Investigate submerged breakwater effect in reducing the force on the seawall facing with sea random waves using SACS software

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Abstract: One of the most important loads on seawall is the load result of stormy sea waves. Water free level in this case is random and functions of time; therefore it can be represented as time series or spectrum. During contact with random waves, the pressure on the walls was as time series and random, therefore internal forces created in the walls such as bending moment or shear force have irregular distribution. In this regard, use submerged breakwater in front of seawall plays important role in significant reduction of bending moment or shear force. The results show that when the wall is subjected to random waves use submerged breakwater in front of seawall cause reduction about 42% in bending moment. The same condition about basic shear force cause reduction 35%. Therefore in wave dynamic response analysis was used SACS software.

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1. Introduction

Sea walls are designed to protect against radiation and to prevent the entry of water into the coast and in order to proper use of coastal land. In order to optimize design in coastal engineering must be have appropriate information about entered loads and costal structures behavior against the loads. The most important loads exerted on the seawalls are sea waves, which it's certainly, greater during storm. Main parameters of waves are height, period, waves length .Due to the random behavior of the wave, cannot be determined behavior of coastal structures just rely on the theory accurately. Therefore, the use of laboratory studies and authentic software will be important. In seawall design because of basic moment is one of the most influential factors so set it when random wave's radiation will contribute to the design.[1] Can be use steep seawall in order to optimize design due to wall slope . Use vertical walls, increases waves shock force because of full reflection. In wall steep with high slope will increase wave lenght and water weight on the wall. So can be seen low slope of wall will be effective in lowering the moment.

2. Review previous Researches

Seawalls around the world due to lack of careful design have caused great damage and many structural defects are result of reversal of the structure, crack in weak part and trembling of structure entire [2].

Waves exerted on the structure in three case; brittle, non-brittle and broken which by similar number of failures (ξ) can be expressed them as follows [3]:

$$\zeta = \left(\frac{H_i}{L_\circ} \right)^{-0.5} .tg\theta \qquad (1)$$

Where H_r is radiation wave height on the structure, L_0 is deep water wave length and θ is angle of wall steep. In wall with low steep and close to state vertical, reflection occurs and reflection coefficient (C_r) will be near to one which in this case wave will be kind of non- brittle but in case with greet slope (C r) is near to zero and wave will be kind of break or brittle [3,4].

$$C_r = \frac{H_r}{H_i} \qquad (2)$$

Where H r is height of reversal wave in front of the structure. To examine the effect of waves on coastal structures are studied three cases of waves; breaker, brittle and non-brittle [3].

The first studies in order to design coastal wall was done by Sainflou in 1928. He is presented simple wave theory to calculate wave hydro dynamic performance on the wall. These studies were completed by Rundgren in 1958 with laboratory studies. Wave effects and the exerted pressure are shown in Figure 4. Equations 3 and 4 offer Sainflou equations to calculate the impact of non-brittle waves on vertical walls [4, 5].

$$p_1 = \frac{1+C_r}{2}\cdot\frac{\rho g H_i}{Cosh\left(\frac{2\pi d}{L}\right)} \qquad (3)$$

$$M = M_{HS} + M_{HD} = \frac{1}{6}\rho g d^3 + M_{HD} \qquad (4)$$

In the above equations,ρ is density, d is water depth in front of the wall ,g is gravity ,L is wave length and M_s is moment result of water hydrostatic force ,M_{HD} is Moment result of hydro dynamic force (moment result of waves shock),P_1 is pressure addition in water level when wave contact with peak and M is entire moment in basic wall. To obtain M can be use represented diagrams by Rundgren which pointed out in figure (5). In 1963 Minikin theories based on empirical observations on large-scale wall mural are presented for regular waves. Relations 10, 11, 12 and figure 6 about diagram of the pressure wave are presented by him [2].

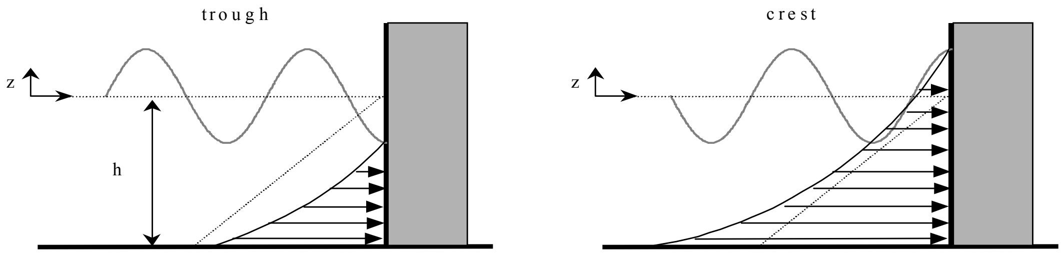
P_{MAX}=101yd(1+d/h)H/L

(5)

$$M=8H2d \qquad \frac{H}{L0} < 0.045 \qquad (6)$$

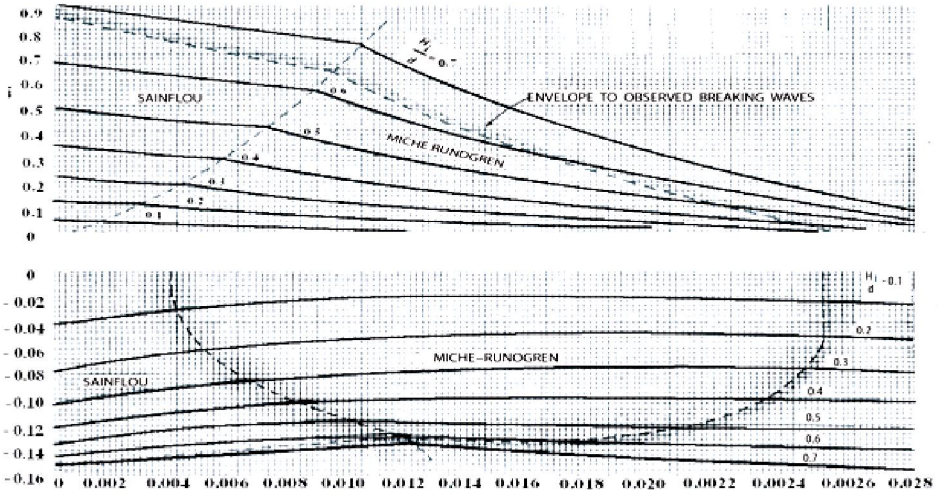
$$M=12.5H^3 \qquad \frac{H}{L0} > 0.045 \qquad (7)$$

In the above equations, H is wave height, L_0 is wave length in deep water based on foot. Goda in 1974 provided the basic theory of wave's effect on the seawall. Equations 5 to 9 represented with assuming a linear distribution for wave pressure and maximum value P_1 in static level [1]. Figure 7 shows pressure distribution diagram by using Goda theory. As shown in this figure the waves are not random and regular waves are considered for maximum mode. Also, using this theory can be investigating wave's pressure for built walls on effective substrate.



Pressure distribution under standing waves based on Sainflou's theory

*Figure 4: Impact of waves on the vertical walls based on Sainflou theory [4, 5].



* Figure 5: Rundgren diagram to calculate the bending moment resulting from the wave's impact on vertical walls[5]

Basic moment by Goda theory is represented based on 5_9 equations as follow:

$$M_{GODA} = 1_{h;Goda}F_{h;Goda} + l_{v;Goda}F_{v;Goda} \qquad (8)$$

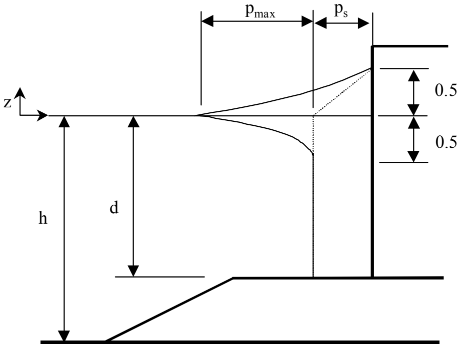
$$F_{h;Goda} = \frac{1}{2}(p_1+2p_4)R_c^* + \frac{1}{2}(p_1+p_3)(d+d_c) \qquad (9)$$

$$F_{u;Goda}=\frac{1}{2}p_u B_c \quad (10$$

$$l_{h;Goda}=d+d_c+\frac{R_c^{*2}(p_1+2p_4)-(d+d_c)^2(p_1+2p_3)}{3R_c^*(p_1+p_4)+3(d+d_c)(p_1+p_3)} \quad (11)$$

$$L_{v;Goda}=\frac{1}{6}B_c \quad (12)$$

In above equations $P_u=0.5\alpha_1\alpha_3\rho g H_i$, $P_4=\alpha_4 P_1$,$P_3=\alpha_3 P_1=0.5(\lambda_1\alpha_1+\lambda_2\alpha^*)\rho g H_i$,$\eta^*=0.75H_i$ α Coefficients, wave conditions coefficients and λ coefficients, structure geometry conditions coefficients and $R^*_c=\min(R_c, \eta^*)$ defined [1].



Minikin's Formula

* Figure 6: Wave pressure diagram Minikin [2]

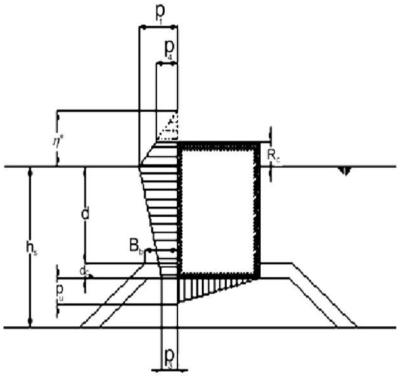


*Figure 7: Pressure distribution using Goda theory [1]

Shunto, in 1972, presented the two-dimensional wave theory to calculate force result of two-dimensional waves using Lagrange theory. This theory can be offer basic moment in case brittle and non-brittle waves [4]. Numerical studies of interaction between the wall and waves were done by Ahrens in 1993, by Vander Meer in 1995 and Schutrumpf,et.al in 1994 to investigate exerted forces from waves [3,5].Neelamanni in 2005, was done laboratory studies on the steep wall and roughness effect on wave effect value [6]. Muni Reddy in 2005 in order to mitigate the effects of wave on the seawall used submerged breakwaters in front wall and saw reduce its impact based on ratio submerged breakwaters height to wall height [7]. Jeng in 2055 used porous submerged breakwaters in front of the wall like as Muni Reddy [8].Zanuttigh in 2005, studied the effect a variety of materials used in the wall in reduce wave effect [9]. Pullen in 2009 studied bending value on the Walling ford seawall in Edinburgh using precision measuring instruments [10]. Cumo in 2010 was done extensive experimental studies on walls with gentle slope facing random waves and Anand in 2010 examined the random wave's effect on curved walls numerically [14]. New software packages are provided to design and modeling of seawall. The most prominent of this software are SACS, OIAC and HYDRO PRO T HDMS. Despite extensive research done on the seawall, about significance impact of steep wall in the direction of the wave and the wave and in order to determine the force of random waves has not been a lot of researches using SACS software.

3. Waves on seawall

In general, waves are classified into two categories regular and random waves. Random waves can be defined by a combination of regular waves. Sea waves are kind of random waves when the sea is stormy and water level is irregular. Random wave hydraulic parameters are defined in Figure 8. In this case, to determine wave height and period are used

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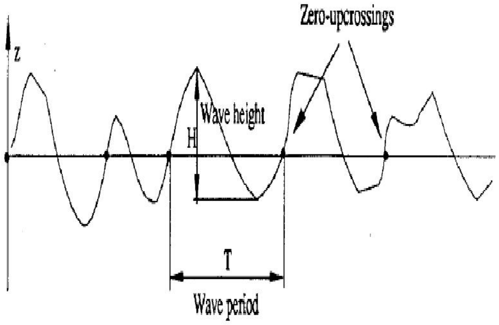


* Figure 8: Water level schema based on time

Random waves can be studied using spectral analysis on recorded signals. In this regard, can be explained the radiated waves in sea condition by spectral density comprehensively [16]. In this same, different spectrums have been defined like as Bretschnider spectrum in 1959, P-M in 1964, TMA in 1985 and JONSWAP spectrum in 1974 [5, 15 and 17]. Sorensen has been introduced JONSWAP spectrum as one of the most useful spectrum to design of coastal structures [17]. On other hand due to natural conditions of Iran waters the JONSWAP and P-M spectrums can be more useful in the design of coastal structures [16]. New researches have begun construction of an appropriate spectrum according to Iran climate. But in the absence of the spectrum, can be used the cited spectrums. In this study used JONSWAP spectrum.

$$S(f)=\frac{\alpha g^2}{(2\pi)^4 f^5}e^{-1.25\left(f_p/f\right)^4}\gamma^a \tag{13}$$

In this spectrum γ coefficient is between 1/6 to 6 but number 3/3 is recommended. γ Coefficient is density ratio in maximum frequency for JONSWAP spectrum to P-M spectrum. In (13) equation,

$$a=e^{-\left[(f-f_p)/\left(2\sigma^2 f_p{}^2\right)\right]} \tag{14}$$

$$f_p=\frac{3.5g}{W}\left(\frac{gF}{W^2}\right)^{-0.33} \tag{15}$$

$$\alpha=0.076\left(\frac{gF}{W^2}\right)^{-0.22} \tag{16}$$

F is wave length, W is wind speed at level 19/5 m ,f is frequency and fp is maximum frequency.

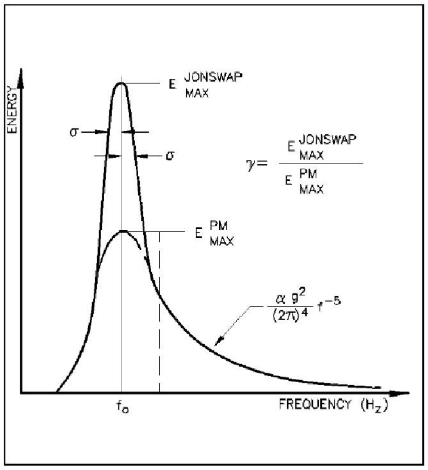


*Figure 9: JONSWAP wave spectrum [17]

4. Materials and Methods

In this study, a steel model of seawall with 1m× 1 m dimension and 1cm thickness is intended which is anchor in floor but free in its sides. The wall can be placed under different angles relative to the vertical axis. Because of the length of seawall is more than their section, unit length is determine for wall and these structures are built along the coast. Thus, the behavior of unit length can be show entire wall. The model is considered under different angles to the wave direction and face to wave under radiation random wave. Time history diagram of water surface profile, force and basic moment is present. Moment maximum values in each case are collected and compared together. In order to obtain the interaction between the wall and the waves is used SACS software.

4.1. SACS software:

SACS is one of the strongest and most widely used software for analysis and design of offshore platforms under various loading conditions. According to the definition, the interaction between the wall and wave will be in sub program of analyze the waves dynamic response. In Figure 10, the overall structure of software and in figure (11) the forward methods of dynamic response analysis are shown [18].

4.2. The used model in the software:

Wall geometry model is a subset of the SACINP software set. In this part in addition to introduce structural geometry, initial load such as structures weight, sea static mode and regular waves are introduced. This information will be used in the analysis of wave dynamic response. Figure 12 show cross-sectional of created model and in figure (13) can be seen three-dimensional model of the wall. In order to analyze the dynamic response of wave 1, first static analysis of wave 2 is done then modal 3 analyses. In table 1 is shown wave profile. These characteristics are expressed according to environmental conditions which are wave input parameters. In practical work, wave period is usually 1 -10 sec and 2/5 seconds period is suitable for beaches condition of Iran. Due to the similarity of Froude number and consider 1 to 5 scales the wind wave period is considered1/12 sec.

Table1-Entered wave characteristic:

Wave height	20cm
Water height	60cm
regular wave period	1/12 second
Wave spectrum	JONSWAP
γparameter in spectrum	3
During effect of wave	300 , 150 second
Pitch	0/02 second
C parameter in spectrum	0/142
submerged breakwater height	25
Distance of submerged breakwater from wall	100
submerged breakwater length at floor	100
submerged breakwater length at peak	50
submerged breakwater slope in direction of wave	45 degree
slope gradient behind the wave of submerged breakwater	45 degree

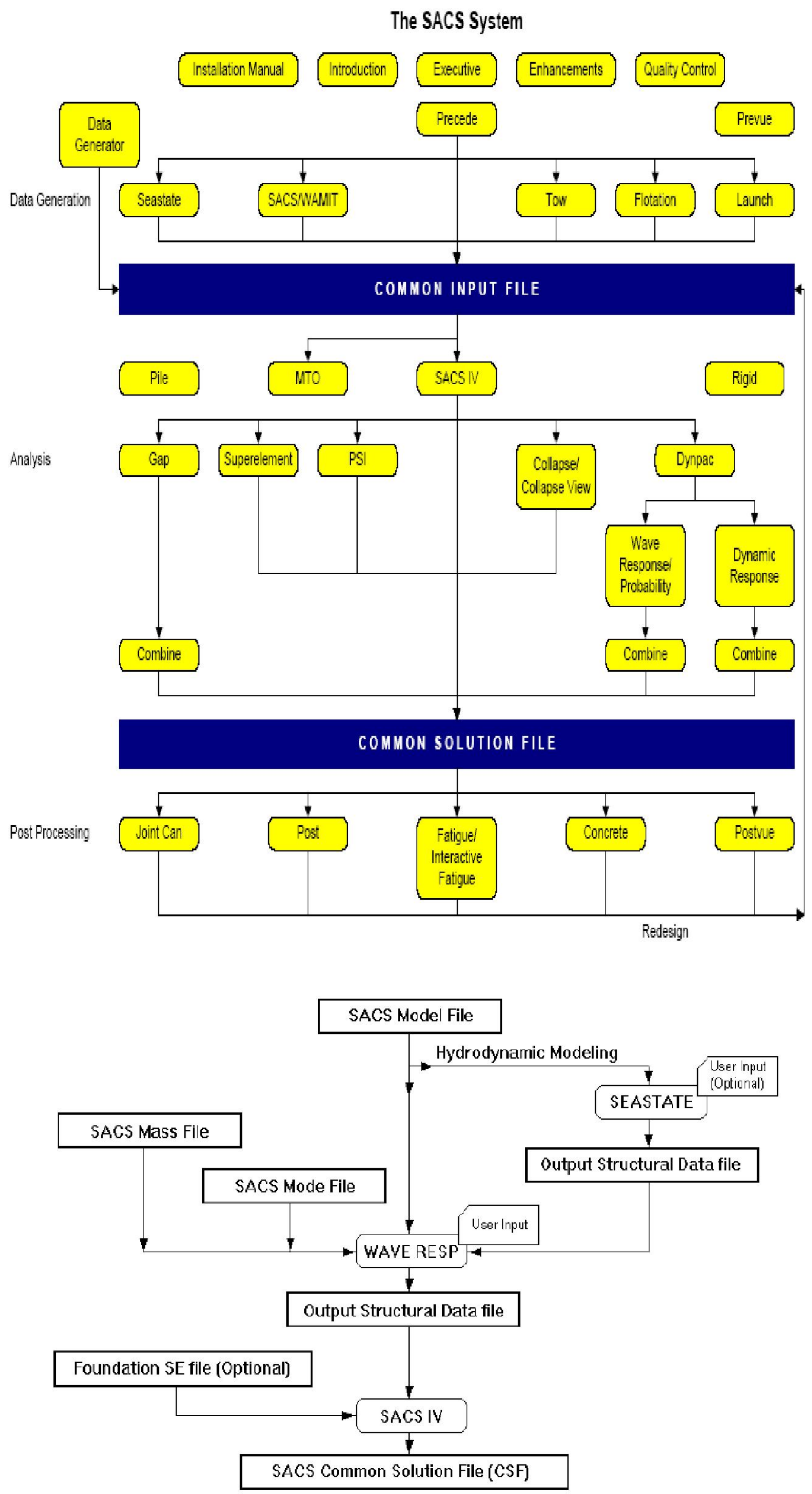


*Figure 11: The forward methods of dynamic response analysis in SACS software

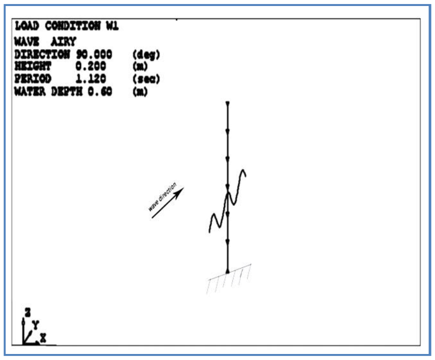


*Figure 12-Wall model in software

Time length of wave effect and suitable pitch the can be important factors in wave simulation either in systems which produce experiment wave either in software. Analysis of these two factors has been carried out on a vertical wall. In this regard, exposure duration, and different pitches was evaluated in the software. An example is shown in Figure 14. For 15 second pitch with time effect 300 second, there is not appropriate overlap between SACS spectrum and JONSWAP spectrum. But in figure 15 can be seen there is suitable overlap at pitch 0/02 second. This condition creates take of some points in a wavelength. Reduce time of wave effect result in reduce its precision and this position cause long time of process and number data. Therefore after many analyze and error and try the time of wave effect are considered 300 second and pitch 0/02 second.

5. Analyzes have been conducted

As can be seen from Figures 19 and 20 the value of dimensionless bending moment reached from 0/97 to 0/56 and using the submerged breakwater in front of the wall in accordance with the specifications in Table 1 cause reduces the bending moment about 42 percent. This has been reducing 35% of shear force and it reach from 0/ 89 to 0/58.

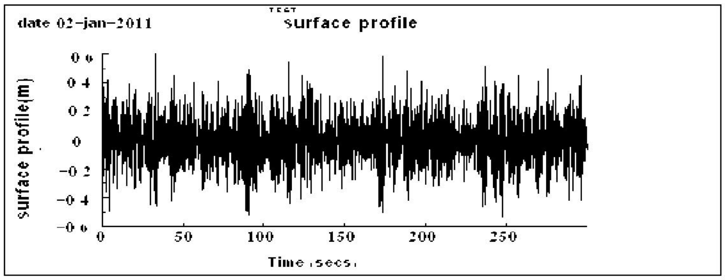
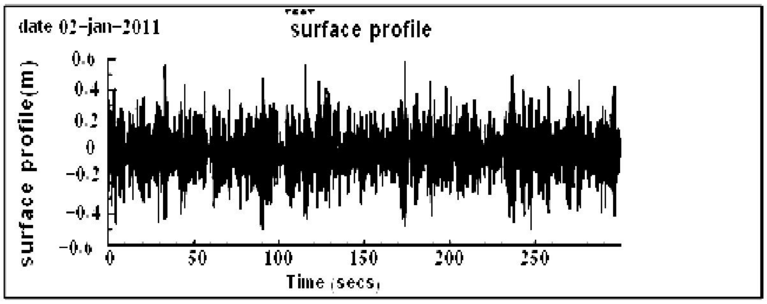
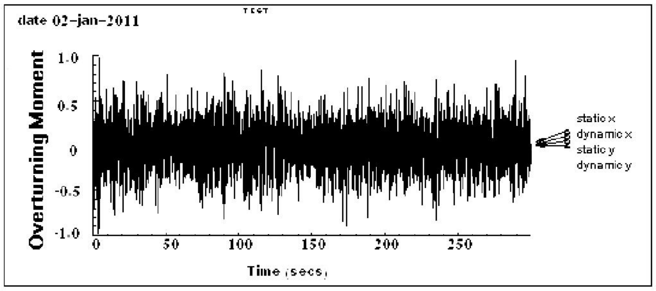


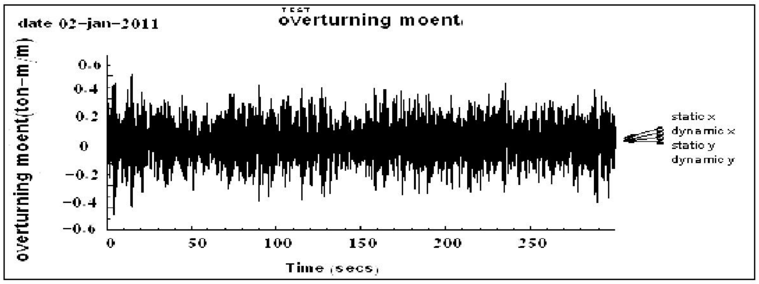
*Figure 17: Pro s 0/15 seconds)



* Figure 18 - Water surface profiles (time length of wave effect is 150 seconds and pitch is 0/02 second)



* Figure 19 - basic bending moment (time length of wave effect is 300 seconds and pitch is second)



* Fig 20. Basic bending moment with submerged breakwater (time length of wave effect is 300 seconds and pitch is 0/02 second)

6. Conclusion and Recommendations

The main results of the study can be summarized as follows.

1-When the wall is subjected to random waves, use submerged breakwater in front of seawall reduce the bending moment about 42 percent. The same case about basic shear force reduces 35% in shear force.

2-The duration of the wave and pitch must be determined such as an appropriate adjustment creates with valid spectrum. In this study, time length of wave effect of 300 seconds and pitch 0/02 2 second covers JONSWAP spectrum.

3-The amount of basic moment against random wave's result of dynamic analysis is more accurate than static analysis.

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