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Design Water Level Calculation And Analysis Of Chittagong Power Plant Project In Bangladesh

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Abstract. The design water level calculation methods in the Chinese and foreign codes are different. The design high and low water levels and extreme high and low water levels in the Chinese norms are calculated using historical cumulative frequencies with tide level data of not less than 1 year and 20 years, respectively. In foreign norms, the average high and low tide levels of spring tides are mostly used as the design high and low water levels, and for the sea areas lacking long-term measured data, the water level combination method is mostly used to determine the extreme water levels. This paper compares the results of different methods used to calculate the design water level using the Chittagong Power Plant in Bangladesh as an example. The calculations show that it is safer to use the tidal eigenvalue method to determine the design high and low water levels, and that the Water Level Combination Method is more suitable for extreme water level determination than Bangladesh National Building Code.

1. Introduction

The design water levels are important design parameters for the coastal power station, which is used to determine the elevation of coal jetty, breakwater and embankment. Therefore, the correct calculation of the design water level is of great significance to the project cost and operational safety[1]. The design water level calculation methods in the Chinese and foreign codes are different. The design high and low water levels and extreme high and low water levels in the Chinese norms are calculated using historical cumulative frequencies with tide level data of not less than 1 year and 20 years, respectively. In foreign norms, the average high and low tide levels of spring tides are mostly used as the design high and low water levels, and for the sea areas lacking long-term measured data, the water level combination method is mostly used to determine the extreme water levels[2]. This paper compares the results of different methods used to calculate the design water level using the Chittagong Power Plant in Bangladesh as an example.

2. Analysis Of Tide Levels In The Project Area

The Chittagong Power Plant Project is located at Maheshkhali zone, Chittagong. In order to understand the tidal characteristics of the project area, hydrological observations were carried out from the end of June to the end of July 2018. Three of the tide level measuring stations were located near the coal jetty, in the deep trough outside the mouth of the Kohelia River, and upstream of the Bakh Khali River, as shown in Figure 1. The one-month water level process lines measured at 3 stations are shown in Figure 2. Based on the measured data, the tidal characteristics of the project area are shown in Table 1.

Figure 1. Project site and tide stations location.

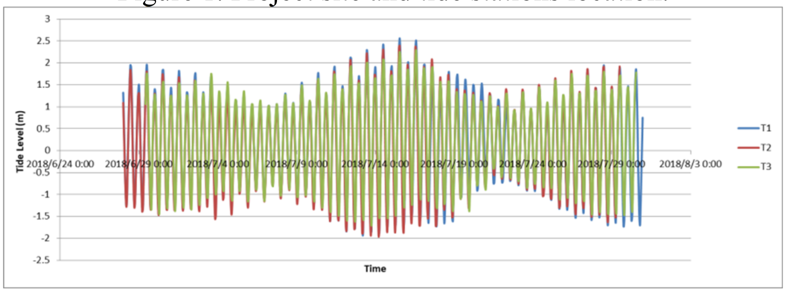

Figure 2. The water level process lines of temporary observation stations.

Table 1. Statistics of measured tidal level characteristic values from June to July in 2018.

Characteristic value	T1	T2	T3
HHWL	2.57	2.45	2.29
LLWL	-1.94	-1.98	-1.76
MHWL	1.58	1.46	1.48
MLWL	-1.34	-1.32	-1.20
MMSL	0.17	0.11	0.26
Extreme Tidal Range	4.36	4.39	3.81
Minimum Tidal Range	1.66	1.59	1.45
Mean Tidal Range	2.92	2.78	2.68

3. Calculation Of Design High And Low Levels

3.1. Methods in Chinese norms

The design high and low water level calculations refer to the recommended method of the Chinese Hydrographic Code[3]. At the preliminary design stage of a new port, there are three methods depending on the duration of the measured data information as follows.

(i) When actual tide data information is available for more than one year in the project area. For ports located in coastal or in the perennial tidal section of a river, the design high water level shall be the tide level with 10% of the high tide accumulation frequency or 1% of the historic accumulation frequency, and the low water level with 90% of accumulation frequency or 98% of the historic accumulation frequency as the design low water level

(ii) If there is more than one year of tide data in the sea area around the new port, and the two sea areas meet the conditions of similar tidal properties, similar geographic location, and similar influence by the river, the synchronous difference method can be used to transfer the surrounding tide data to the project location, and then use the above (i) method to calculate.

(iii) If none of the above conditions are met, the following formula can be used for the calculation:

$$h_s = A_N \pm (0.6R + K)$$
$$A_N = A + \Delta A \quad (1)$$

Where,

h_s = Design high water level and design low water level (m), "+" for design high water level and "-" for design low water level.

R = Mean tidal range (m) from short-term tide gauge data over one month.

K = Constant (m), can be 0.4m.

A_N——Annual mean sea level (m).

A ——Monthly mean sea level (m) for short-term tide gauge data.

ΔA——Monthly correction of sea level at or near the port (m).

Only short-term 1-month measured tide data are available for the power plant project area described in this paper, and the only place in the vicinity with continuous 1-year tide data is Chittagong Port. However, Chittagong Port is located within the Kamaphuli River, which is subject to a significant difference in runoff from the project area, and therefore only the above (iii) is met at this location. In order to better compare the calculation results, after harmonic analysis of the measured tide level data, the hindcast tide level from 1988 to 2018 are calculated as shown in Figure 3, and the design water level can be calculated according to above (i). Therefore the cumulative frequency curve for 20 consecutive years at T1 can be drawing as Figure 4. According to the curve, the tide level with a cumulative frequency of 1% is taken as the design high water level, which is 2.15m, and the tide level with 98% cumulative frequency of duration is taken as the design low water level, which is -1.70m;

The short-term measured average tidal range of T1 station is 2.92m, and the monthly average sea level in the short-term measured period is 0.17m. According to the chart, the sea level of the project sea area rises by about 0.3m from August to September, and decreases by about 0.4m in March, as shown in Figure 5. Therefore, the monthly correction value of sea level during T1 water level measurement is taken as 0.3m, and the annual average sea level is approximately 0.47m, so the design high water level is 2.62m, and the design low water level is -1.68m according to above (iii)。

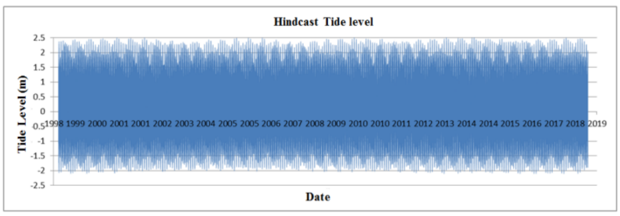

Figure 3. Tidal processes predicted for 1998-2018 year after harmonic analysis based on T1 water level observations.

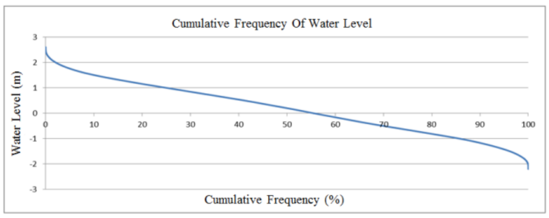

Figure 4. Cumulative frequency curve for 20 consecutive years based on the measured water level of T1 station and harmonic analysis.

Tidal Levels referred to Datum of Soundings

Place	Lat. N	Long. E	Heights in meters above datum					Remarks
			MHWS	MHWN	MLWN	MLWS	LAT	
Chittagong	22°20′	91°50′	4.7	3.8	1.1	0.2	-0.4	These levels may vary with season being about 0.4m lower in March and about 0.3m higher in August – September. See Admiralty Tide Table Vol-3, Bangladesh Navy Tide Table & Bangladesh Tide Table.
Kutubdia Island	21°52′	91°50′	3.8	2.7	1.4	0.3	-0.3	
Cox's Bazar	21°26′	91°59′	3.8	3.0	1.0	0.2	-0.3	

Figure 5. Explanation of water level change in engineering sea area on chart (3506).

3.2. Comparative analysis of the results of the tidal eigenvalue method

In foreign norms, the tidal eigenvalue method is commonly used, in which mean high and low tide levels of spring tides are mostly used as the design high and low water levels. Based on the results of 20 consecutive years of water level hindcast at T1 tide station, the statistical mean high tide level during spring tide as the design high water level is 2.38 m, and the mean low tide level during spring tide as the design low water level is -1.84 m.

The design water level obtained by the above three methods is shown in Table 2. The measured tide level in the project area is July, and the rainy season is from July to October in Bangladesh. The tide level is also at the high water level of the whole year. The maximum T1 water level is 2.57m, which should be the annual high water level. The design high water level obtained by approximate formula is 2.62m, which is larger than the maximum water level in the measured period. The water level in July can not reach the design high water level. So the result according to approximation formula has large deviation. The results obtained by using the tidal eigenvalue method are safer than those obtained by the cumulative frequency method. Therefore, it is suggested that the tidal eigenvalues method is used for the design water level, that is the design high water level is 2.38m, and the design low water level is -1.84m.

Table 2. Comparison of calculation results of design water level in engineering sea area.

Design Water Level	Epochal Cumulative Frequency Method	Approximation Formula	Tidal Eigenvalue Method
Design High Water Level	2.15m	2.62m	2.38m
Design Low Water Level	-1.70m	-1.68m	-1.84m

4. Calculation Of Extreme Design Water Level

4.1. Calculation According To Bangladesh National Building Code

Bangladesh currently has extreme vulnerability to cyclones, both on account of its somewhat unique location and topography (that creates an inverted funnel effect), and because of the low (though growing) capacity of its society and institutions to cope with such extreme events. A cyclone in 1970 resulted in close to 300,000 deaths, and another, in 1991 led to the loss of 138,000 lives, although in recent years greater success in disaster management has significantly reduced the lives lost[4]. Due to the lack of measured data, the storm surge estimates of different return periods are given in the code[5], which can be used as reference. The surge height should not include tide level.

Table 3. Design Surge Heights at the Sea Coast, h_T .

Coastal Region	Surge Height at the Sea Coast, h_T (m)	
	T=50-year	T=100-year
Teknaf to Cox's Bazar	4.5	5.8
Chakaria to Anwara, and Maheshkhali-Kutubdia Islands	7.1	8.6
Chittagong to Noakhali	7.9	9.6
Sandwip, Hatiya and all islands in this region	7.9	9.6
Bhola to Barguna	6.2	7.7
Sarankhola to Shyamnagar	5.3	6.4

4.2. Calculation According To Water Level Combination Method

The extreme water level in Bangladesh is caused by storm surge[6]. In order to obtain the extreme water level of the project area, a mathematical model was used to simulate 18 tropical cyclones which had an impact on the project area in the 30 years from 1988 to 2017. The cyclone track and central pressure time-series were obtained from The U.S. Navy Joint Typhoon Warning Center (JTWC). The Mike21 Holland model was used to generate the cyclonic wind and pressure fields[7-9]. At the same time, according to the hindcasting astronomical tide process from 1988 to 2017, the annual maximum and low water levels are calculated, as shown in Table 4. According to the extreme value of water levels for 30 consecutive years, the PIII curve is used to analysis the extreme water level in different return periods as shown in Figure 6.

Table 4. Statistics of storm water level and annual maximum astronomical tide level from 1988 to 2017

Year	Storm high water level (m)	Storm low water level(m)	The highest astronomical tide level (m)	The lowest astronomical tide level (m)
1988	2.98	-2.89	2.43	-2.30
1989	/	/	2.64	-2.37
1990	2.62	-2.38	2.50	-2.28
1991	6.28	-2.76	2.52	-2.19
1992	2.95	-2.50	2.44	-2.30
1993	/	/	2.65	-2.40
1994	3.99	-2.77	2.52	-2.34
1995	/	/	2.62	-2.23
1996	3.11	-3.24	2.50	-2.24
1997	4.14	-2.44	2.43	-2.38
1998	2.83	-2.45	2.46	-2.37
1999	/	/	2.61	-2.30
2000	/	/	2.63	-2.11
2001	/	/	2.61	-2.26
2002	/	/	2.62	-2.31
2003	/	/	2.60	-2.33
2004	2.90	-2.52	2.50	-2.16
2005	/	/	2.51	-2.18
2006	/	/	2.58	-2.31
2007	4.59	-2.58	2.47	-2.35
2008	2.68	-2.26	2.53	-2.26
2009	2.83	-1.85	2.47	-2.16
2010	3.14	-2.66	2.38	-2.33
2011	2.86	-1.69	2.45	-2.37
2012	/	/	2.52	-2.33
2013	2.86	-2.34	2.53	-2.18
2014	/	/	2.63	-2.28
2015	2.91	-0.49	2.45	-2.38
2016	2.94	-2.24	2.50	-2.33
2017	2.77	-2.21		-2.24

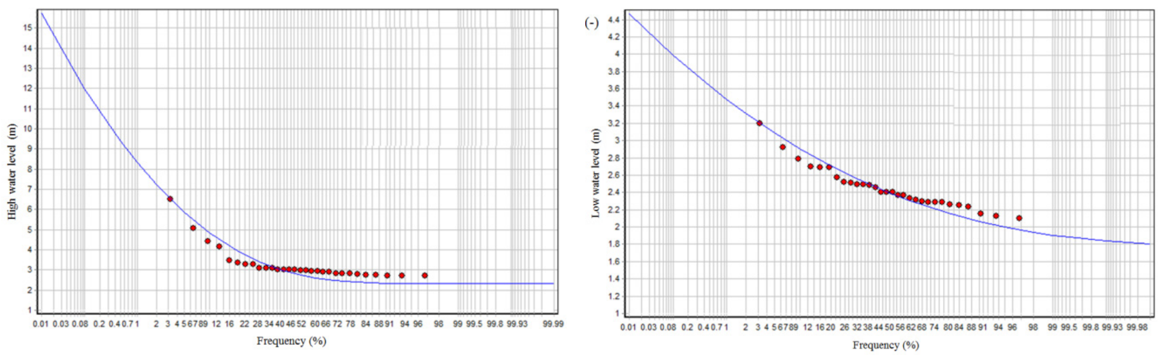

Figure 6. PIII fitting curve of designed extreme high and low tide levels considering storm surge.

Sea level rise factor cannot be ignored in the calculation of design extreme water level. According to Intergovernmental Panel on Climate Change (IPCC), in the project area, sea level rise is about 13mm / year. The final result of design extreme water level in the project sea area is shown in Table 5.

Table 5. Design Extreme Water Level In Engineering Sea Area

Design Extreme Water Level	Frequency Of Occurrence	Return Period	Water Level (m)
Extreme High Water Level	0.1%	1000	12.39
	0.5%	200	9.80
	1%	100	8.71
	2%	50	7.63
	3.3%	30	6.85
Extreme Low Water Level	97%	33	-3.21
	98%	50	-3.31
	99%	100	-3.48

5. Conclusion

For the coastal projects in Bangladesh, the calculation of design water level is very important due to the lack of long-term measured data. According to the calculation results of this paper, it is suggested that the design high and low water level should be determined by the mean high and low tide level of spring tide. For the design extreme water level, if only using the reference surge height in Bangladesh National Building Code adding design high water level, the water level obtained is much larger than the simulation calculation result. Therefore, it is suggested that similar simulation calculation can be carried out in the future design of coastal engineering in Bangladesh to obtain more reasonable results.

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