INVESTIGATION STRESS AND SETTLEMENT UNDER FOUNDATION OF VERTICAL BREAKWATER USING NUMERICAL MODEL AND FIELD DATA

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Abstract: *Coasts of any country can have a important role from economic, social, political and military aspects. This is due to, spread oceans and seas on earth and many of marine structure are established in coastal regions. Breakwaters are one of the main parts of ports. Stability of breakwaters is one of the most important topics in design of structure that must be considered by engineers of marine, port and coastal. In present study, rate of stress and settlement at bed of vertical breakwater using field data and numerical model (PLAXIS model) investigated for achievements goals of this study at first, some samples at Imam Khomeini port located at Iran, extract and transferred to laboratory for test. After test, defined scenarios for run of model. These scenarios imported to model include of geometrical parameters and geotechnical data selected based on current standards of geotechnics. Geotechnical data are including two boring holes to 8.5m depth and geometrical data are including of height of structure, height of foundation, slide slope.*

The results of this study show that in fixed condition of soil type and soil mechanical characteristics, with increasing in slope side the stability of structure increased and settlement decreased also structure will be stable. Also in fixed geotechnical condition with fixed side slope, increasing in height of structure reduces the stability.

Keywords: *coastal engineering, vertical breakwater, PLAXIS software, geometrical parameters*

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1. INTRODUCTION

Breakwaters are most commonly coastal structure that constructed with different goals including to keep environment, Mooring buoys and coast protection. Extensive research on various aspects of the structure has been studied that among of these researches, attention to the stability of the structure is considered less. According to the statement above can realized importance of the stability of structures such as breakwaters. The aim of present study is investigating the stability of vertical breakwater. For this purpose, investigated various geometric parameters including to height, slope side, the height of rack foundation and bed geotechnical characteristics on stability of structure.

2. LITERATURE REVIEW

Kao et al (1990), studied berm breakwater in the laboratory and find a criteria for design of this structure. [3].

Van der Meer (1994) carried out Extensive research with many experimental tests for determination equation between profile parameters and hydraulic and structural parameters. The result of these research, provide a numerical model (breakwat) [8].

Melby and Kobayashi (1998), provide a stochastic method for protection and repair of breakwater based on physical modeling. In this study the effect of elevation of water on ratio of repair at traditional breakwaters investigated. They finally present an empirical formula to predict the level of damage induces by storms for a breakwater structure with a slope of 1: 2 and 1:20 have presented the slope of the beach [4].

Sayao (1990), analysis profile of reshaping breakwater by physical modeling.The result show that the effect of failure parameter on profile is high [6].

Torum et al (2002), carry out many experiments on reshaping breakwaters. Their results extract equation between Withdrawal of berm and the shape of final profile of breakwater. The different of this study with others is effect of grading factor and depth water [7].

Rao et al (2003) carry out many experiments on armor. The result show that with decreasing size of armor stability of structure will be reduce. They find a relationship between stability and damage parameter [5].

Aghtouman et al (2005), provide criteria for thickness of armor layering reshaping breakwater using physical modeling [1].

Aghtouman et al (2011) studied the effect of width of berm breakwater on final shape of profile. This research shows that width of berm has a significant effect on shape of final profile [2].

3. METHOD AND MATERIAL

PLAXIS is a finite element package intended for the two dimensional analysis of deformation and stability in geotechnical engineering. It is equipped with features to deal with various aspects of geotechnical structures and construction processes using robust and theoretically sound computational procedures. With PLAXIS the geometry of the model can be easily defined in the soil and structures modes, after which independent solid models can automatically be intersected and meshed. The staged construction mode allows for simulation of construction and excavation processes by activating and deactivating soil clusters and structural objects. The calculation kernel enables a realistic simulation of the non linear, time dependent and anisotropic behaviour of soils and/or rock. Since soil is a multi phase material, special procedures allow for calculations dealing with hydrostatic and non hydrostatic pore pressures in the soil. The output consists of a full suite of visualization tools to check the details of the 2D underground soil-structure model. Typical PLAXIS applications include: assessing street level displacements during the tunnel construction, consolidation analysis of embankments, soil displacements around an excavation pit, dam stability during different water levels, and much more. PLAXIS is a user friendly geotechnical program offering flexible and interoperable geometry, realistic simulation of construction stages, a robust and reliable calculation kernel, and comprehensive and detailed post-processing, making it a complete solution for your daily geotechnical design and analysis.

3.1. Information

In this study field data of two bore located at Imam Khomeini port of Khuzestan province in Iran are presented. For each boring hole extract information in three depth including (2-2.5m), (5-5.5m) and (8-8.5m) and then transfer samples to laboratory for test and determined some geotechnical characteristics of soil. In tables (1-6) information of boring hole is show.

3.1.1. First bore

a) 2 - 2.5 m depth

The results shows in this depth that average of dry density is 1.6(g/cm3) and average of humidity is 27 percent and in this depth texture of soil is clay. Other parameters presents in table (1).

Table (1): characteristic of soil (2.5 m)

OCR			e'_o	e_o	Cr	Cc
4.73	0.22	1.04	0.724	0.647	0.03	0.19

b) 5 - 5.5 m depth

The results shows in this depth that average of dry density is 1.6(g/cm3) and average of humidity is 30 percent and in this depth texture of soil is clay. Other parameters presents in table (2).

Table (2): characteristic of soil (5.5 m)

OCR			e'o	eo	Cr	Cc
3.23	0.53	1.71	0.800	0.662	0.05	0.36

c) 8 - 8.5 m depth

The results shows in this depth that average of dry density is 1.6(g/cm3) and average of humidity is 32 percent and in this depth texture of soil is clay. Other parameters presents in table (3).

Table (3): characteristic of soil (8.5 m)

OCR			e'_o	eo	Cr	Cc
1.14	0.88	1.00	0.853	0.662	0.04	0.22

3.1.2. The second bore

a) 2 - 2.5 m depth

The result of this depth show that average of dry density is 1.6(gr/cm3) and average of humidity is 27 percent and in this depth texture of soil is clay. Other parameters presents in table (4).

Table (4): characteristic of soil (2.5 m)

OCR			e'_o	e_o	Cr	Cc
4.48	0.22	0.98	0.720	0.657	0.03	0.17

b) 5 - 5.5 m depth

The result of this depth show that average of dry density is 1.6(gr/cm3) and average of humidity is 30 percent and in this depth texture of soil is clay. Other parameters presents in table (5).

Table (5): characteristic of soil (5.5 m)

OCR			e'ₒ	eₒ	Cr	Cc
1.58	0.54	1.00	0.802	0.662	0.02	0.16

c) 8 - 8.5 m depth

The results shows in this depth that average of dry density is 1.6(g/cm3) and average of humidity is 32 percent and in this depth texture of soil is clay. Other parameters presents in table (6).

Table (6): characteristic of soil (8.5 m)

OCR			e'o	eo	Cr	Cc
1.57	0.88	1.38	0.855	0.664	0.02	0.21

In the above tables:

OCR: over consolidation ratio=p_c/p_o

e_o: void ratio

e'_o: w%*GS

G_S: density

W:moisture content

P_o: initial pressure

P_c: pre-consolidation pressure

3.2. The scenario of research

For achievement the goal of research, at first draw schematic of plan and then defined scenarios for research. These scenarios are included of difference in geometrical parameters and foundation. The scenarios of this research present in next section completely.

Model A

In this model, slope side in right is 1:2 and in left is 1:3 and the height of structure is 11.5m and rack foundation is 2.5m. The information need for this model extract from bore 1.

Model B

In this model the slope side in right is 1:1.5 and in left is 1:1.25 and the height of structure is 11.5m and rack foundation is 2.5m and like to model A the information for foundation extract from bore 1.

Model C

In this model, slope side in right is 1:1.5 and in left is 1:1.25 and the height of structure is 12.5m and rack foundation is 3.5m. The information need for this model extract from bore 1.

Model D

In this model, slope side in right is 1:2 and in left is 1:1.25 and the height of structure is 12.5m and rack foundation is 3.5m. The information need for this model extract from bore 1.

Model E

In this model, slope side in right is 1:2 and in left is 1:3 and the height of structure is 11.5m and rack foundation is 2.5m. The information need for this model extract from bore 2.

Model F

In this model, slope side in right is 1:1.5 and in left is 1:1.25 and the height of structure is 11.5m and rack foundation is 2.5m. The information need for this model extract from bore 1.

Model G

In this model, slope side in right is 1:2 and in left is 1:3 and the height of structure is 12.5m and rack foundation is 3.5m. The information need for this model extract from bore 1.

Model H

In this model, slope side in right is 1:1.5 and in left is 1:1.25 and the height of structure is 12.5m and rack foundation is 3.5m. The information need for this model extract from bore 1.

In the table (7) characteristics of scenarios presents.

Table (7): characteristic of scenario

Bore	Side slope		Height of rack foundation(m)	Height of breakwater (m)	model
	Left	Right			
1	1:3	1:2	2.5	11.5	A
1	1:1.25	1:1.5	2.5	11.5	B
1	1:3	1:2	3.5	12.5	C
1	1:1.25	1:1.5	3.5	12.5	D
2	1:3	1:2	2.5	11.5	E
2	1:1.25	1:1.5	2.5	11.5	F
2	1:3	1:2	3.5	12.5	G
2	1:1.25	1:1.5	3.5	12.5	H

3.3. Boundary conditions

For setup of model is required to apply boundary conditions. In this model, have been used standards boundary conditions this boundary conditions established based on following rules:

- ✓ Vertical geometrical lines fixed in horizontal direction where X- axial has minimum and maximum values.
- ✓ Horizontal geometrical lines fixed where Y-axial has minimum of values.
- ✓ The plain that extended to boundary, don’t rotate at defined point on model.

3.4. Initial condition

In this research for initial condition, pore pressure and initial stresses, has been defined. For pore pressure, has been used field data that read level of ground water and define to model and then select phreatic level.

4. RESULT AND DISCUSSION

In this section the result of this research presented in three parts. In the first part, the results run of model is Presented, in the second part the results of stress are presented and the third part the results of displacements is presented. The results are presented in 7 phases that the first phase is immediately settlement after construct rack foundation of structure, second phase is consolidation settlement, the third phase is consolidation after 100days, the fourth phase is immediately settlement after construct of vertical section of structure, the fifth phase is consolidation settlement after construct of vertical section of structure, the sixth phase is final consolidation settlement and the 7th phase is control of stability. The result of this research is present part by part in next section.

4.1. The results run of model

4.1.1. Evaluation of stress in model A

Table (8); show the value of stress in various layers.

(8): Changes in stress and displacement in the model A

Total stress (KN/m^2)	Effective stress (KN/m^2)	Total displacement (m)	phase
527.07	275.73	0.85	First
527.10	275.75	0.85	Second
527.10	275.75	0.85	Third
583.43	330.16	1.83	Fourth
584.55	333.20	1.85	Fifth
584.55	333.20	1.87	Sixth

4.1.2. Evaluation of stress in model B

Table (9); show the value of stress in various layers.

(9): Changes in stress and displacement in the model B

Total stress (KN/m^2)	Effective stress (KN/m^2)	Total (m)displacement	phase
530.93	280.93	1.09	First
530.96	280.96	1.09	Second
530.96	280.96	1.09	Third
587.31	337.31	2.02	Fourth
587.31	337.31	2.02	Fifth
587.31	337.31	2.05	Sixth

4.1.3. Evaluation of stress in model C

Table (10); show the value of stress in various layers

(10): Changes in stress and displacement in the model C

Total stress (KN/m^2)	Effective stress (KN/m^2)	Total (m)displacement	phase
537.56	288.90	1.08	First
537.58	288.92	1.12	Second
537.57	288.91	1.14	Third
593.99	345.33	2	Fourth
593.99	345.32	2.05	Fifth
593.99	345.32	2.07	Sixth

4.1.4. Evaluation of stress in model D

Table (11); show the value of stress in various layers.

(11): Changes in stress and displacement in the model D

Total stress (KN/m^2)	Effective stress (KN/m^2)	Total displacement (m)	phase
544.73	295.06	1.11	First
544.75	295.09	1.12	Second
544.75	295.10	1.15	Third
602.75	353.09	1.99	Fourth
602.75	353.08	2.01	Fifth
602.75	393.03	2.04	Sixth

4.1.5. Evaluation of stress in model E

Table (12); show the value of stress in various layer of soli present.

(12): Changes in stress and displacement in the model E

Total stress (KN/m^2)	Effective stress (KN/m^2)	Total displacement (m)	phase
538	288.16	0.65	First
538.03	288.19	0.67	Second
538.04	288.2	0.70	Third
598.52	349.12	1.27	Fourth
598.52	349.12	1.37	Fifth
598.53	349.12	1.40	Sixth

4.1.6. Evaluation of stress in model F

Table (13); show the value of stress in various layer of soli present.

(13): Changes in stress and displacement in the model F

Total stress (KN/m^2)	Effective stress (KN/m^2)	Total Displacement (m)	phase
542.05	290.71	0.8	First
542.08	290.74	0.82	Second
542.09	290.75	0.87	Third
603.46	352.12	1.4	Fourth
630.46	352.12	1.41	Fifth
630.46	352.12	1.52	Sixth

4.1.7. Evaluation of stress in model G

Table (14); show the value of stress in various layer of soli present.

(14): Changes in stress and displacement in the model G

Total stress (KN/m^2)	Effective stress (KN/m^2)	Total displacement (m)	phase
559.04	308.99	0.84	First
559.05	309	0.85	Second
559.05	309	0.85	Third
620.20	370.23	1.40	Fourth
620.20	370.23	1.46	Fifth
620.20	370.23	1.54	Sixth

4.1.8. Evaluation of stress in model H

Table (15); show the value of stress in various layer of soli present.

(15): Changes in stress and displacement in the model H

Total stress (KN/m^2)	Effective stress (KN/m^2)	Total displacement (m)	phase
549.68	297.85	0.8	First
549.69	297.86	0.81	Second
549.69	297.87	0.84	Third
610.22	359.56	1.48	Fourth
610.21	359. 56	1.50	Fifth
610.21	359.56	1.58	Sixth

4.2. Investigation stresses

4.2.1. Effective stress

In the Fig (1) is shown the effective stress in various models and phases.

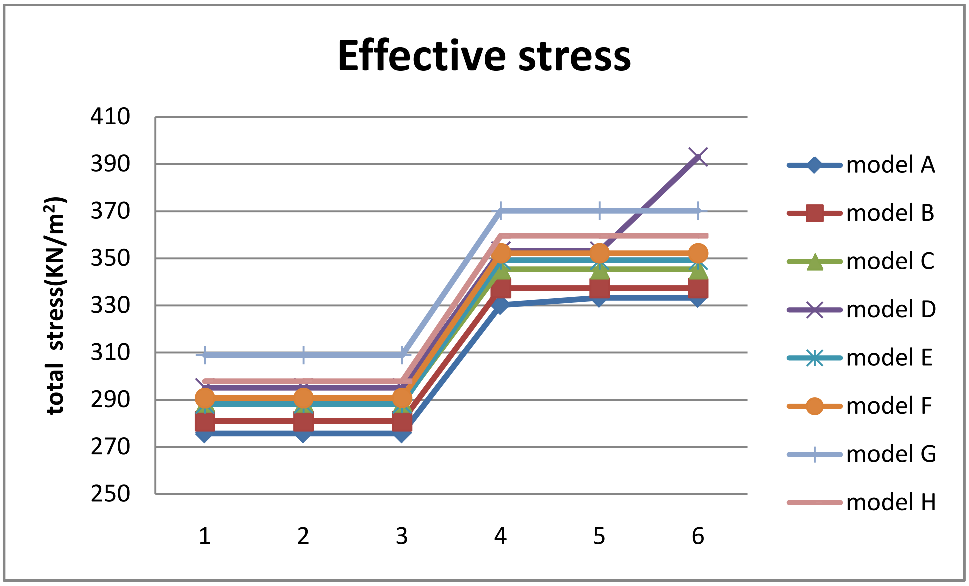

Fig (1): changes of effective stress in different phase

As show in the Fig (1), for each of models there is a similar Process from first phase to sixth phase. Investigation show the rate of effective stress in bed layers, when construct vertical section of breakwater is 20 percent increased than when rack foundation constructed.

4.2.2. Total stress

In the Fig (2) is shown the total stress in various models and phases.

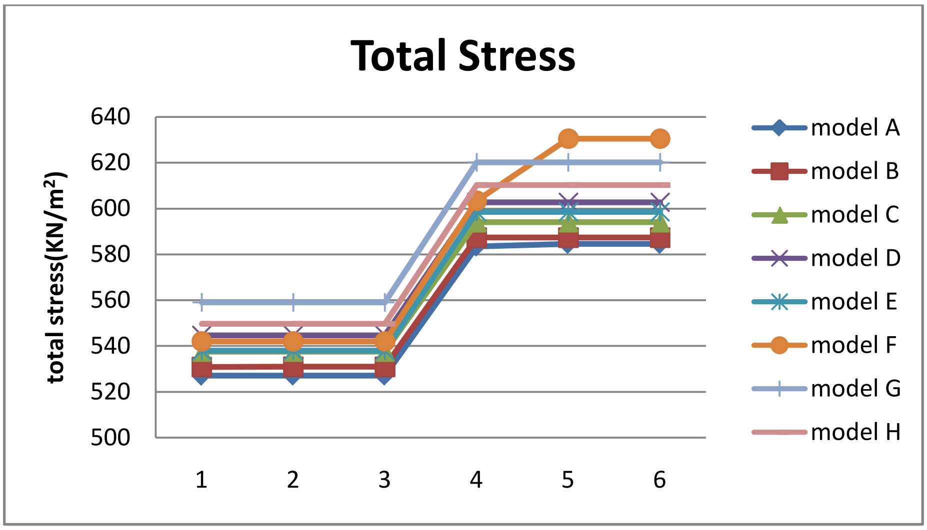

Fig (2): changes of total stress in different phase

As show in the Fig (2), for each of models there is a similar Process from first phase to sixth phase. Investigation show the rate of total stress in bed layers, when construct vertical section of breakwater is 11 percent increased than when rack foundation constructed.

4.2.3. Total displacement

In the Fig (3) is shown the Total displacement in various models and phases.

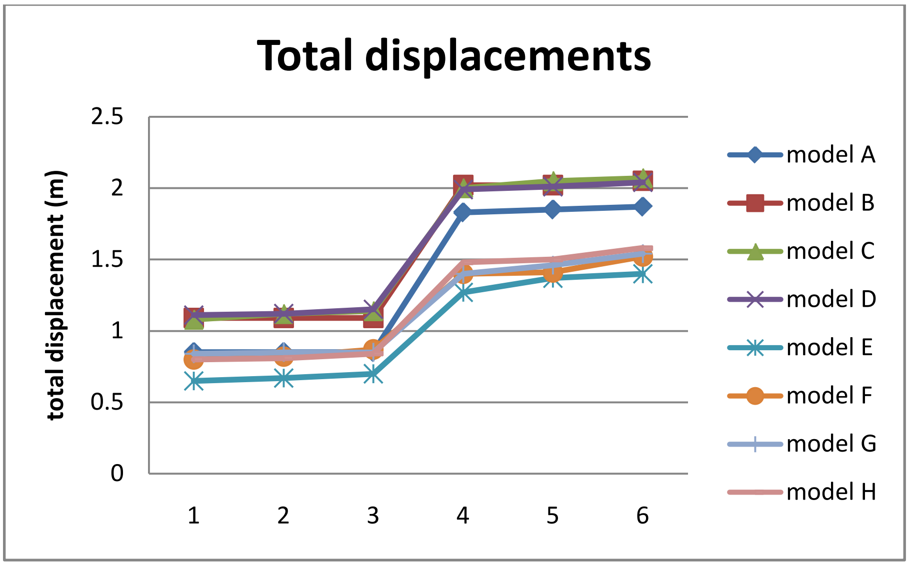

Fig (3): changes of total displacements in different phase

As show in the Fig (3), for each of models there is a similar Process from first phase to sixth phase. Investigation show the rate of total stress in bed layers, when construct vertical section of breakwater is 80 percent more than when rack foundation constructed.

According to result of model A compare to model B that the characteristics of soil is equal but the slope side has been changed, the stability of model A is higher than model B and settlement of model A is less that model B. the results of this section shows that increasing in slope side decrease the satiability

According to result of model A compare to model C that the characteristics of soil is equal but the Height of rack foundation and height of structure and slope side has been changed, the stability of model A is higher than model C and settlement of model A is less that model C. the results of this section shows that increasing in Height of rack foundation cause to satiability is reduce.

According to result of model A compare to model D that the characteristics of soil is equal but the Height of rack foundation and height of structure and side slope is changed, the stability of model A is higher than model D and settlement of model A is less that model D. the results of this section showed that increasing in Height of rack foundation cause to satiability is reduce.

According to result of model B compare to model C that the characteristics of soil is equal but the Height of rack foundation and height of structure and side slope is changed, the stability of model A is higher than model D and settlement of model B is less that model C. the results of this section showed that increasing in Height of rack foundation, side slope and height of structure cause to satiability is reduce.

According to result of model B compare to model D that the characteristics of soil is equal but the Height of rack foundation and height of structure and side slope is changed, the stability of model B is higher than model D and settlement of model B is less that model D. the results of this section showed that increasing in Height of rack foundation, side slope and height of structure cause to satiability is reduce.

According to result of model C compare to model D that the characteristics of soil is equal but the side slope is changed, the stability of model C is higher than model D and settlement of model C is less that model D. the results of this section showed that increasing in side slope cause to satiability is reduce.

According to result of model A compare to model E that the characteristics of soil is different but geometric parameters are similar, the stability of model E is higher than model A and settlement of model E is less that model A. the results of this section showed that increasing in side slope cause to satiability is reduce.

CONCLUSION

The result of this research shows, in fixed geotechnical condition, if the slope side increases the stability and also settlement will be increased. Therefore the structure will be safety. In other side if the height of structure increases therefore the stability and safety reduced.

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