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Optimum Design of Gravity Wall Founded on Specially Random Soil Subjected to Earthquake Load

التصميم الامثل للجدار الساند الثقالي المتواجد على تربة عشوائية موضوع تحت حمل زلزالي

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Abstract:

A 2D(Plain strain) wall – backfill – foundation interaction is modeled using finite element method by ANSYS to find the optimum design based on the principle of soil-structure interactions analyses. A concrete gravity retaining wall founded on random soil subjected to earthquake loads has been considered in this research. Earthquake records which are obtained from the records of Iraq for the period 1900-1988 are transformed as time–history force. The optimization process is simulated by ANSYS /APDL language programming depending on the available optimization commands. The components of the optimization process are the objective function OBJ is to minimize the area of the gravity retaining wall, the state variables SVs are the stress, strain, and displacement of retaining wall, also the factors of safety and stability considered as a SVs, and the design variables DVs are the dimensions of the retaining wall. In order to specify random soil parameters in the built model, the random field theory is adopted to generate random $C - \emptyset$ soil. The results show that the initial section of gravity Retaining wall that is provided according to initial variables is not representing the optimum section, which it is needed to present in sectional area equal to 37.41% in order to achieved all safety requirements . In other hand, it has been taking various heights of gravity retaining wall as 3, 4, and 5m, the results showed that when the height of gravity retaining wall is increased by 66.6% from (3 to 5m), the optimum cross-sectional area increases in a percent of (177.27%). Further, the comparison between the sub-problem (zero-order) optimization method and the first-order optimization method is demonstrated that the first-order optimization method is more economical and sensible. Also, from studying the effect of some parameters which angle of internal friction of back fill soil, angle of internal friction of foundation soil, foundation soil cohesion, and unit weight of backfill soil ($\emptyset_1, \emptyset_2, C, and\ \gamma_{sb}; respectively$) is proved that the foundation soil cohesion (C) is more important than the other parameters, while unit weights of backfill soil have little effect on optimum section. It is concluded that the finite element method simulated by ANSYS is efficient with the optimization process.

Keywords: Optimum Design, Gravity Retaining Wall, Random soil, ANSYS Parametric Design Language (APDL), Soil-Structure-Interaction, seismic effect.

المستخلص

في هذا البحث تم نمذجت المسألة كموديل ثنائي الابعاد (المساحة لكل وحده طول من الجدار) باستخدام طريقه العناصر المحددة بواسطه برنامج انسز(ANSYS 11.0) لإيجاد التصميم الامثل مع اخذ بنظر الاعتبار تداخل الجدار- تربه الردم- الاساس. الجدار الساند الثقالي المتواجد على تربة عشوائية الموضوع تحت تأثير الحمل الزلزالي تم اعتماده في هذا البحث. حيث تم تحويل سجلات الزلازل التي تم الحصول عليها من سجلات العراق للفترة 1900-1988 الى صيغة قوة مع زمن (Force-time). عملية الامثلية تمثل بواسطة لغة البرمجة (ANSYS / APDL) اعتمادا على الأوامر الأمثلية المتاحة.

مكونات عملية الامثلية هي دالة الهدف والتي هي تقليل مساحة المقطع العرضي للجدار الساند، متغيرات الحالة (SV_S) والتي هي الاجهاد، الانفعال و الازاحة للجدار الساند، أيضا عوامل الأمان والاستقرار اعتبرت كمتغيرات حاله (SV_S)، و المتغيرات التصميمية (DV_S) والتي هي أبعاد الجدار الساند. من أجل تحديد معلمات التربة عشوائية في نموذج الذي تم بنائها، اعتمدت نظرية الحقل العشوائي لتوليد عشوائي $C - \emptyset$ التربة. النتائج بينت ان المقطع الاولي للجدار الساند الثقالي الذي يتم توفيره وفقا للمتغيرات الأولية لا يمثل المقطع الأمثل، والذي يحتاج لنسبة في مساحة المقطع تساوي 37.41% من أجل تحقيق جميع متطلبات الامان. في جهة أخرى، فقد تم اتخاذ ارتفاعات مختلفة من الجدار الساند الثقالي كما 3 و 4 و 5م، وأظهرت النتائج أنه عندما يتم زيادة ارتفاع الجدار الساند بنسبة 66.6% من (3 الى 5م)، المساحة المقطعية المثلى سوف تزداد بنسبة (177.27٪). علاوة على ذلك، المقارنة بين طريقه الامثليه التقريبية (sub-problem approximation method) وطريقه الامثلية (first-order method) اثبتت ان طريقة first-order method اكثر اقتصادية ومعقولية. بالإضافة الى ذلك، من دراسة تأثير بعض المعلمات على التصميم الامثل والتي هي زاويه الاحتكاك الداخلي للتربة الساندة ($\emptyset_1$)، زاويه الاحتكاك الداخلي لتربة الاساس ($\emptyset_2$)، تماسك تربة الاساس (C)، و الكثافة الوزنية للتربة الساندة (γ_{sb})، اثبت ان تماسك تربة الاساس (C) اكثر تأثيرا من المعلمات الاخرى، بينما الكثافة الوزنية لتربه الساندة($\emptyset_1$) تمتلك التأثير الاقل على المقطع الامثل. ويستنتج من ذلك كله ان المحاكات بطريقة العناصر المتناهية بواسطة الانسزANSYS فعالة مع عملية الامثلية.

I. INTRODUCTION

The retaining wall is one important sort of structure in civil engineering. As a commonplace illustrative of the retaining wall, the gravity retaining wall is generally utilized as a part of housing construction, hydraulic engineering, railway, and other projects, because of its convenience and reliability.

The weight of the gravity wall provides the required stability against the effects of the retained soil and the ground water. This type of wall is generally constructed of plain concrete and masonry. In some cases, the provision of sand, gravel and cement are easier and cheaper than masonry, so it is preferable to use concrete as a construction material rather than masonry.

Conventional design of concrete retaining walls is exceedingly subject to the experience of engineers. The structure is characterized on a trial–and–error premise. Tentative design must fulfill the limit states endorsed by concrete codes. This process prompts safe designs, however the expense of the concrete retaining walls is, consequently, highly dependent upon the experience of the designer. In this manner, keeping in mind the end goal to conserve the expense of the concrete retaining walls under design constraints, it is advantageous for designer to give the issue a role as an optimization problem [1].

There are several approaches for optimization including analytical methods, graphical methods, experimental methods, and numerical methods. Analytical methods are based on the classical techniques of differential calculus and cannot be applied to highly nonlinear problems. Graphical methods require a plot of the function to be maximized and minimized. However, the number of independent variables does not exceed two. Experimental methods use a setup and change variables while the performance criterion is measured directly in each case. Numerical techniques can be utilized to solve highly complex optimization problems of the sort that cannot be solved analytically. The discipline including the theory and practice of these strategies has come to be known as mathematical programming techniques [2]. The branches of mathematical programing are linear programing, quadratic programing, nonlinear programing, dynamic programing, Modern optimization techniques, etc. The most general class optimization problem is nonlinear programing. These problems can be solved using a variety of methods, such as penalty-and barrier-function methods, SQP methods, etc [3].

The seismic reaction of retaining frameworks is still a matter of progressing experimental, analytical and numerical researches. The dynamic interaction between a wall and a retained and foundation soils make the reaction entangled. The dynamic analysis becomes much more complex, as usually material and/or geometry non-linearities must be considered [4, 5]. Depending on the expected material conduct of the retained soil and the possible mode of the wall displacement, there are two principle categories of analytical methods utilizing as a part of the design of retaining walls against earthquakes: (a) the pseudo-static limiting-equilibrium solutions which assume yielding walls resulting in plastic behavior of the retained soil [6,7], and (b) the elasticity-based solutions that view the retained soil as a viscoelastic continuum [8,9].

In this paper, the optimum design of concrete gravity retaining wall including soil-structure-interaction due to time-dependent history load will be investigated. In other hand , random soil will be considered as a foundation of the retaining wall in the analysis.

In order to achieve the aim above, the paper is organized as follows: Section II describes the numerical modeling of problem by finite element software ANSYS which include simulate wall-backfill-foundation problem and all caverning equations related with soil-structure interactions, and random soil modeling. The formulation optimization problem is distributed in three sections, namely Sections III, VI, and V to describe the formulation of optimization problem by ANSYS, applied of different loads, and procedure of running the built optimization model, respectively. The numerical results and discussions are presented in Section IV. Finally, Section IIV presents conclusions.

II. NUMERICAL MODELING OF PROBLEM BY FINITE ELEMENT ANSYS PROGRAMING

In this section the numerical model will be used to simulate the dynamic response of a gravity retaining wall based on principle of soil–structure interaction. The procedure for the dynamic analysis of wall–backfill–foundation interaction is described as follows

a- Soil-Structure interaction

Modeling and analysis of dynamic soil-structure-interaction during earthquakes have gone through direct method(Global Method)where the soil and structure are included within the same model and analyzed in a single step. The discretized structural dynamic equation including the structure and soil subject to ground motion can be formulated using the finite–element approach as [10]:

$$M\ddot{r}(t) + C\dot{r}(t) + Kr(t) = -M\ddot{u_g}(t)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where: r , $\dot{r}$ and $\ddot{r}$ are represent the system relative displacements, velocity and acceleration vectors with respect to base, respectively; M , C and K are represent the system mass, damping and stiffness matrix respectively, and term $\ddot{u_g}$ represent the horizontal component of ground acceleration.

A four–nodes PLANE 42 element (structural 2D solids) plain strain, shown in Fig. 1 which available in ANSYS is used for both wall body and the soil of foundation and backfill modeling.

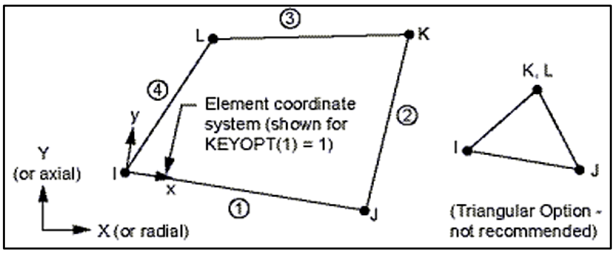

Fig. 1 PLANE42 Element Geometry [11]

Also, the interface of the soil–structure interaction problem can be discretize by making NUMMRGE command for all nodes and elements on the contact surfaces (interaction planes) or by CONTA172 Fig. 2 and TARGE 169 Fig. 3elements which making a SURF between them [11].

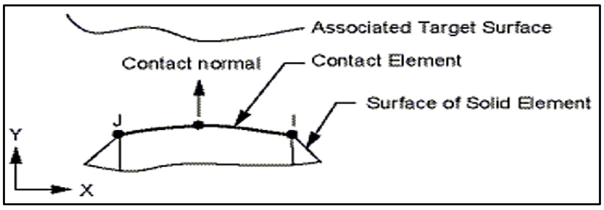

Fig. 2 CONTA172 Geometry [11]

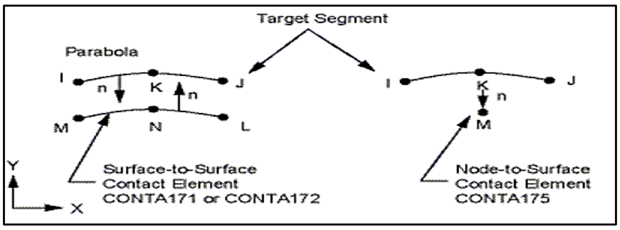

Fig. 3 TARGE169 Geometry [11]

b- Model of Random Soil Properties

The properties of this soil (C and $\emptyset$) could be modeled by using random field theory [12]. The soil cohesion, C, is assumed to be lognormally distributed with mean μ_c, standard deviation σ_c, and spatial correlation length θ_{lnc}ln . The lognormal distribution is selected because it is commonly utilized to represent nonnegative soil properties and also it has a simple relationship with the normal. A lognormally distributed random field is obtained from a normally distributed random field, $G_{lnc}(x)$, having zero mean, unit variance, and spatial correlation length θ_{lnc} through the transformation [12].

$$C(x) = \exp\{\mu_{lnc} + \sigma_{lnc} G_{lnc(x)}\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where x is the spatial position at which C is desired. The parameters μ_{lnc} and σ_{lnc} are obtained from the specified cohesion mean and variance by utilizing the lognormal distribution transformations,

$$\sigma_{lnc}^2 = \ln(1 + \frac{\sigma_c^2}{\mu_c^2}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\mu_{lnc} = \ln\mu_c - \frac{1}{2}\sigma_{lnc}^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

The friction angle, $\emptyset$, is assumed to be bounded both above and below, so that neither normal nor lognormal distributions are appropriate. A beta distribution is often used for bounded random variables, but a beta distributed random field simulation is cumbersome and numerically difficult. To keep things simple, a bounded distribution is selected which resembles a beta distribution but which arises as a simple transformation of a standard normal random field, $G_{\emptyset}(x)$ according to.

$$\emptyset(x) = \emptyset_{min} + \frac{1}{2}(\emptyset_{max} + \emptyset_{min})\left\{1 + tanh\left(\frac{sG_{\emptyset}(x)}{2\Pi}\right)\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where $\emptyset_{min}$ and $\emptyset_{max}$ are the minimum and maximum friction angles, respectively, and s is a scale factor which governs the friction angle variability between its two bounds. Fig. 4 shows that the friction angle $\emptyset$ changes when s changes, by going from an almost uniform distribution at s = 5 to a very normal looking distribution for smaller s.

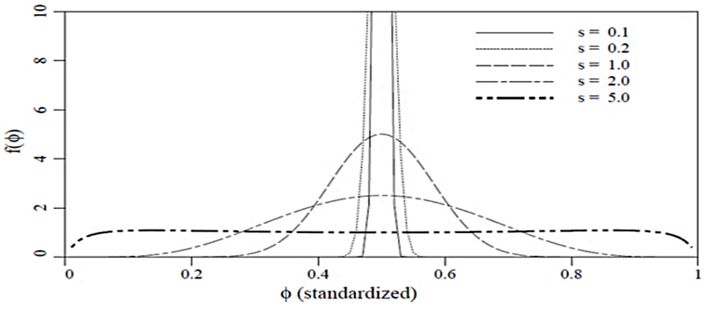

Fig. 4 Bounded distribution of friction angle normalized to the interval [0,1][12]

In this research the material properties of wall, backfill, and foundation could be summarized in Table 1, 2, and 3 where represent the properties of concrete, backfill soil and foundation soil, respectively:

Table 1: Dam Material properties

Properties Item	Density ρ (Kg/m^3)	Bulk modulus of elasticity E_s (Gpa)	Poison ratio υ	Note
concrete	2400	25	0.2	Homogeneous, isotropic, and elastic of concrete are assumed

Table 2: backfill soil material properties

Properties Item	Density ρ (Kg/m^3)	Bulk modulus of elasticity E_s (Mpa)	Poison ratio υ	Angle of internal friction φ	Note
soil	1600	200	0.3	30	Taken as sandy soil

Table 3: foundation soil material properties

Properties Item	Density ρ (Kg/m^3)	Bulk modulus of elasticity E_s (Mpa)	Poison ratio υ	Cohesive of soil C (Kpa)	Angle of internal friction φ	Note
Soil	1570	250	0.35	21	35	Taken as random soil

III. FORMULATION OF THE OPTIMIZATION PROBLEM

The scheme of the practical section of retaining wall with boundary condition of backfill and foundation that will be optimized by ANSYS can be given in Fig. 5

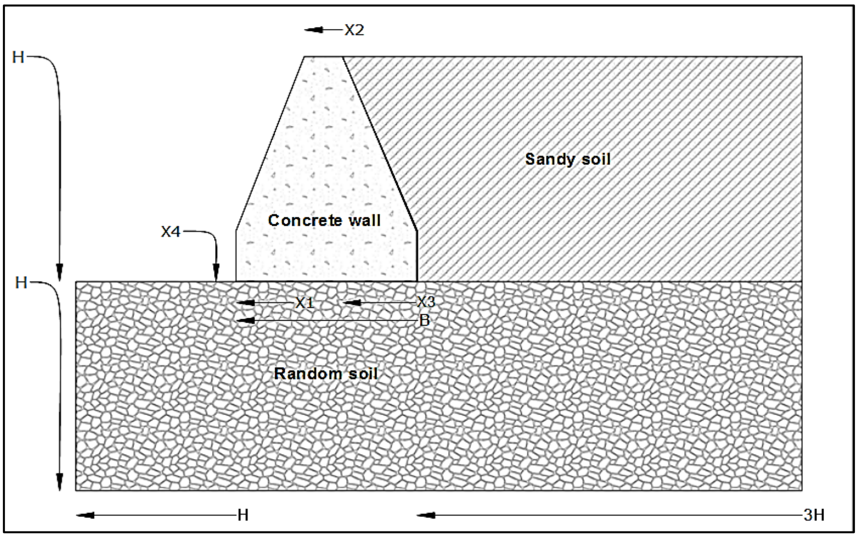

Fig. 5 Scheme of optimized MCGR wall model by ANSYS

In this section the optimization problem to be solved is explained. The design variables DVs, the parameters, the state variables SVs (constraints), the objective function OBJ and the optimum design process are presented.

a- Design variables (DVs)

The design variables of the problem are shown in Fig. 5. These are the width of the toe x_1, the top width of wall x_2, the heel width x_3 and the base thickness x_4. Table 4 shows the design variables and their corresponding lower limits.

Table 4: Design variables of the optimization problem and their lower bounds.

Design variables	Lower limit(m)
$\boldsymbol{x_1}$	0.4
$\boldsymbol{x_2}$	0.3
$\boldsymbol{x_3}$	0.4
$\boldsymbol{x_4}$	0.36

b- Constraints

The stability of the retaining wall include different modes of failure as [15], overturning, sliding, bearing capacity, and deep-seated sheet failures.

The factors of safety that should be realized for stability and safety after optimization process will be finished could be given as:

1. Against overturning, $FS_o = \frac{resistant\ moment}{driving\ moment} = \frac{\sum M_R}{\sum M_D} \geq 2$ ……………(9)
2. Against sliding, $FS_s = \frac{resistant\ force}{\text{horizontal driven forces}} = \frac{\sum F_R}{\sum F_D} \geq 1.2$ …………..(10)
3. Against bearing capacity of soil, $FS_B = \frac{q_{ult}}{q_{max}}$ ≥ 3 under static loads …………………(11)
   ≥ 1.5 under static and seismic loads

Where: $q_{uE} = CN_cF_{cs}F_{cd}F_{ci}e_c + qN_qF_{qs}F_{qd}F_{qi}e_q + \frac{1}{2}\gamma_{s2}B'N_\gamma F_{\gamma s}F_{\gamma d}F_{\gamma i}e_\gamma$ is Meyerhof's ultimate bearing capacity under seismic effect, [15]; B′= (B-2e), and e is the eccentricity; $q = \gamma_{sf}.D_f$; F_{cs}, F_{qs}, $F_{\gamma s}$ are shape factors; F_{cd} ,F_{qd} ,$F_{\gamma d}$ are depth factors; F_{ci} , F_{qi} ,$F_{\gamma i}$ are inclination factors; N_c ,N_q, N_γ are baring capacity factors; e_c, e_q, e_γ are the seismic factors; $q_{max} = \frac{V}{B}\left(1 + \frac{6e}{B}\right)$, where: V is a normal loads, B is width of foundation of retaining wall, and e is an eccentricity.

4. The tension crack should be avoided. The resultant force must passes through middle third of the dam width i.e. $e \leq \frac{B}{6}$

   Against eccentricity; $FS_e = \frac{B}{6e} \geq 1$ ………………..(12)

c- Objective function (OBJ)

An objective function is a mathematical expression that should be maximized or minimized in certain conditions and chosen as the volume, cost, weight, etc.in structural engineering [16]. The aim of this optimization problem is to determine the cross-section of the wall that minimizes the cost. Therefore, the objective function is chosen as the cross-sectional area, because the cost of the formwork and the scaffolding is mainly dependent on the wall's height. Thus, the wall with minimum cross-sectional area can be considered to have the lowest cost.

Min. area $F(x) = \frac{1}{2}(X_1 + 2X_2 + X_3) \times (H - X_4) + B * X_4$ ………………..(13)

Where: $B = X_1 + X_2 + X_3$

d- Optimization method

The ANSYS optimization procedure offers a few methods and tools that in different ways attempt to address the mathematical problems. In this research, the zero-order (sub problem) and first order optimization method are applied to minimized the objective function.

In these method, it will be shown that the constrained problem will transform into an unconstrained one that is eventually minimized [11]. The OBJ is written as:

Minimize $f = f(X)$……………………….(14)

Where : $f(X)$ is the function of variables design.

IV. LOADS OF OPTIMIZATION PROBLEM

In the design of concrete gravity retaining wall, it is essential to determine the loads required in the stability and stress analyses which are weight of wall (dead load or stabilizing force), lateral earth pressure (static and dynamic), surcharge load (live traffic load), earthquake forces (inertia forces) , and seismic load (ground motion excitation) .The forces of wind waves, silt, and Ice are ignored in this research. Fig. 6 shows these forces.

The seismic load is concerned according to the records of earthquake of Iraq for the period 1900-1988 which are the 1031 events ranging magnitudes between 3.0-7.4 on Richter scale. Therefore, the records is transformed as time-history force as shown in Fig. 7 by multiplying response acceleration by the inertia masses of the retaining walls.

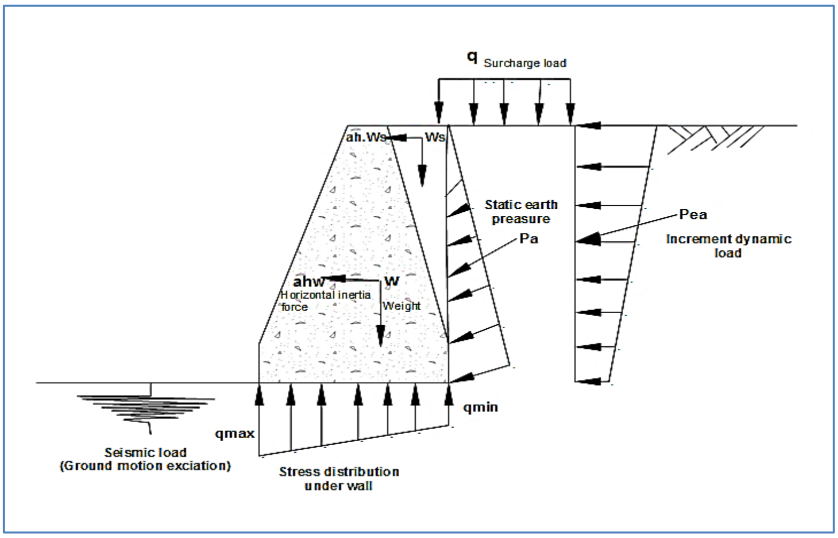

Fig. 6 Loads on optimization wall model

Fig. 7 Earthquake time-history force[17]

V.RUNNING OF OPTIMIZATION PROBLEM BY ANSYS

The scheme of ANSYS APDL steps of the modeling of the optimization process including wall–backfill–foundation interaction under seismic effect could be shown in Fig. 8

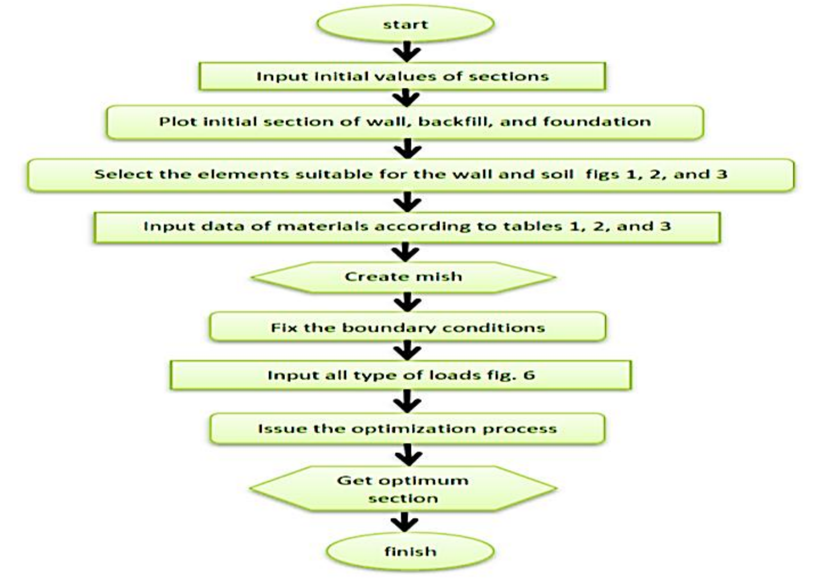

Fig 8 Scheme of ANSYS APDL modeling

The 2D finite element model of the optimization problem using ANSYS APDL is given in Fig. 9. It is shown from the figure the discretization of model and the interaction among wall-backfill-foundation interaction, the fixed boundary, and applied loads.

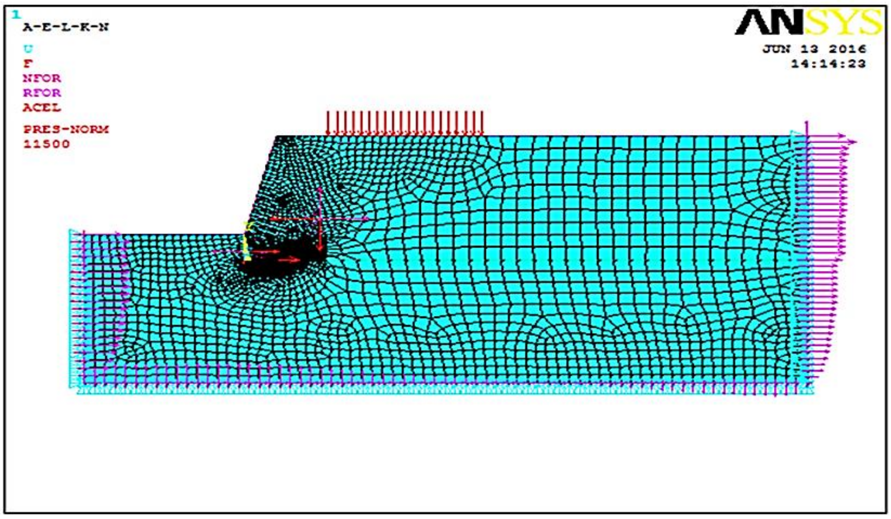

Fig. 9 Finite element discretization model of optimization process

In this research, the individual-accumulative optimization process is developed. This process aim to carry out each constraint individually through the optimization process. Therefore, the modified sections are provided to reach the final optimum section.

VI. NUMERICAL RESULTS AND DISCUSSIONS

Several physical and mechanical properties of the walls and soils are assigned to the functions of the optimization problem in order to obtain the optimum cross-section of these situations. The assigned parameters corresponding to the optimization problem are given in table 5

Table 5: The values of design parameters

N0.	Input Parameters	Sy.	unit	value
1	Height	H	m	3.0
2	Surcharge	q	kN/m^2	11.5
3	Unit weight of back fill soil	γ_{s1}	kN/m^3	16
4	Unit weight of foundation soil	γ_{s2}	kN/m^3	15.68
5	Internal friction of back fill soil	$\emptyset_1$	degree	30
5	Internal friction of foundation soil	$\emptyset_2$	degree	35.14
6	Cohesion of foundation soil	C	Kpa	20.96
7	Inclination of back fill slope	α	degree	0
8	Wall soil angle friction	δ	degree	$0.5\emptyset_1$
9	Unit weight of concrete	γ_c	kN/m^3	24
10	Horizontal seismic coefficient	K_h	D.L	0.2
12	Safety factor of sliding	FS_s	D.L	1.2
13	Safety factor of overturning	FS_o	D.L	2
14	Safety factor of Bering capacity	FS_b	D.L	1.5* 3**
15	Safety factor of eccentricity	FS_e	D.L	1

*safety factor for seismic bearing capacity

** safety factor for static bearing capacity

After the optimization process is conducted, the initial, infeasible, and optimum sections of gravity retaining wall are given in Table 6. The solution of the example was found as shown in Table 6 by using Zero-order (subproblem) method.

Table 6: the result of wall sections from optimization process

Design Variables	Sy.	Initial Section	Infeasible Section*	Optimum Section*	Optimum Section**
Width of the toe	x_1	0.60000	0.73729	0.73147	0.86204
width of top	x_2	0.30000	0.34314	0.35124	0.35912
Width of the heel	x_3	0.60000	1.1101	1.1228	1.1219
thickness of the base	x_4	0.60000	0.38845	0.39863	0.49390
Min Area of the section	F(x)	3.0600	4.1593	4.2047	4.5432
Safety factor of sliding	FS_s	1.1979	1.2323	1.2424	1.3313
Safety factor of overturning	FS_o	1.2657	2.0909	2.1142	2.3225
Safety factor of Bering capacity	FS_b	1.4788	2.0009	2.0271	4.2787
Safety factor of eccentricity	FS_e	0.46080	0.97765	$0.9983 \cong 1$	1.2032

*safety factor for seismic bearing capacity

** safety factor for static bearing capacity

In this table, the initial section is an unsuitable on because both stability and safety are not satisfied; while infeasible section pass in some requirements and failed in others. To overcome this problem, an individual-accumulative optimization technique is developed through optimization process. The area of infeasible section* of the wall is increased by 35.92% to pass factors of safety except eccentricity (i.e. tensile crack e < b/6); while the area of feasible section (optimal section*) of wall is increased by 37.41% to pass through all factor of safety. Also, the area of optimal section** is increased by 48.47% to pass through all factor of safety.

For comparison reason, both the zero-order optimization method (Subproblem Approximation method) and first-order optimization method are investigated by using the same objective and constraints functions, input data of material properties and same initial point stated in table 5, the final results in Table 7 shows that the optimum design results are fundamentally the same for both the zero-order optimization method and the first-order optimization method, there are different in optimization efficiency.

Table 7: The optimization result of comparison between zero-order and first-order optimization methods

Design Variables	Zero-order method	First- order method
Min Area of Section F(x)	4.2047	4.2016
Width of the toe (x_1)	0.73147	1.2246
width of the top (x_2)	0.35124	0.30000
Width of the heel (x_3)	1.1228	0.62087
thickness of the base (x_4)	0.39863	0.57797
$\boldsymbol{FS_s}$	1.2424	1.3301
$\boldsymbol{FS_o}$	2.1142	2.0587
$\boldsymbol{FS_b}$	2.0271	2.2273
$\boldsymbol{FS_e}$	$0.9983 \cong 1$	1.0029

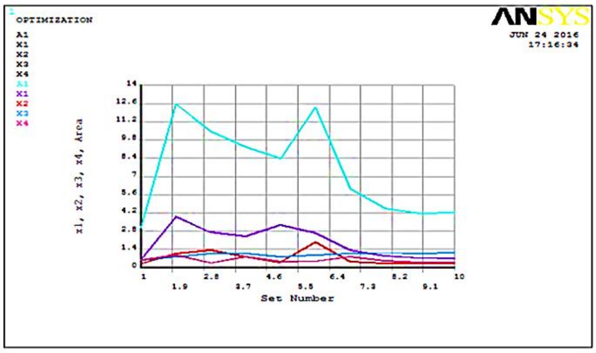

Fig. 10 Optimum curves of DVs and OBJ by zero-order method

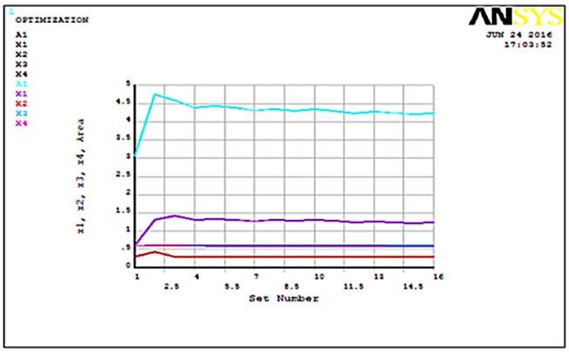

Fig. 11 Optimum curves of DVs and OBJ by first-order method

As shown in Fig. 10, the design variables continuously be changed, the objective function does not always meet the relevance condition, but rather the decay is wavering, and the general pattern is as yet keeping on drawing nearer the most optiml soluetion. Since in the zero-order technique, curve fiting is applied rather than the genuine objective function and constrint function, there exist certeain approximtion, which is an imprtant featur based on ANSYS. Fig. 11 reflects that the first-order method can better accomplish the optiml solution by diminishing after reaching the vertex along the path of the objective function. Generally, the first-order technique is more economic and effective than zero-order technique.

For the purpose of studying the effect of the wall height of the optimal section taken several heights to be investigated as shown in table 8. The heights of the walls are chosen to be 3.0, 4.0 and 5.0 m, because gravity retaining walls are generally used for heights of less than 6 m. Also, other parameters $(\emptyset_1, \emptyset_2, C, \gamma_{sb})$ are selected to study there effects as shown in Figs. 12 to 15.

Table 8 Results of several heights of gravity retaining wall

Design Variables	H=3m	H=4m	H=5m
x_1	0.73147	0.99455	1.4953
x_2	0.35124	0.30554	0.30517
x_3	1.1228	1.4949	1.8831
x_4	0.39863	0.88550	1.0023
F(x)	4.2047	7.3033	11.665
FS_s	1.2424	1.4058	1.3595
FS_o	2.1142	2.1195	2.3163
FS_b	2.0271	1.7059	1.5088
FS_e	$0.9983 \cong 1$	1.0461	1.2139

The percent of increment in the value of the height from 3(m) to 5(m) which is equal to (66.66%) will increase the optimum cross-sectional area in a percent of (177.27%).

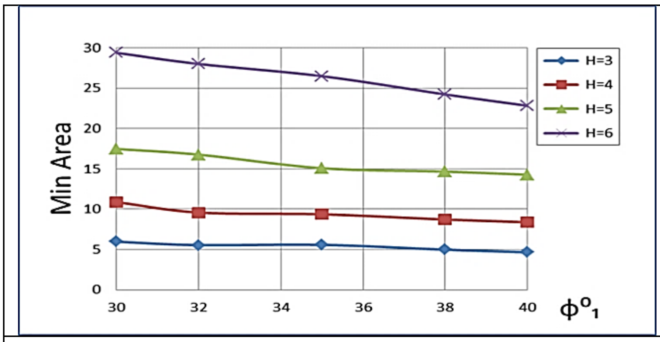

Fig.12: Effect of internal friction angle of backfill on minimum Area of the section

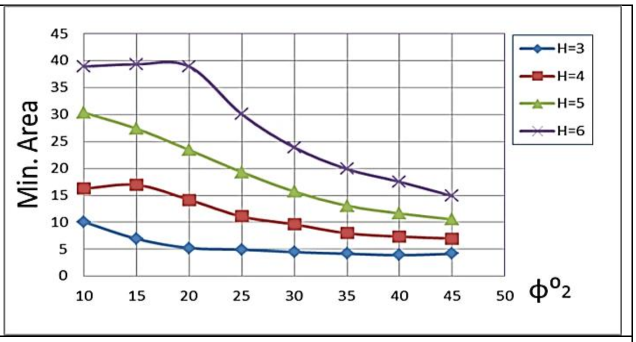

Fig. 13: Effect of internal friction angle of foundation soil on minimum Area of the section

Fig.12 shows the relationship between Min Area. (minimum cross-sectional area) and $\emptyset_1$(angle of internal friction of backfill soil), when $\emptyset_1$ increases, Min Area decreases. The increase in the value of $\emptyset_1$from 32° to 40° which equal to 25% decreases Min Area in a percent of (19.13%) at height equal to 3(m). This is because that the amount of active earth pressure coefficient of seismic and static K_{AE} is changed from (0.6317047 to 0.5324942) for $\emptyset_1$of 32° and 40° respectively.

Fig.13 showed relationship between minimum cross-sectional area with internal friction angle of foundation soil $\emptyset_2$, when $\emptyset_2$ increases, the Min Area decreases. The percent of increase in the value of the $\emptyset_2$ from 15° to 30° which are equal to 100% decreases Min Area in a percent of (55.22%) at height equal to 3 (m), this is because that the higher value of $\emptyset_2$ gives the higher resistance against sliding and bearing failure modes.

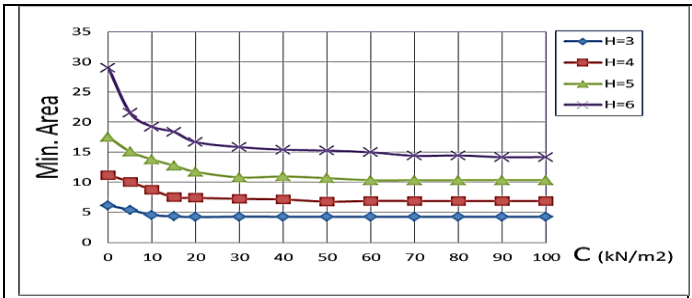	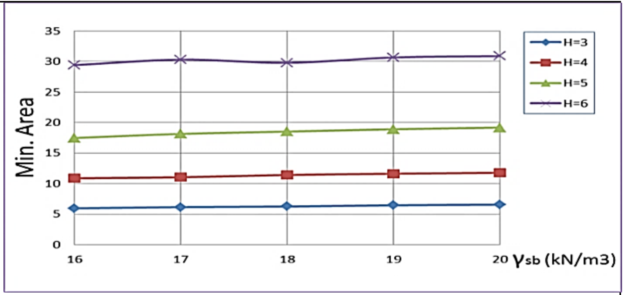
Fig. 14: Effect of cohesion of foundation soil vs. minimum area of the section	Fig. 15: Effect of unit weight of backfill soil vs. minimum area of the section

Also, Fig.14 shows the effect of cohesion of soil foundation (C) on the minimum cross-sectional area. The percent of increase in the value of (C) from 10 kN/m^2 to 20 kN/m^2 which equal to 100% will decrease Min. Area in amount of (8.05%) for H=3m. This parameter is very important in design to satisfy the resistance force against sliding failure mode which is mostly control the design, it is better to use foundation soil that has a high value of C.

Fig. 15 shows the relationship of unit weight of backfill soil (γ_{sb}) and minimum cross-sectional area. The increment in (γ_{sb}) value from 16.0kN/m^3 to 20.0kN/m3, which equal to 25%, will increase Min. Area in amount of 10.04% for H=3m.

VII. CONCLUSIONS

1. Through the gathering of optimization module (/OPT) and APDL, the optimum reuse examination is quick and the results are dependable and sensible.
2. The initial section of Retaining wall that is provided according to initial variables is not representing the optimum section because of falling of factors of safeties.
3. the first-order optimization method is more economic and effective than the zero-order (sub problem) optimization method, on the grounds that the first-order method can better accomplish the optimum solution by diminishing along the path of OBJ, On the other hand the zero-order method, the DVs constantly variation, and the OBJ does not generally meet the relevance situation.
4. The factor of safety against eccentricity (as external stability) is the most important safety factor compared with the other factors followed the factor of safety against sliding, against bearing capacity and for overturning.
5. Among the soil properties, it has been found that the cohesion of foundation soil is more important than the others. The angles of internal friction of backfill soil and foundation soil also highly affect optimum section, while unit weights of backfill soil have little effect on optimum section.

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