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18 Sentences were found in a text with the title: „***Shaking Tie-back wall.pdf***", located at:
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https://civilengineeringbible.com/article.php?i=38

5 Sentences were found in a text with the title: „***eScholarship UC item 87q2b3b0.pdf***", located at:
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5 Sentences were found in a text with the title: „***Seismic Design and Construction of Retai.pdf***", located at:
http://www.arunachalpwd.org/pdf/Seismic Design and Construction of Retaining wall.pdf

5 Sentences were found in a text with the title: „***IJSDR1704022.pdf***", located at:
http://www.ijsdr.org/papers/IJSDR1704022.pdf

5 Sentences were found in a text with the title: „***Seismic Design and Construction of Retaining wall.pdf***", located at:
http://arunachalpwd.org/pdf/Seismic Design and Construction of Retaining wall.pdf

4 Sentences were found in a text with the title: „***Seismic Design of Retaining Walls | Earthquakes | Force ...***", located at:
https://www.scribd.com/presentation/374275145/Seismic-Design-of-Retaining-Walls

3 Sentences were found in a text with the title: „***Microsoft Word - Visone.doc***", located at:
http://www.reluis.it/doc/pdf/Pubblicazioni/Visone-Santucci.pdf
https://pdfs.semanticscholar.org/e5a1/87a6be57644c4882ca5d07c5b052377d0091.pdf

3 Sentences were found in a text with the title: „***Shaking Tie-back wall - GEO-SLOPE International***", located at:
http://downloads.geo-slope.com/geostudioresources/examples/7/Shaking Tie-back wall.pdf

3 Sentences were found in a text with the title: „***Tie Back Wall Subjected to Earthquake Shaking***", located at:
http://downloads.geo-slope.com/geostudioresources/8/0/examples/QuakeW/Shaking Tie-back wall.pdf
http://downloads.geo-slope.com/geostudioresources/examples/8/13/QuakeW/Shaking Tie-back wall.pdf

3 Sentences were found in a text with the title: „***A review of design methods for retaining structures under ...***", located at:
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2 Sentences were found in a text with the title: „***Seismic Earth Pressures on Retaining Structures in Cohesionless Soil***", located at:
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2 Sentences were found in a text with the title: „***The Shape of Slide Surface of Gravity Retaining Walls ...***", located at:
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2 Sentences were found in a text with the title: „***_4_ د.محمد يوسف***", located at:
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2 Sentences were found in a text with the title: „***A Review of Design Methods for Retaining Structures under ...***", located at:
http://www.doc88.com/p-0837191339438.html

Numerical Analysis of Retaining Wall Subjected to Earthquake Loading

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ABSTRACT

The retaining walls in different branches of civil engineering are used to support the massive mass such as hydraulics, irrigation structures, highways, railways, tunnels, mining, etc. The computation of lateral earth pressure is an important item to design a retaining wall. The lateral earth pressure in the static condition is caused by retained mass only, so the deformation in retaining wall due to static loading may be negligible and small, in other cases such as an earthquake can generate large disrupt force in retaining wall and retained mass. Earthquakes have caused lasting deformations in retaining walls in many historical earthquakes. In some cases, retaining walls have fallen down during an earthquake with devastating physical and economic consequences. Simultaneously, it is very much important to estimate dynamic earth pressure accurately. In this study, a numerical method through (FEM) was used to investigate the seismic behavior of retaining walls supporting cohesion less backfill. Horizontal and vertical deformations, at the face of the wall, and maximum dynamic shear stress in the soil, at the base, was evaluates for historical earthquakes.

1- INTRODUCTION:

Retaining structures can be defined as structures which retain ground, comprising soil, rock or backfill, and water. The material is retained at a slope steeper than it would eventually adopt if no structure was present. Retaining structures include all types of walls and support systems in which structural elements have forces imposed by the retained material. They are used throughout seismically active areas and frequently represent key elements of ports and harbors, transportation systems, lifelines, and other constructed facilities. **Al-Taie (2013); Al-Taie and Mohammed (2014); Al-Busoda et al. (2017); Das and Sobhan (2018).**

Earthquakes have caused permanent deformation of retaining structures in many historical earthquakes. In some cases, thesedeformations were negligibly small; in others, they caused significant damage. In some cases, retaining structures have collapsed during earthquakes, with disastrous physical and economic consequences, **Das and Luo (2017)**; **Al-Taie and Albusoda (2019)**.

As suggested by **Stadler (1996),** analytical solutions for the dynamic earth pressures problem canbe divided into three broad categories depending on the magnitude of the anticipated walldeflection. These categories include **rigid-plastic**, **elastic**, and **elasto-plastic methods.** Relativelylarge wall deflections are usually assumed for rigid-plastic methods, while very small deflectionsare assumed for elastic methods. Elasto-plastic methods, appropriate for moderate walldeflections, are usually developed using finite element analysis and are therefore presented underthe numerical methods section of this chapter. It is important to note that analytical seismic earthpressures methods are usually based on idealized assumptions and simplifications that do notnecessarily represent the real retaining structures–backfill seismic behavior. Therefore, suchmethods often result in overconservative estimates of dynamic earth pressures.

2-1- Rigid-Plastic Methods

Rigid-plastic methods, which generally assume large wall deflections, are either force-based or displacement-based. The most commonly used force-based rigid-plastic methods are the M-Oand **Seed and Whitman (1970)** methods. Displacement methods are generally based on the**Newmark (1965)** or modified Newmark sliding block.

2-1-1-The Mononobe-Okabe Method and Its Derivatives

The M-O method developed by Okabe (1926) and Mononobe and Matsuo (1929) is the earliestand the most widely used method for estimating the magnitude of seismic forces acting on aretaining wall. The M-O method is an extension of Coulomb's static earth pressure theory toinclude the inertial forces due to the horizontal and vertical backfill accelerations. The M-O forcediagram is presented in Figure (1).

The M-O method was developed for dry cohesion less backfill retained by a gravity walland is based on the following assumptions (Seed and Whitman 1970):

The wall yields sufficiently to produce minimum active pressure.

The soil is assumed to satisfy the Mohr-Coulomb failure criterion

When the minimum active pressure is attained, a soil wedge behind the wall is at the point of incipient failure, and the maximum shear strength is mobilized along the potential sliding surface

Failure in the backfill occurs along a plane surface inclined at some angle with respect tothe horizontal backfill passing through the toe of the wall

The soil wedge behaves as a rigid body, and accelerations are constant throughout the mass

Equivalent static horizontal and vertical forces, $W.K_h$ and $W.K_v$, are applied at the center of gravity of the wedge represent the earthquake forces. Parameters K_h and K_v representgravitational accelerations in the soil wedge.

Fig. 1 Forces considered in Mononobe-Okabe analysis (Wood 1973).

Based on the M-O method, the active lateral thrust can be determined by the staticequilibrium of the soil wedge shown in Figure 1. The maximum dynamic active thrust per unitwidth of the wall, P_{AE}, is determined by optimizing the angle of the failure plane to thehorizontal plane, and is given by:

PAE=12γH2*1-Kv*KAE (1)

WhereKAE=cos2(∅-θ-β)cosθcos2βcos(δ+β+θ)1+sin∅+δ*sin∅-θ-icosδ+β+θ*cos(i-β)2 (2)

PAE= Maximum dynamic active force per unit width of the wall.

KAE = Total lateral earth pressure coefficient.

γ = unit weight of the soil.

H = height of the wall;

∅ = angle of internal friction of the soil.

δ = angle of wall friction.8

i = slope of ground surface behind the wall;

β= slope of the wall relative to the vertical.

θ=tan-1Kh1-Kv

Kh= horizontal wedge acceleration divided by g; and

Kv= vertical wedge acceleration divided by g.

The M-O method gives the total active thrust acting on the wall but does not explicitlygive the point of application of the thrust or the dynamic earth pressure distribution. The point ofapplication of the M-O active thrust is assumed to be at H/3 above the base of the wall.

1-1-2-Elastic Methods

Elastic methods are generally applied in the design of basement walls that usually experiencevery small displacements and can be considered as "truly" rigid walls. The underlying assumption is that the relative soil-structure movement generates soil stresses in the elastic range Elastic methods are usually based on elastic wave solutions and result in the upper-bound dynamic earth pressures estimates. The **Wood (1973)** method is the most widely used in this category. Other work in this area includes **Matsuo andOhara (1960), Scott (1973), and Tajimi (1973)**.

2-2- NUMERICAL METHODS

Numerical modeling efforts have been applied to verify the seismic design methods in practiceand to provide new insights into the problem. Various assumptions have been made and severalnumerical codes have been applied (PLAXIS, FLAC, SASSI…) to solve the problem. Whileelaborate finite element techniques and constitutive models the soil pressure for design, simple methods for quick prediction of the maximum soilpressure are rare. Moreover, while some of the numerical studies reproduced experimental dataquite successfully.

3- TYPES OF RETAINING WALLS

The problem of retaining soil is one of the oldest in geotechnical engineering; some of the earliest and most fundamental principles of soil mechanics were developed to allow the rational design of retaining walls. Many different approaches to soil retention have been developed and used successfully. In recent years, the development of metallic, polymer, and geotextile reinforcement leads to the development of many innovative types of mechanically stabilized earth retention systems. Retaining walls are often classified in terms of their relative mass, flexibility and anchorage conditions (Figure 2). Gravity walls are the oldest and simplest type of retaining wall. Gravity walls are thick and stiff enough so that they do not bend; their movement develops essentially as rigid-body translation and/or rotation. Certain types of the composite wall systems, such as crib walls and mechanically stabilized walls, are thick enough so that they bend very little and consequently are often designed as gravity walls (including appropriate consideration of internal stability). Cantilever walls, which bend as well as translate and rotate, rely on their flexural strength to resist the lateral earthpressures. The actual distribution of lateral earth pressure on a cantilever wall is influenced by therelative stiffness and deformation of both the wall and the soil. Braced walls are constrained againstcertain types of movement by the presence of external bracing elements. In the cases of basementwalls and bridge abutment walls, lateral movements of the tops of the walls may be restrained by thestructures they support. Tieback walls and anchored bulkheads are restrained against lateralmovement by anchors embedded in the soil behind the walls. The provision of lateral support atdifferent locations along a braced wall may keep bending moments so low those relatively flexible structural sections can be used.

Fig.2. Common types of earth retaining structures.

4- Effect of Earthquake on Stress in Structural Element

In this study, an investigation of the behavior of wall tied-back with two rows of anchors subjected to earthquake loads with record history was done **(Geostudio software manual).** The prime purpose is to show how the forces in the structural components oscillate during an earthquake and to show the procedures required to do this type of analysis.

4-1- Description of Problem

The configuration of the problem is shown in Figure 3. It is a 9 m high sheet-pile wall tied-back with two rows of anchors. The anchors have a bonded length, and a free length. The bonded portion is modeled as a beam with an E-Modulus of 2 x 108 kPa, a cross-sectional area of 0.00126 m2 and a Moment of Inertia of 0.00025 m^4. The free length is modeled with a bar with an E-Modulus of 2 x 108 kPa and a cross-sectional area of 0.00126 m^2. The sheet pile wall is modeled with a beam with a cross-sectional area of 0.002 m^2 and a Moment of Inertia of 0.0005 m^4.

To set up the state of stress in the ground and in the structural components prior to the earthquake shaking, we must start with the stress in the ground and then simulate the construction of the wall. The initial in situ stress is established with a simple gravity turn-on analysis using the In-situ option in SIGMA/W. The Effective E-Modulus is set to 5,000 kPa with a total unit weight of 20 kN/m^3 and aPoisson's ratio of 0.334. The Initial analysis simulates the stress of the ground prior to the excavationof the material and construction of the wall (Figure 4).

Fig.3 Tie-back wall configuration.

Fig4. Initial stress problem configuration.

The next step is to establish the stress conditions that would be present in the ground and structuralmembers after excavation and construction just before the earthquake. This can be done by"wishing in place" the structural members and then removing the excavation soil. In this example,this is all done in one step. This could be done in many stages to more accurately simulate the construction sequence, as in the SIGMA/W tie-back wall example, but for this illustrative example, itis sufficient to do it in one step. Next, the SIGMA/W can be used to compute static stresses as the initial (Parent) conditions for theQUAKE/W dynamic analysis. The earthquake record used for this case is shown in Figure 5.

Fig.5 Earthquake time history record.

Only linear-elastic soil properties are used to reduce the complexity of this illustrative example.Linear-elastic properties are adequate to demonstrate the QUAKE/W features and capabilities. TheDamping Ratio is 0.1 with a Gmax of 100,000 kPa.

4-2-Results and Discussion

The results of the Insitu analysis can be explored with the Graph command in CONTOUR by creatingplots along a vertical profile.At the end of the second SIGMA/W analysis, the static forces and stress are known. The momentdistribution in the sheet-pile wall is, for example, as in Figure (6 and 7) before and after earthquake.

Fig. 6 Moment distribution in the sheet-pile wall before the earthquake.

Fig.7 Moment oscillations in the sheet-pile wall during the earthquake.

Figure 8 shows the variation of the axial force in the grouted length of the anchor during the shakingat five different times. The forces are, of course, the highest (most negative indicating tension)where the bonded length is connected to the free length portion of the anchor (x = 16.75).

Fig.8 Axial forces in the grouted (bonded) anchor length during the earthquake.

Figure 9 shows the corresponding axial force in the free (unbonded) length of the upper anchor.Note that at time zero, the axial force is equal to the static force from the SIGMA/W analysis.

Fig.9 Axial force in the free length of the upper anchor.

5-Effect of Earthquake on Stress in Soil

5-1- Description of Problem

In this study, a case with model Linear Elastic was studied in which through Figure (10) the wall dimensions can beseen. Tables (1) and (2) show the material properties and dimensions. Figure (11) shows the FE mesh used in the analysis, and also two acceleration time history that needed for the analysis namely: Kobe, Ali ALgharbi,Halabja, and El-Centro earthquake as shown in figure (12,13,14 and 15).

Fig.10 Typical cantilever retaining wall (Bowels, 1988).

Table (1): Wall dimensions (Bowels, 1988)

Wall dimension	value
H(m)	4
A(m)	0.28
B(m)	2.8

C(m)	0.4
H_B(m)	0.4

Table (2): Material Properties (Bowels, 1988)

Properties	wall	fill	soil
Unit weight,γ (kN/m^3)	23.25	18	17
Young modulus,E (kN/m^2)	17384000	45000	11500
poisson's raio,ν	0.18	0.45	0.2

Fig. 11 The finite element mesh.

Fig. 12 Acceleration time history for Kobe earthquake

Fig. 13 Acceleration time history for Ali ALgharbi earthquake

Fig. 14 Acceleration time history for Halabjaearthquake (Al-Taie and Albusoda (2019)).

Fig. 15 Acceleration time history for El-Centro earthquake

5-2-Results and Discussion

5-2-1-Horizontal displacement:

The figures (16, 17, 18 and 19) show thechanging of the horizontal displacement with time during the earthquake atdifferent **node 1**.

Fig. 17 The variation of horizontal displacement at node 1 during earthquake (Kobe)

Fig. 17 The variation of horizontal displacement at node 1 during earthquake (Ali ALgharbi)

Fig. 18The variation of horizontal displacement at node 1 during earthquake (Halabja)

Fig. 19The variation of horizontal displacement at node 1 during earthquake (El-Centro)

5-2-2-Vertical displacement:

The figures (20, 21, 22 and 23) show thechanging of the horizontal displacement with time during the earthquake atdifferent **node 3**.

Fig. 20 the variation of vertical displacement at node 3 during earthquake (Kobe)

Fig. 21 the variation of vertical displacement at node 3 during earthquake (Ali ALgharbi)

Fig. 22 the variation of vertical displacement at node 3 during earthquake (Halabja)

Fig. 23 the variation of vertical displacement at node 3 during earthquake (El-Centro)

5-2-3-dynamic shear stress (q):

The figures (24 25, 26 and 27) show thechanging of the horizontal displacement with time during the earthquake atdifferent **node 2**.

Fig. 24 the variation of peak dynamic stress at node 2 during earthquake (Kobe)

Fig. 25 the variation of peak dynamic stress at node 2 during earthquake (Ali ALgharbi)

Fig. 26 the variation of peak dynamic stress at node 2 during earthquake (Halabja)

Fig. 27 the variation of peak dynamic stress at node 2 during earthquake (El-Centro)

Conclusions

Finite element investigations have been performed under various past earthquake motions namely (**Kobe, Ali ALgharbi, Halabja and El-Centro**) in order to understand the seismic behavior of earth retaining structures. For horizontal displacement, the maximum displacement reaches 1.72m at the top of the wall for case (El-Centro earthquake) also the verticals displace due to earthquake at base of wall. As earthquake acceleration changes with time, the max. shear stressoscillates under the base because so, the determination of these force has great influence on the stability of structures.

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