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Investigation of geometric parameters of seawalls on the amount of earth subsidence and its horizontal displacement by FLAC 3D software

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ABSTRACT: Seawalls are built for Protecting of beaches against waves and preventing the progression of water to the beach. For a proper understanding about these constructions, a suiTable information about applied loads on these constructions should be existed. One of the important load that applied on these constructions is sea wave. Others loads are included: weight force of the walls, weight force of the soil behind wall, weight force of the sea water on wall base and the forces applied on beach. Seawalls are built in different geometric shapes like vertical, Inclined and curvature walls (with variable slope). In this study, 4 geometric shape: vertical, Inclined, Convex and concave are simulated for analyzing the effect of geometry on stability of seawalls. So FLAC 3D software are used. The results show that the minimum earth subsidence and horizontal displacement are obtained for convex wall and the maximum amount of these parameters for vertical wall.

Keywords: *seawalls; Coastal protection; the stability analysis; subsidence control; FLAC 3D software*

INTRODUCTION

Seawalls are built for Protecting of beaches against waves, preventing the progression of water to the beach and Proper use of coastal lands. For a proper understanding about these constructions, a suitable information about applied loads on these constructions should be existed. The duty of seawall is keeping of soil behind itself. Seawall is designed so that the soil erosion caused by intense wave action in the place of construction is decreased. Seacoast is undergone erosion when reacting against normal waves or sea storms. With the development of the industry, need of human to sea transport is increased. There are many kinds of seawalls. Every kind of seawall has its own advantages and disadvantages. So in order to select the best kind of seawall in special coastal condition, a suitable and complete understanding about stability and subsidence of the seawall must be made. From geometric point of view, the seawalls include tree main groups: vertical steep, slope and curvature walls. Every kind of these seawall has its own advantages and disadvantages and selecting of them is based on investigation of behavior of them against waves and its conditions. Vertical steep wall causes reflection of waves and this action causes of applying great force on the wall. On the other side, the weight of water isn't applied on the wall. This is a special advantage for huge seawalls. By construction of this kind of seawall, there are greater uses from coastal land. The main advantage of slope walls is its depreciable property. This property cause decreasing the forces that applied by waves and so this action causes that moment and shear force are decreased. In this situation, flexural forces that are applied by wave force are the wall weight and water weight. In curvature walls (with variable slope), the base is vertical and upper

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part of walls are slope. In this kind of wall, the weight of water on the construction, the impact force of wave and the moment caused by construction are decreased considerably. So this kind of walls have the advantages of both other walls. According the importance and application of curvature walls, in this research, the effect of geometric of wall on the amount of earth subsidence and its horizontal displacement is studied by FLAC 3D software. The different aspects of seawalls were studied by different researchers. Manikin (1963) calculated the maximum pressure in the surface of water and the moment of wall base according practical observation on vertical walls. Goda (1974) introduced the basic theory of effects of waves on seawalls with permeable and impermeable bed. This theory was developed in 1989 and 2000 for vertical crate and short walls by him. Today, this theory was used for designing of seawalls in Japan. Ahrens *et al*. (1993) investigated the effect of irregular wave mode reflection on vertical walls. Neelamani and et al. (1998) do experiments for measuring of pressures that applied on Impermeable vertical and slope walls when they experience wave in irregular mode and observe errors between experimental and theoretical results. Muni Reddy (2005) used from sunken breakwater in the front of wall in order to decreasing effects of waves and observed that these effects were decreased. Pullen (2009) studied the amount of bending that is created on vertical wall by precision measuring tools. Anand (2010) investigated the effect of irregular wave mode on walls with curvature.

MATERIALS AND METHODS

Introducing of FLAC 3D software

FLAC 3D software is a numerical modeling code in Two-dimensional and three-dimensional continuum environment that was developed by ITASCA. This software could use for many problems in Geomechanics, Civil and Mining. This software also could simulate non-linear behavior constructions that were built in soil, stone and other materials. The environment is created by elements that its geometry of every element could be select by user. Every element acts according to linear or non-linear behavior that adjusted before. This software was designed for quick calculating in modeling of several thousand elements. It should be noted that the speed of problem solving in this software is nearly a linear function of number of elements. different kinds of loadings that could be simulated in this software include: mechanical loadings such as loading of speed and tension, hydraulic loading such as simulation of pore pressure and analysis of effective stress, thermal loadings such as simulation of thermal conductivity of materials, stress and displacements caused by temperature change, dynamic loadings such as loadings in earthquake and explosion. This software solves problems by Differential equations using finite difference method. The steps of problem solving in FLAC 3D are as follow:

1) To make the basic model
2) To make the geometrical model
3) Selecting behavior model and characterization of material
4) Applying of initial and boundary conditions

Input parameters of FLAC 3D software include: vertical and horizontal tension, adhesion, internal friction angle, wall geometry, pore pressure, Poisson's ratio, elastic modulus, shear modulus, bulk modulus and tensile strength. It must noted that all parameters input as SI units.

MATERIALS AND METHODS

In order to investigating of effect of wall geometry on earth subsidence and its horizontal displacement in FLAC 3D software, seawalls with 4 different geometries were simulated. These geometries include: simple vertical, Inclined, Convex and concave. The forces that were included in the simulations, are wave force of sea water, water weight of soil stored behind wall, weight force stored under wall, weigh force of wall and weight force of subjects that are located on beach. Wave power is considered as the developed forces that located on wall. The first step of simulation, is determination of model dimensions. In Fig. 1 shows the dimensions of vertical walls. Also Fig. 2 shows the schematic forces that are applied on seawalls.

The step 2 of simulation, is selection of behavior model and application of material

characterization. The characterizations of soil that is recorded in FLAC 3D, included elastic Modulus, Poisson's ratio, cohesion, angle of internal friction and tensile strength. In Fig. 1 the properties of seawalls concrete, base soil and soil behind the wall are showed. It's noted that the cohesion of base soil is more that the soil located behind wall.

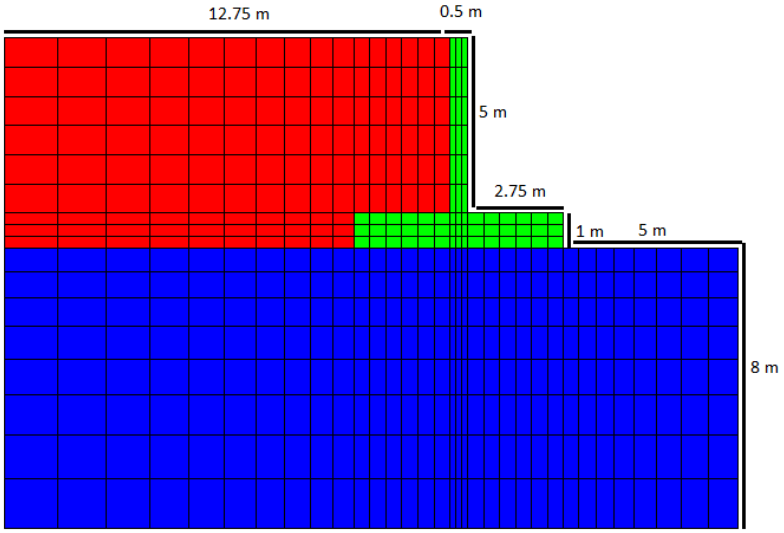


Fig. 1: Schematic forces on vertical wall

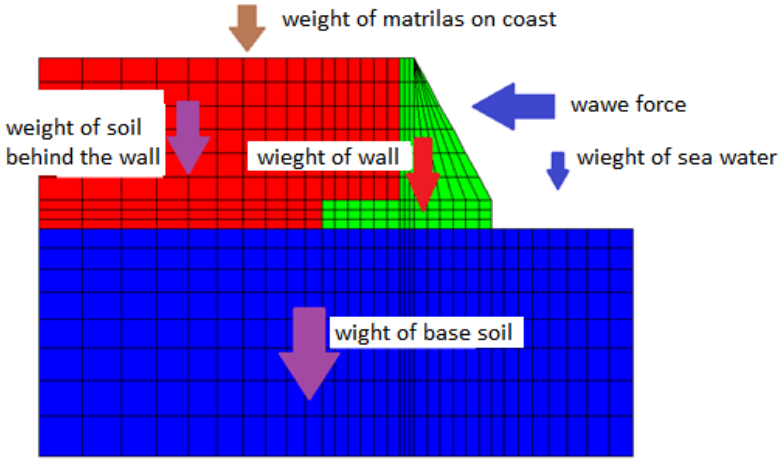


Fig. 2: Schematic forces on seawall

Tab 1: Mechanical properties of soil and concrete

parameter	unit	Wall concrete	Base soil	Soil behind wall
Bulk modulus	MPa	1000	20	15
Shear modulus	MPa	500	6.7	5
density	Kg/m^3	2100	1900	1800
cohesion	KPa	-	90	80
Tensile strength	KPa	-	200	100
internal friction	degree	-	23	25

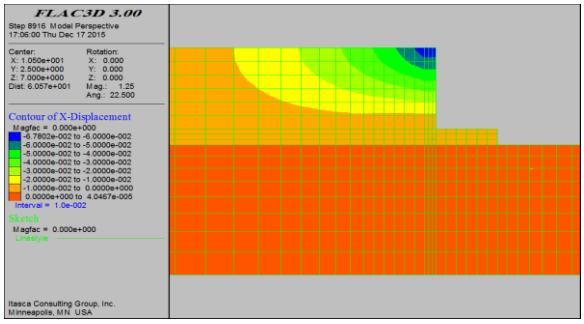
It is noted that loads applied by sea waves to wall is considered as 200 KN. This force is applied as pressure that developed on seawall. This information about pressure is collected from Department of Ports and Shipping. The weight forces that are applied on beach is considered as 50 KPa. As stated before, the goal of this research is investigation effect of geometry wall on stability of wall so, follow scenarios are simulated:
Vertical, Inclined, Convex and Concave with the height of 5 meters, was simulated and the amount of vertical and horizontal displacements and stability of walls were investigated.

RESULTS AND DISCUSSIONS

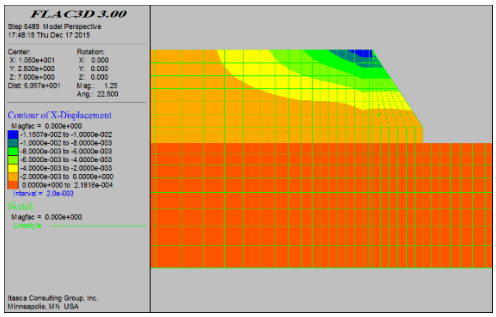
In this section, the amount of vertical and horizontal displacements of this research are showed.

Amount of vertical and horizontal displacements (subsidence) that caused by applying of forces in Scenarios 1

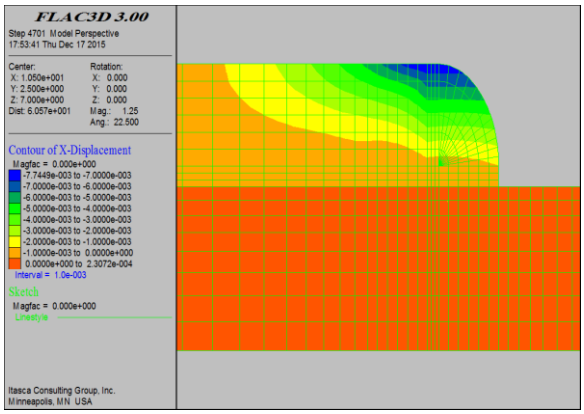
In Fig. 3 and 4, amount of horizontal and vertical displacements are showed respectively:
In Table 2, the amount of horizontal and vertical displacements are showed.



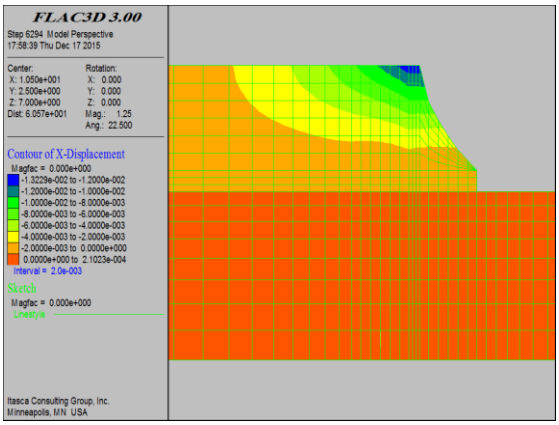
horizontal displacements in vertical wall



horizontal displacements in Inclined wall

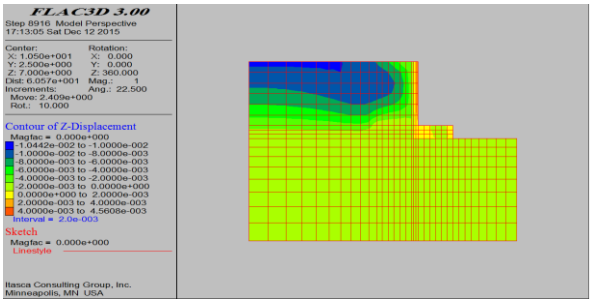


horizontal displacements in Convex wall

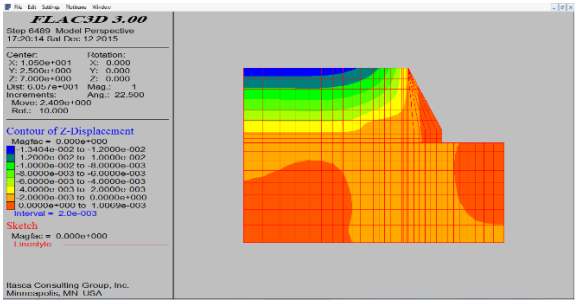


horizontal displacements in concave wall

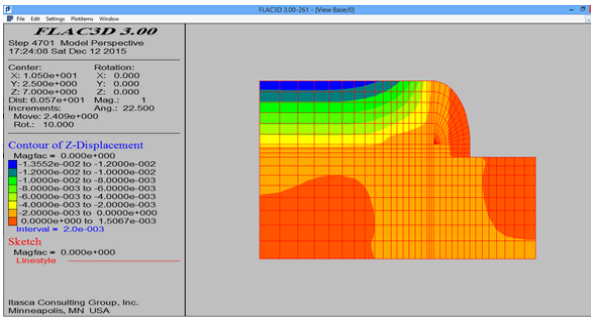
Fig. 4: Horizontal displacements in walls



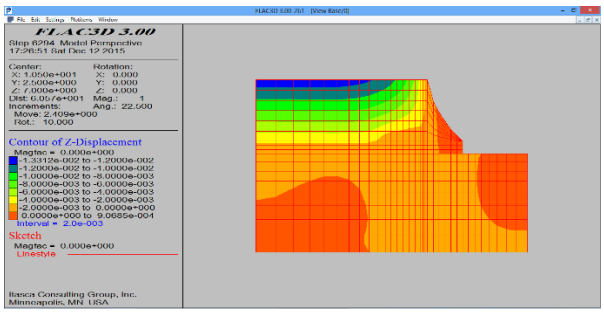
vertical displacements in vertical wall



vertical displacements in Inclined wall



vertical displacements in Convex wall



vertical displacements in concave wall

Fig. 5: Vertical displacements in walls

Table 2: The amount of horizontal and vertical displacements of seawalls

The kind of wall	horizontal displacements (cm)	vertical displacements (cm)
Simple vertical	6.78	0.6
Inclined	1.15	0.4
Convex	0.77	0.2
concave	1.32	0.4

Numerical Analysis on results shows that the minimum amount of displacements in both directions created in convex wall and after that, inclined wall have smallest horizontal displacements. After these two kind of walls, there are concave and simple vertical walls respectively. According to results, it could be said that in those conditions of soil and loadings in horizontal displacements, convex wall is the best and simple vertical wall is the worst.

Investigating of amount of horizontal and vertical displacements (subsidence) that caused by applying of forces in Scenarios 2

In order to investigation of wall height and base thickness on the amount of horizontal and vertical displacements, the height of walls is decreased to 2.5 meters and the base thickness is considered 0.5 meters. In Fig. 6 and 7, the amount of horizontal and vertical displacements in 4 groups of walls are showed respectively.

In Table 3, the amount of horizontal and vertical displacements in 4 groups of walls are showed.

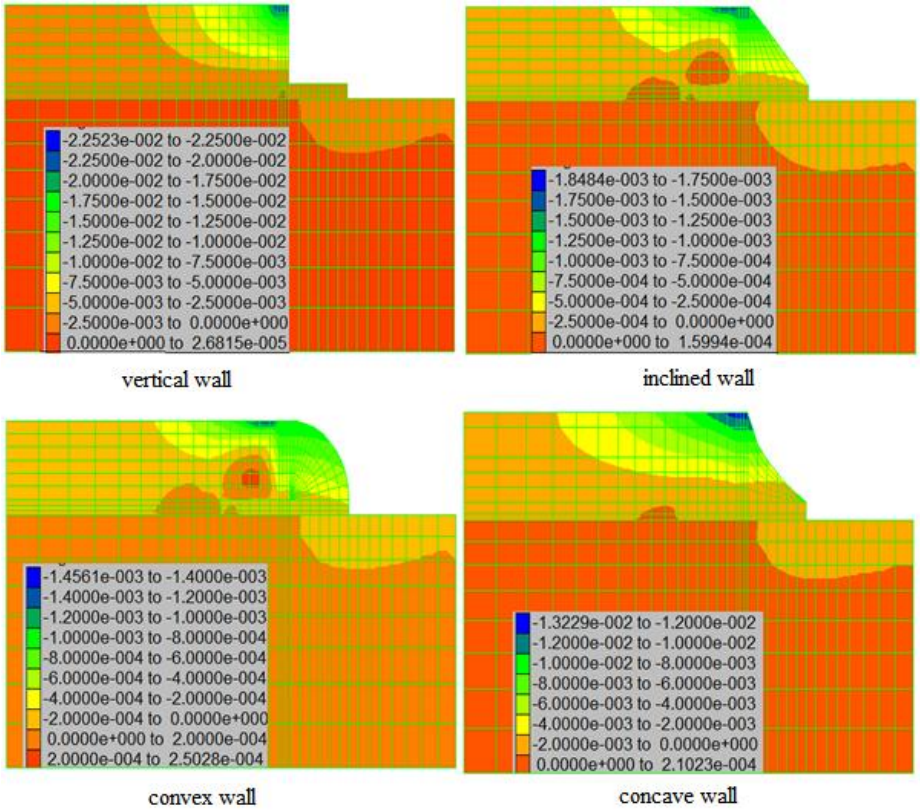


Fig. 6. the amount of horizontal displacements in different walls

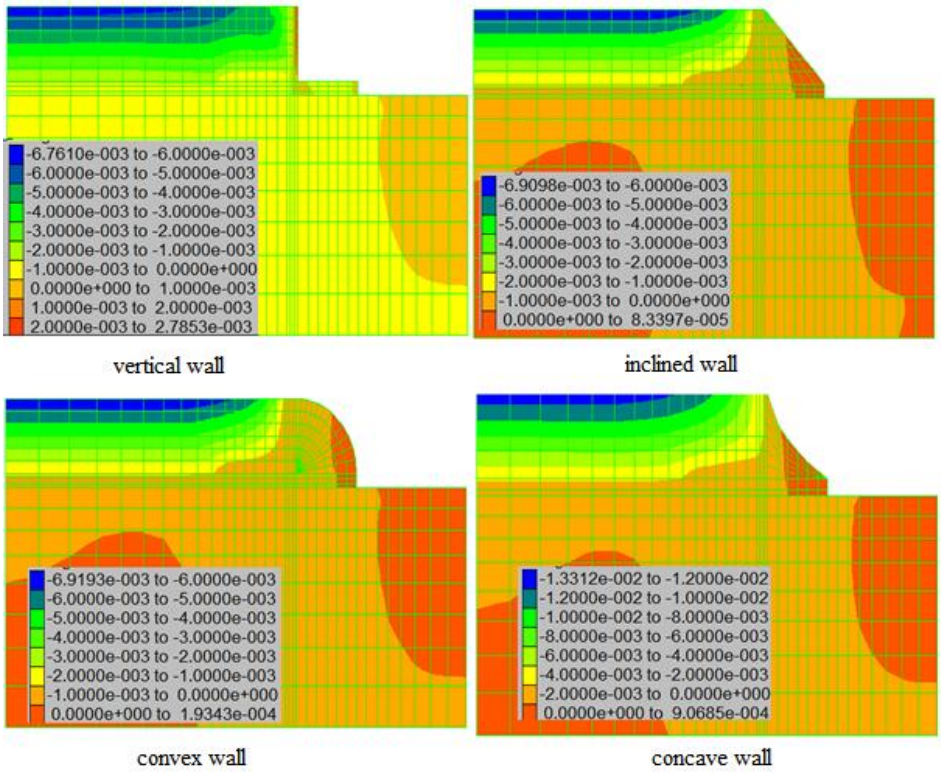


Fig. 7: Amount of vertical displacements in different walls

Tab 3. The amount of horizontal and vertical displacements in walls

wall	horizontal displacements (cm)	vertical displacements (cm)
Simple vertical	2.25	0.4
Inclined	1.85	0.3
Convex	0.14	0.2
concave	0.62	0.3

The results of scenario 2 show that, in summary, it could be said that the minimum amount of subsidence and displacement in this state, is similar to scenario 1.

CONCLUSION

1) Between 4 groups of wall: simple vertical, Inclined, convex and concave, convex wall has minimum amount of horizontal and vertical displacements (subsidence). This means that convex wall has minimum Moving to the coast and subsidence. So in same situation, convex seawall is the best option.
2) Simple vertical seawall has maximum horizontal and vertical displacements (subsidence) between 4 groups of walls. So it's the worst option.
3) It could be said that the minimum of horizontal and vertical displacements in convex seawall, is because of shape and hydrodynamic situation of the wall. In fact, the hydrodynamic shape causes that wave depreciable occurred in addition of wave reflection. The phenomena is a result of applied forces.

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