

# Analysis to Bulk Density in Trial Dredged-Trough for Immersed Tube Tunnel

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**Abstract.** On the basis of studying water-sediment movement in the Lingdingyang sea area, sedimentation characteristics of the trial dredged-trough of immersed tube tunnel of HZMB are analyzed, with 17 groups of underwater topographic survey data and the measured results of fluid mud and silt unit weight in the base trough and slopes. And some results are obtained, including siltation rate changes and its distribution characteristics of the trial dredged-trough, the slope ratio of steady slope, the thickness and its trends of the fluid mud layer and silt layer in the trough. This paper analyzes the statistics of ultrasonic depth-sounding with three different frequencies, and it's found that there is a difference of 0.3m between multi-beam and low frequency, which coincides with the measured values of the fluid mud thickness of 0.29m very well.

## Introduction

A planned Hong Kong-Zhuhai-Macao Bridge (HZMB), from west Zhuhai ~ Macao to east Hong Kong, crosses the Lingdingyang baymouth of the Pearl River estuary which is the most important waterway along it many large vessels must pass through from Guangzhou, Shenzhen harbors in the South China. In order to meet navigation requirements, a design scheme of a bridge in combination with tunnel has been worked out, i.e. the seabed tunnel structure is placed on the Lingdingyang main navigable section by use of the immersed tube tunnel construction. Because Dahao waterway through which the tunnel passes has a deep waterway with high velocity, a base trough 5400m in length and 42m in depth must be excavated if the immersed tube tunnel is used. However, a few issues such as excavation of the base trough, sedimentation after excavation, density distribution and slope stability have aroused considerable attention.

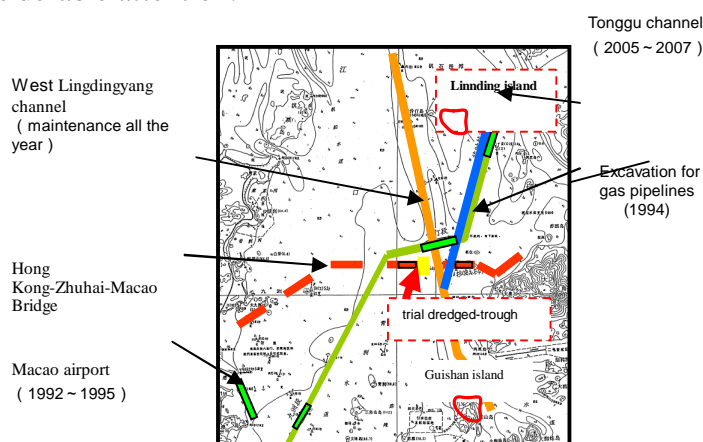


Figure 1 Sketch Of The Trial Dredged-trough

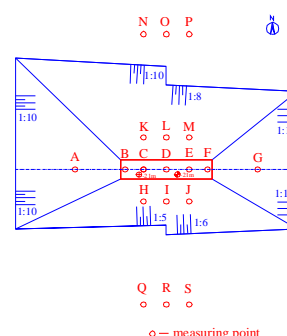


Figure 2 Layout Of the Trial Dredged-Trough and the Observation Points

In order to understand these questions, a sedimentation observation of the trial dredged-trough and its analysis should be carried out in the study. The trial dredged-trough is chosen in the east sea-bed of the west artificial Island, which has a length of 100 m and -21m in bottom elevation (average depth of

excavation 11.5m), from east to west, and respectively having the slope ratio of 1:5,1:6 (south side) and 1:8,1:10 (north side). And its location is shown in fig. 1 and its excavation scale is shown in fig. 2. Construction excavation and topographic survey after excavation have been completed by Guangzhou Navigation Bureau Corp. Ltd, and Nanjing Hydraulic Research Institute carried on researches such as sediment bulk density observation and sedimentation analysis.

## Field Observation of the Trial of the Dredged-Trough

### Observation Time Period

The trial dredged-trough was completed on February 6, 2009, and observation period starts from that date until October 14, lasted a total of 250 days, which spans more than eight months, i.e. spring, summer and autumn, during which suffered from a relatively large flood and two typhoons.

### Observation Records

(1) Underwater topography survey for slope and the base trough of the trial dredged-trough was done for 17 times using the multi-beam and dual-frequency sounder.

(2) Fluid mud and sludge bulk density detection for slope and the base trough of the trial dredged-trough was done for 4 times using  $\gamma$ -ray sludge densitometer.

(3) Sea-bed material sampling and particle analysis were done for many times on the seabed excavated as the base trough of the trial dredged-trough and its slope.

The field observation and periods corresponding to items above are listed in table 1.

Tab.1 The Field Observation Items Of The Trial Dredged-trough  
and Corresponding Statistical Times

No	Observation Time	Regime	Topographic Survey	Bulk Density Observation	Bed Material Sampling
1	2009.02.06	Before flood	√	√	√
2	2009.02.15		√		
3	2009.02.23		√		
4	2009.03.02		√		
5	2009.03.10		√		
6	2009.03.26		√		
7	2009.03.31		√		
8	2009.04.11		√	√	√
9	2009.05.08		√		
10	2009.05.27	During flood	√		
11	2009.06.13		√		
12	2009.07.09		√	√	√
13	2009.07.24		√		
14	2009.08.08		√		
15	2009.09.09		√		
16	2009.09.24	After flood	√		
17	2009.10.13		√	√	√

## Change in bulk density in the trough

From field observations of bulk density of deposition it was found that there is fluid mud with silt layer in the trial dredged-trough, and of which the mean thickness of fluid mud is 0.29m; the mean thickness of soft silt mud is 0.98m, and their total mean thickness is 1.27 m.

Comparing the total thickness of fluid mud with silt layer for each measuring time, it is shown that the total mean thickness is within 0.2m during the trough initially forming, and it has increased to 0.5m 2 months after the dry season, and the total mean thickness is up to 0.9m after 3 months of the flood season, and the total mean thickness is close to 1.3m after 3 months from flood season to the dry. Field

observation shown that the growth rate of the fluid mud and silt thickness in the trial dredged-trough is not very fast .

From changes in the fluid mud and silt thickness for eight times it is seen that there is not great changes in thickness of the fluid mud and soft silt thickness is remarkably increasing with time. It is shown a phenomenon or process, i.e. the fluid mud in the trough is gradually becoming dense and finally converted into the soft silt. Fig.3 shown the bulk density distribution curves of silt layers obtained from observation of B and C points in the trial dredged-trough.

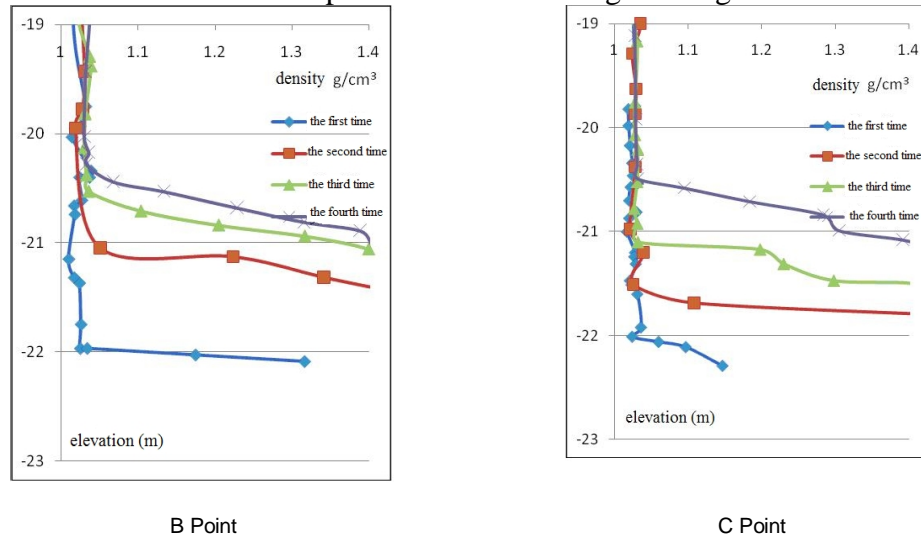


Fig.3 The Mud Density Distribution Curves With The Depth In The Trial Dredged-trough

### Comparisons of measured depth data with different frequencies

The statistical analysis of changes in topograph in the trial dredged-trough has been made by use of water depth data obtained from the multi-beam measurements. In order to understanding some differences between the data obtained from the dual-frequency sounder, according to the longitudinal and horizontal sections, the water-depth data with three different frequencies have been respectively recorded from the seventh measured depth data, as listed in table 2. From comparison of data in the table it can be found that all measured depth data average from multi-beam is the minimum, and that from high-frequency is the middle and that from low-frequency is the maximum, and its differences are 0.18m, 0.17m (horizontal profile) and 0.14m, 0.13m (longitudinal profile) whether the horizontal or longitudinal profiles. However, in the tables it is also found that the depth data of few measuring points from multi-beam is greater than that from the high-frequency (blue data in the table), and data from the low frequency at very few measuring points is the minimum (red data in the table) and that from the high-frequency is the maximum (green data in the table). Most of the measured depth data conformed with distribution regularity, i.e. “the minimum form the multi-beam, the middle from the high-frequency and the maximum form the low-frequency”.

The corresponding relations of the measured depth data given by three kinds of frequencies are basically reasonable. It can be found from preliminary estimates that the depth from multi-beam measurement should be 0.15m smaller than that from the high-frequency measurement, and the depth from high-frequency measurement is also 0.15m smaller than the low-frequency measurement, and there may be 0.30m of the thickness deviation between data from the multi-beam and the low-frequency measurements, which conformed with the observed results of the fluid mud thickness very well.

As the multi-beam observed data is very intensive, it is favourable for improving the statistical accuracy, but to some differences should be paid more attention when the data is used because the absolute values of the depth displays small tendencies.

From comparative analysis it is seen that differences between underwater ultrasonic echo signal interference and impacts should be very great in sometimes under different sediment conditions, thus in most cases, the thickness of fluid mud and silting mud can not be divided only by use of the differences between the high or low frequency measured depth data.  $\gamma$ -ray density measurement method described in the paper can be used in calibration of the dual-frequency sounder.

**Tab.2 Depth Data Comparisons Of The 7th Measuring Time With Different Frequencies Of The Horizontal Profile**

Distance Form West Starting Point (m)	Depth (m)		
	Multi-beam	High-frequency	Low-frequency
0	11.70	11.90	12.10
10	12.25	12.90	13.10
20	13.65	13.74	13.90
30	15.43	15.90	16.10
40	17.20	17.50	17.60
50	18.20	19.10	19.40
60	20.20	20.60	20.80
70	21.20	21.52	21.62
80	21.33	21.20	21.50
90	20.30	20.30	20.40
100	19.20	18.90	19.30
110	17.80	17.80	17.80
120	16.60	16.90	17.00
130	16.00	16.00	16.10
140	14.80	14.80	14.90
150	14.00	14.10	14.10
Average	17.04	17.22	17.39

## Conclusions

From comparative analysis of the depth data given by three measurement methods(high, low-frequency and multi-beam) it is seen that there is a corresponding relationship among the three methods, i.e. the depth from multi-beam measurement is 0.15m smaller than that from the high-frequency measurement, and the depth from high-frequency measurement is also 0.15m smaller than the low-frequency measurement, and there is 0.30m of the thickness difference between data from the multi-beam and the low-frequency measurements, which conformed with the observed results of 0.29m in thickness of the fluid mud very well.

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