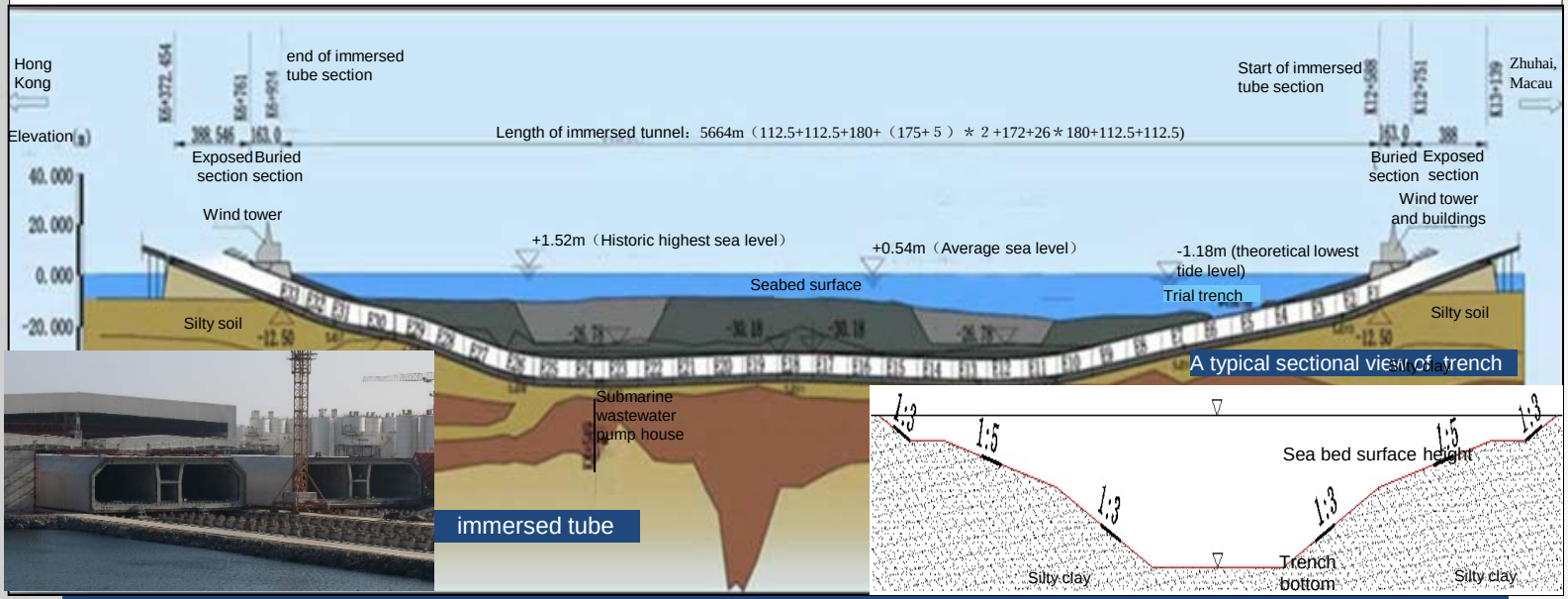
General layout of Hong Kong-Zhuhai-Macao Bridge

1. HZM-Bridge Project Profile

The immersed tunnel, the length of 5.7 km, width of 41.95 m, and the maximum bottom elevation is about - 50 m, different slope ratios horizontally and multiple combinations of slope ratios between 0.3% and 3% longitudinally in the shape of W. It is made up of **33 sections of immersed tubes**, with the length of 180m, the weight of about 80,000 t each section, the same as that of one **airplane carrier**.

The trench is easy to be silted, due to complex sea conditions, the changeable climate, and the tunnel almost vertical to the water flow. To ensure quality of the tunnel foundation, and the stern requirement of water density while installing immersed tube, the contractor should have to take effective measures:

(1) to reduce external sources of siltation; (2) to remove siltation from trench in an effective manner.



Vertical & crossing sections of immersed tunnel trench

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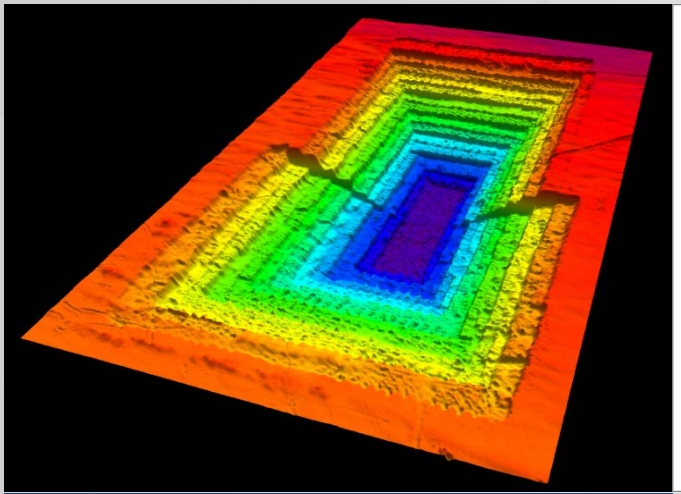
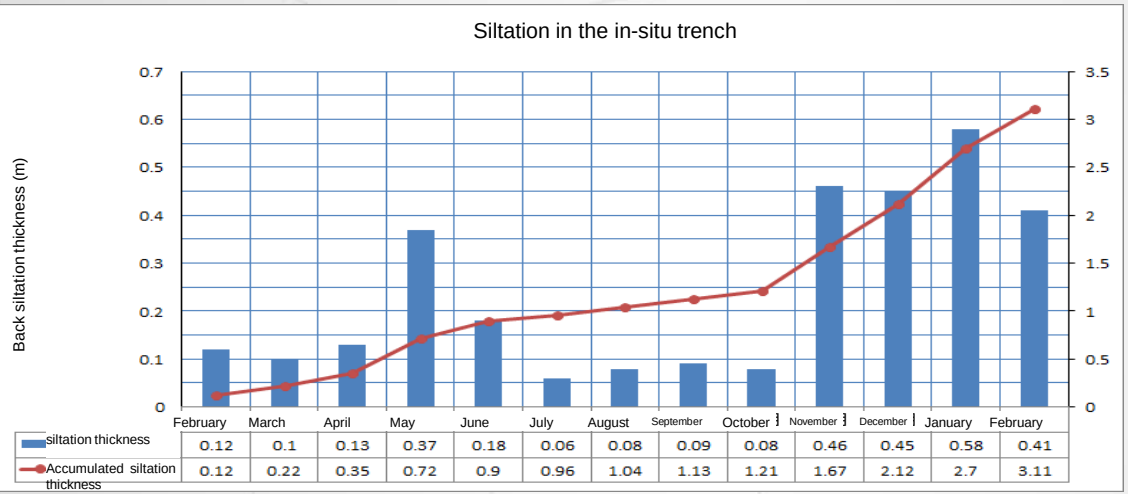
（1）Impact of the siltation from the upstream flow (natural conditions)

1) **Long-term observation, mathematical models**: The Lingding Bay, the marine outfall of Pearl River, its runoff rate of 3,000~30,000 m3/s, maybe silted at a rate of about 15~25 cm per month.

2) Special trench in-situ for the tunnel: to assess the stability of the slopes and the siltation rate, for guidance of trench design and construction, the contractor conducted an in-situ trench (100m*21m*(-21m)) excavation and observation for one year, before the commencement of construction, with the result of 24cm/mon on average.



3D graph of the in-situ trench for the tunnel



	February	March	April	May	June	July	August	September	October	November	December	January	February
siltation thickness	0.12	0.1	0.13	0.37	0.18	0.06	0.08	0.09	0.08	0.46	0.45	0.58	0.41
Accumulated siltation thickness	0.12	0.22	0.35	0.72	0.9	0.96	1.04	1.13	1.21	1.67	2.12	2.7	3.11

Siltation intensity curve in the in-situ trench

（2）The impact of upstream sandpit (human influence)

Upstream Sandpit, with its excavation quantity up to 200,000 m3/month, making cloudy tailing water, the distance from the project site is about 20km, decreasing more than 10km in recent years, has been influenced the tunnel construction more and more seriously.

High-precision Satellite Remote Sensing Image Showing Suspended Silt Transportation Caused by Sand Mining Operations in November, 2014.

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3. Quality Standards of siltation control for the tunnel

To meet the 120-year service life requirement of the immersed tunnel, and the floating conditions for installation of the immersed tube, the contractor has established the dredging requirements and water density control standards for each stage of operations relating to the tunnel foundation.

Inspection Items and Standards concerning the Trench Dredging

S/N	Working procedures for tunnel foundation	Quality standards for dredging	Inspection method
1	Before the fine excavation of the trench	The siltation, thickness less than 0.3 m, with its density more than 1.26 g/cm3	MeterMultibeam echosounder, sludge density meter
2	After the fine excavation of the trench, Before riprap compaction	The siltation, thickness less than 0.3 m, with its density more than 1.26 g/cm3	Multibeam echosounder, sludge density meter, inspection by divers
3	After riprap compaction, before compaction of hardcore bed (crushed-stone cushion)	The siltation, less than 0.1 m with its density more than 1.26 g/cm3, or less than 0.3 m with its density more than 1.15 g/cm3	Multibeam echosounder, sludge density meter, inspection by divers
4	After compaction of hardcore bed, before segment sinking	The siltation, less than 0.06 m with its density more than 1.26 g/cm3, or less than 0.08 m with its density more than 1.15 g/cm3	Multibeam echosounder, sludge density meter, inspection by divers
5	Dredging for trench side slope before laying of crushed-stone cushion	The average siltation thickness is less than 0.5 m	MeterMultibeam echosounder
6	Maintenance dredging for trench during construction	The average siltation thickness is less than 2 m	MeterMultibeam echosounder

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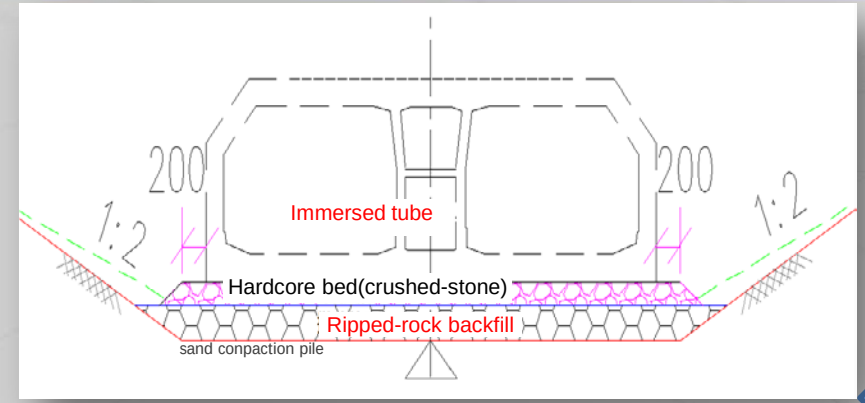
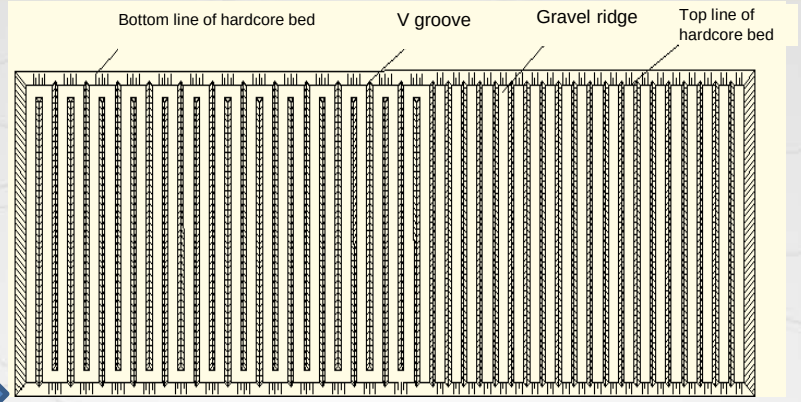
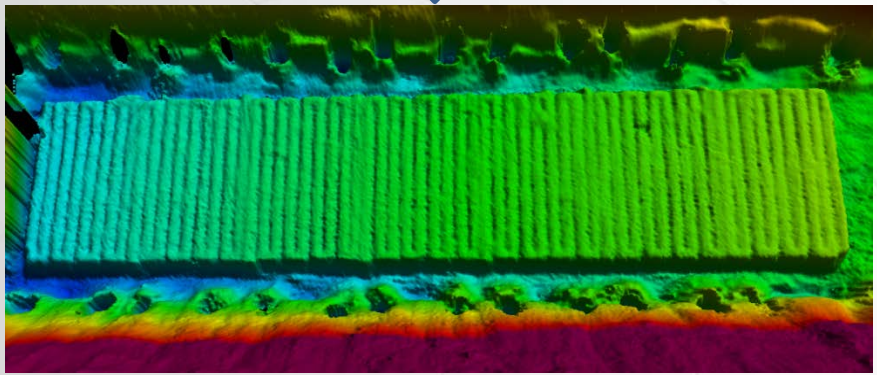
4.1. Design for increasing sedimentation capacity of the trench foundation



A typical section of the tunnel foundation



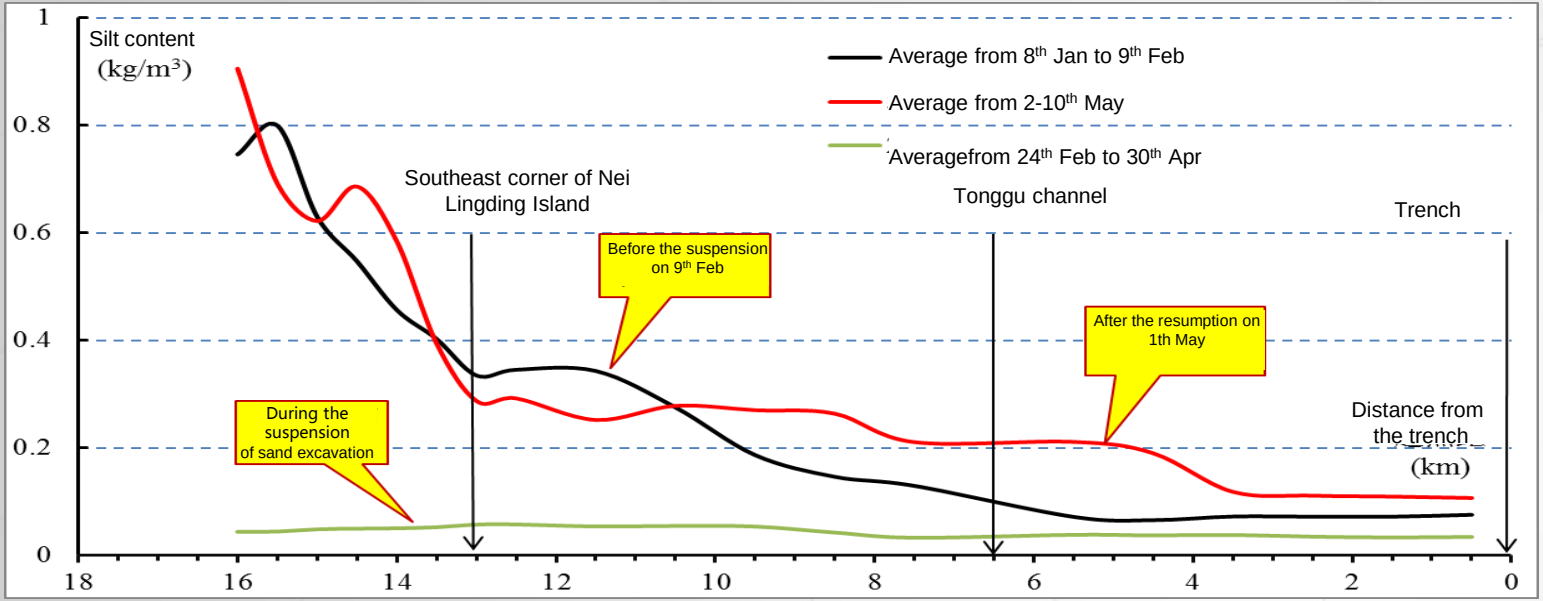
Layout of hardcore bed above the ripped-rock



3D graph of hardcore bed

4.2. to Suspend the sand excavation

Siltation of the tunnel trench:
(1) 3.7 cm/d, during sand excavation;
(2) 1.3 cm/d, during suspension of sand excavation.
To assure the construction of the tunnel, **the sand excavation has to be suspended**.
However, the dredging for the tunnel foundation at various stages, should be well-prepared and implemented.



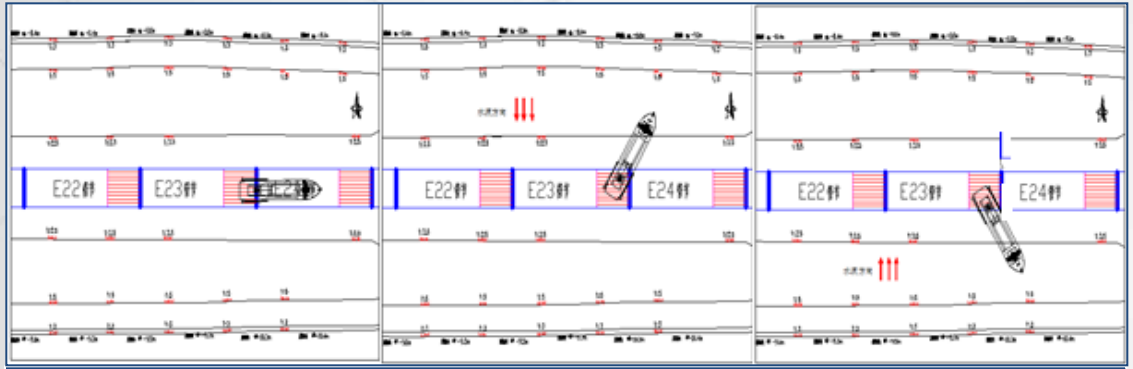
Curve of Silt Content at various Stages of Sand excavation & Suspension

4.3. Dredging for the tunnel trench at various stages

(1) Trailing suction hopper dredger

Suitable for large-scale dredging for the trench and its side slopes, equipped with DPDT(Dynamic Positioning and Dynamic Tracking) and DTPS (Dredging Track Presentation System) operating systems. While fast flow, performed with human assistance.

TSHD “Junhai 5” from Guangzhou Dredging Co., capacity of 10,000 m3



Schematic Diagram for TSHD Operating in Parallel to the Trench during the Moderate Tides, Perpendicularly to the Trench during the Ebb or Rising Tides

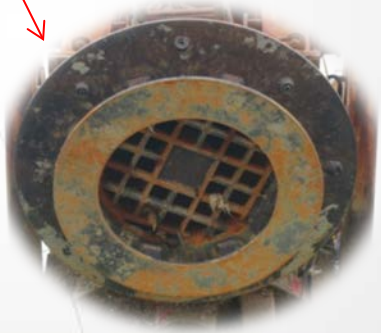
4.3. Dredging for the tunnel trench at various stages

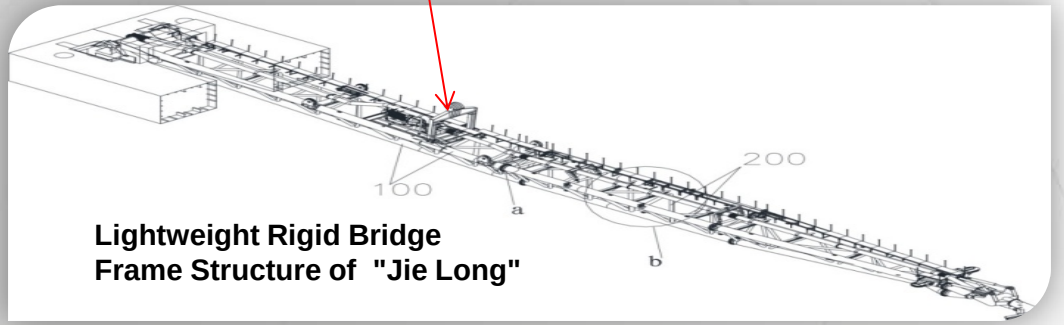
(2) Fixed-point desilting dredger

Fixed-point desilting dredger "Jie Long“, applied a new floating bridge frame with the length of about 80m. This structure helps to significantly reduce the weight of bridge, on the premise of ensuring adequate bridge length and intensity. Meanwhile, this allows the bridge to be lifted by existing equipment.

Fixed-point desilting dredger "Jie Long“ from Guangzhou Dredging Co.

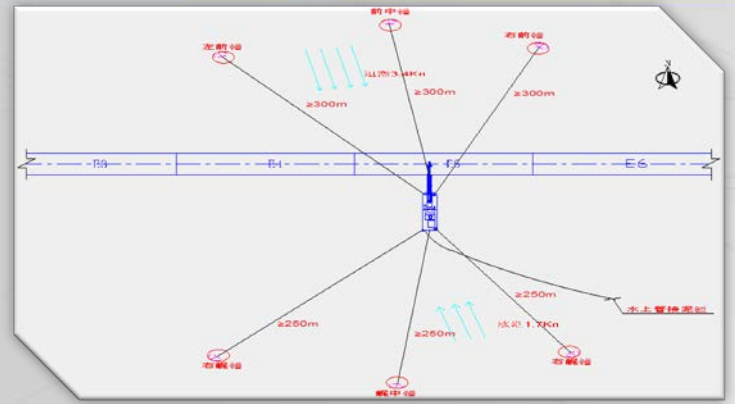
Structure of the Suction Head

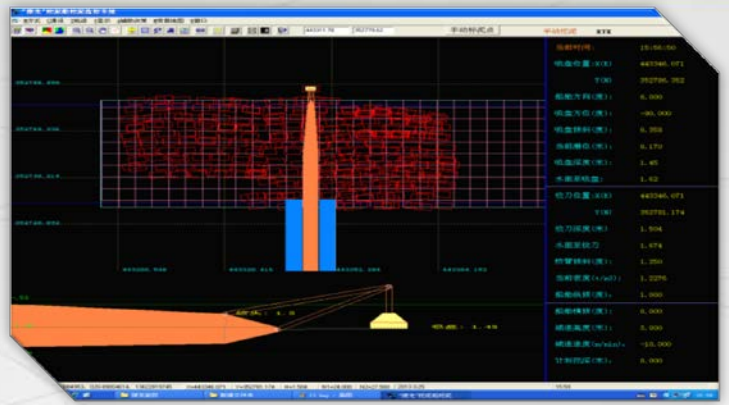




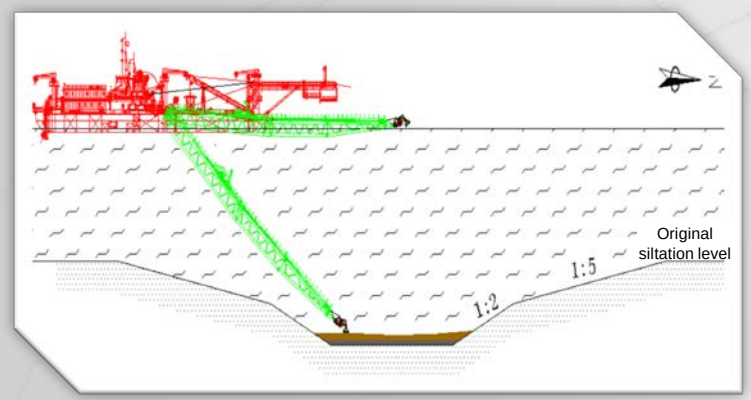
Lightweight Rigid Bridge Frame Structure of "Jie Long"

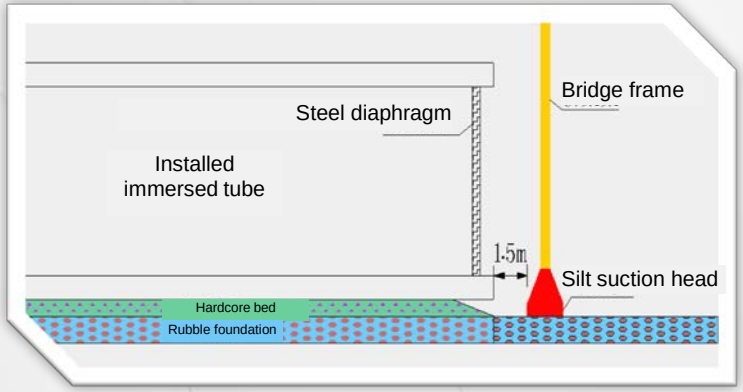
4.3. Dredging for the tunnel trench at various stages





Dredging Operations by “Jielong” (six-anchor positioning, vertical to trench, and dredging “stamp by stamp ”)





Fixed-point Dredging within limited Areas in front of the Installed Immersed Tube

4.3. Dredging for the tunnel trench at various stages

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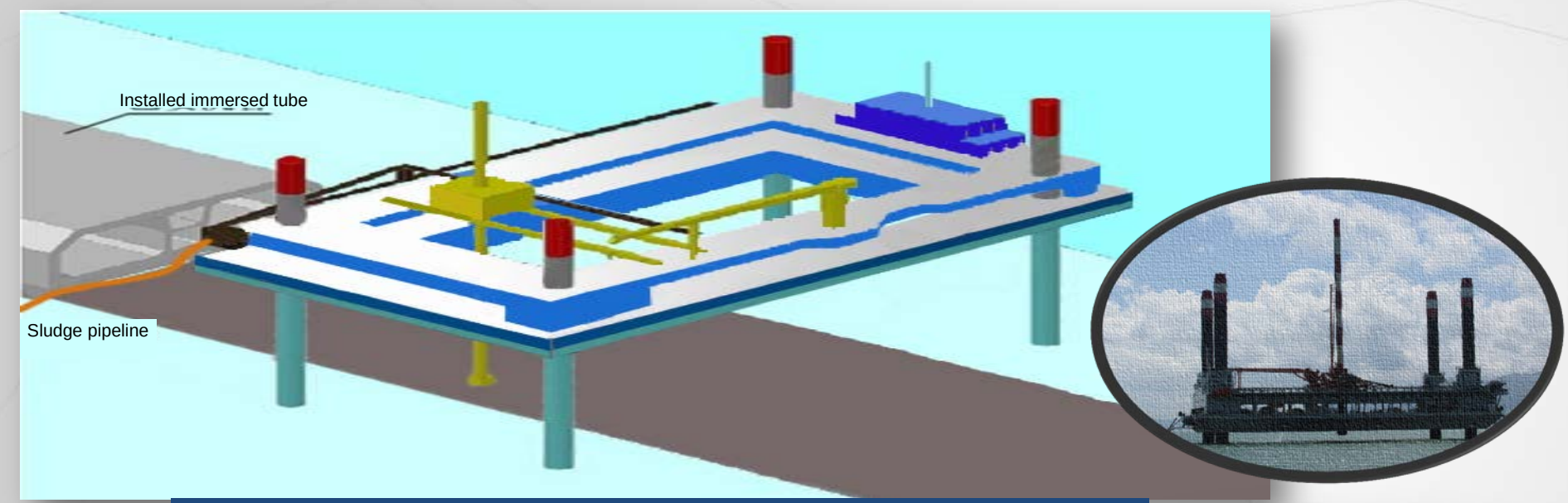
（3）Desilting above the hardcore bed by Hardcore Bed Leveling Barge

The leveling barge from CCCC, installed with a special suction disk, moving longitudinally along the central axis at the top of the hardcore bed ridge. The rise and fall of the bridge and suction disk, controlled with the travelling crane. To minimize the influence of hardcore bed, the main suction port of the suction disk, is positioned in the horizontal direction, while the other auxiliary suction ports are suspended over and vertical to the ridge bottom.



Hardcore bed Leveling Barge with High-precision Dredging Function

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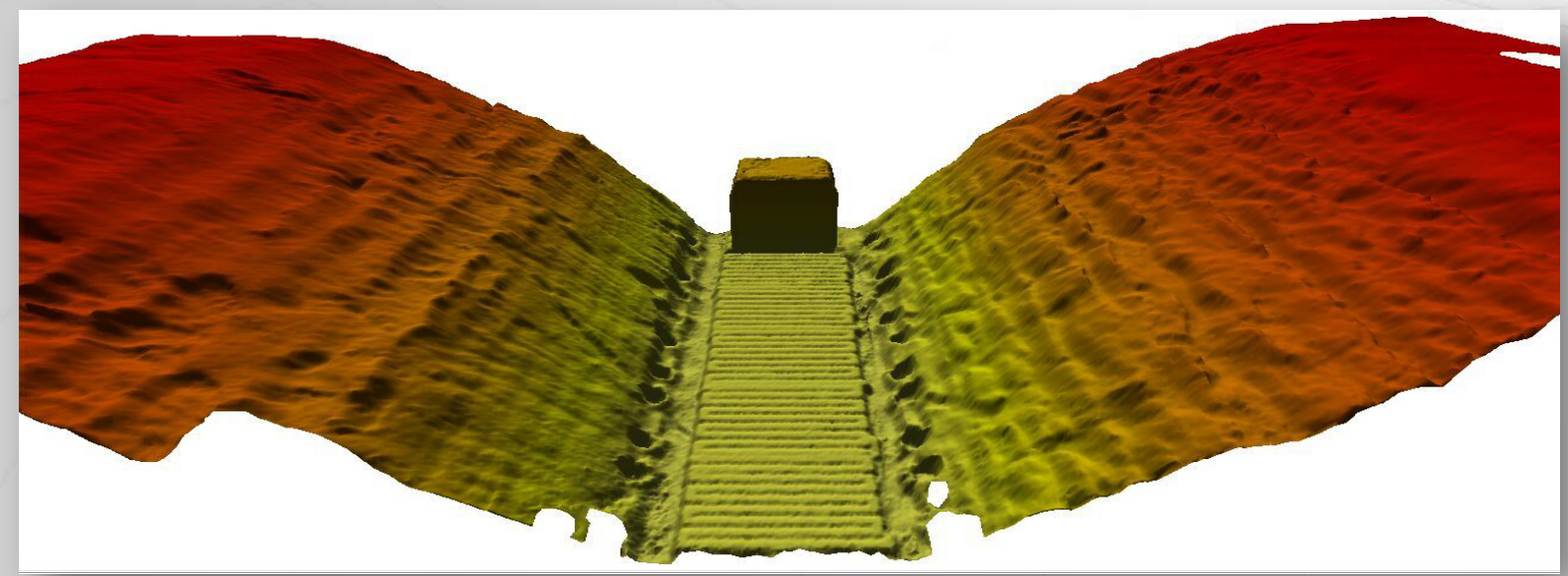
5、Results and conclusions

Up to now, the E1-E27 immersed tubes have been properly installed. The relevant dredging processes have been well done, like that: before fine trench excavation, or before riprap compaction, or before or after the laying of the hardcore bed, or before installation of the immersed tube, as well as for special areas, like that in front of the installed immersed tube, and the side slopes of trench.

This fully demonstrates that, the siltation control equipment, technology and measures for the immersed tunnel of the Hong Kong-Zhuhai-Macao Bridge project, are practical and effective.



3D graph of dredged trench before immersed tube installation

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Thanks!