12 Mar 1991, 10:30 am - 12:00 pm

Study and Design of Earth Reinforced Structures Under Dynamic Efforts

Ammar Dhouib
Fondasol, Paris, France

Grant Knochenmus
Terrasol, Paris, France

Proceedings: Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, March 11-15, 1991, St. Louis, Missouri, Paper No. 4.5

Study and Design of Earth Reinforced Structures Under Dynamic Efforts

Ammar Dhouib
Dr, Engineer, Fondasol, Paris (France)

Grant Knochenmus
Engineer, Terrasol, Paris (France)

SYNOPSIS : This paper aims at giving a synthesis of recent design methods of earth reinforced structures submitted to dynamic actions.

In the first instance, we intend to tackle a comparative study on scaled - down models and on real works in reinforced earth. This study is led by the finite elements method.

Secondy, we propose a simple method to design reinforced earth structures.

1. INTRODUCTION :

The studies and techniques of reinforced earth structures have developed further and further over the last few decades. So far, a large part of the research in this field has been devoted to the static aspect (SCHLOSSER et al 1973, JURAN et al, 1980). The study of the dynamic aspect only started a few years ago.

2. BEHAVIOUR OF REINFORCED SOIL UNDER STATIC AND DYNAMIC EFFORTS :

The present study aims at following (DHOUIB et al, 1987) :

- the evolution of static and dynamic tensile forces in the strips,
- the distribution and the locus of maximum static and dynamic forces.

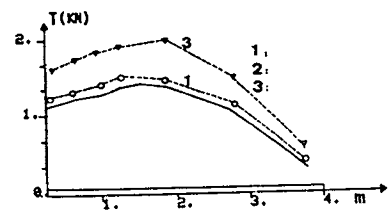
We note that the static values are détermined by non-linear analysis whereas the dynamic values are calculated by a linear equivalent approach (LYSMER, 1975) for different ratios m (equal to horizontal a_h over gravity g).

When the reinforced earth wall is submitted to dynamic actions, we note (RICHARDSON, 1974 ; CHIDA et all, 1980) :

i - A dynamic tensile increment Td is developed in the strips and it increases when ratio m increases. So far, the whole tensile force T, to take into account in the dynamic design, results in the static component T_s and the dynamic part Td. We can simply write :

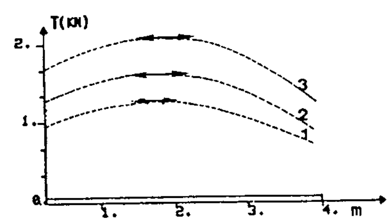
$$T = Ts + Td,$$

We present the evolution of T relating to m on figure 1. Figure 1 a shows the experimental measures and figure 1.b illustrates the theoretical values.



a - Experience (CHIDA, 1980)

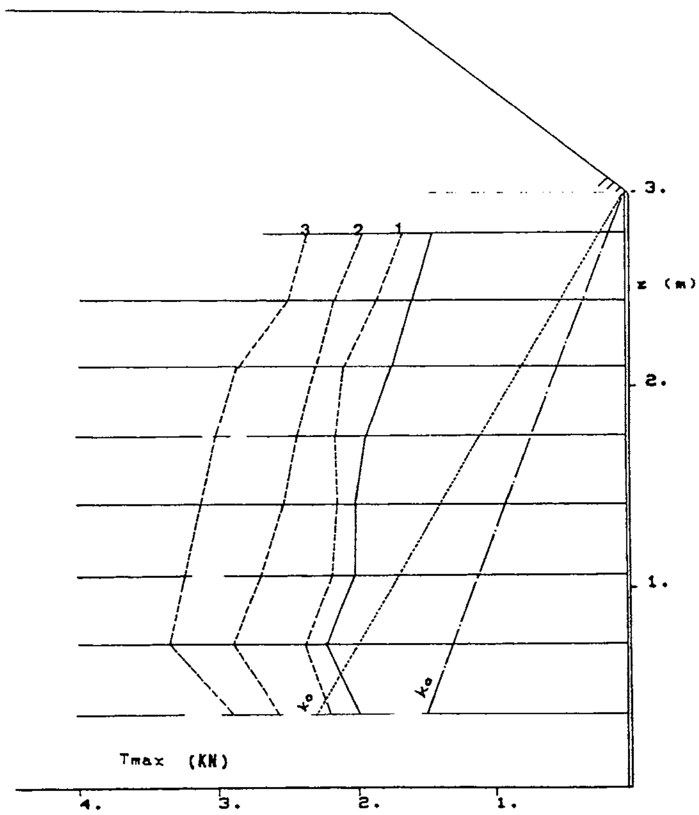
_____ static values
----- static + dynamic
1 : m = 0,10
2 : m = 0,25
3 : m = 0,40



b - Finite elements calculation

FIGURE 1 : Evolution of tensile force T in the strip n° 7

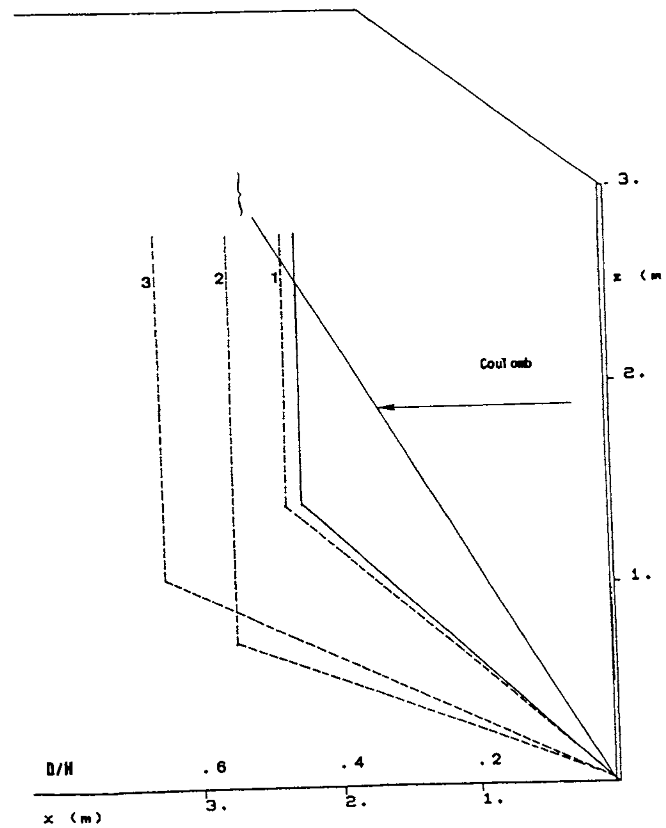
ii - The distribution of maximum static and dynamic forces T_{max} as function of height z is modified in quantity. We simply observe that T_{max} increases when ratio m increases. Figure 2 gives the theoretical evolution of T_{max} for the same example previously studied.



_____ static values

----- static + dynamic
m = 0,10
m = 0,25
m = 0,40

FIGURE 2 : Distribution of maximum static and dynamic tensile forces Tmax.



_____ static values

----- static + dynamic
m = 0,10
m = 0,25
m = 0,40

FIGURE 3 : Locus of maximum static and dynamic tensile forces Tmax.

iii - By examining the evolution of the whole tensile forces T (given on figure 1), we can observe that the maximum value T_{max} is located beyond its static homologue. The maximum goes beyond the latter whenever m increases. Figure 3 illustrates the locus of maximum static and dynamic tensile force for different given ratios m.

In summary, we can conclude :

i - The tensile force increases in the strips under dynamic actions effect.

ii - The locus of the maximum tensile force is modified,

iii - The active zone width is increased.

The important results require the taking into account of the dynamic actions to design the reinforced earth wall. It's the subject of following paragraphs.

3. CURRENT STATE OF KNOWLEDGE IN THE DYNAMIC DESIGN OF REINFORCED SOILS :

The recent methods are (DHOUIB, 1987) :

i - MONOBE and OKABE Theory : this method combines static and dynamic actions P by means of coefficient K. The pressure behind the reinforced wall is an increasing function of depth z. It's written :

$$P = \gamma . z^2 \ K/2$$

ii - RICHARDSON method : it adds a lateral dynamic pressure P_d to lateral static pressure P_s. The first is given by :

$$P_d = \frac{9}{8} . ko. \gamma . z^2 . m$$

iii - Pseudo-static method : it introduces an inertia force P_I proportional to an active zone weight W. In the logarithmic spiral hypothesis (0,3 x wall height H), P_I is expressed :

$$P_I = m. W = \frac{9}{4} m. \gamma . H^2$$

iv - SEED ans MITCHELL Method : this method is a simple synthesis of the last two methods. It considers both the inertia force P_I and the lateral dynamic pressure Pd as is shown Figure 4.

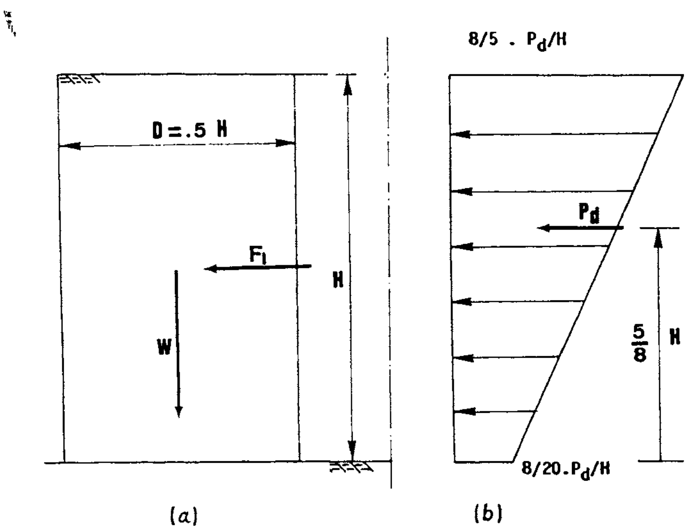


FIGURE 4 : Dynamic actions (SEED and MITCHELL method)
a - Inertia force
b - Lateral pressure behind the reinforced wall

A critical analysis of these various methods leads us to formulate the following statements :

- The MONOBE and IKABE theory omits the inertia force and does not clarify the lateral dynamic pressure.
- The Pseudo-static method takes into account neither the widening of the active zone nor the lateral pressure of the backfill behind the wall.
- The SEED and MITCHELL design method has the advantage of introducing both the inertia and dynamic pressure forces. However, it overstimates the width of the active zone (D = 0,5 H) to determine the inertia force.

4. REFLECTIONS AND MODIFICATIONS IN CURRENT DESIGN :

For the purpose of a design proposal, we envision works with quasi-inextensible strips, and a design adapted to both "internal" and overall stability.

The parametric study (DHOUIB et al, 1987) and the resultats obtained on three-dimensional down-scaled models (RICHARDSON) show that the dynamic tensile force Td is proportional to a static tensile force T_S. We simply note that $Td = m. T_S$,

The criterion of failure by strips breakage is written :

$$T = (1 + m) \ T_S \quad R_T,$$

The criterion of failure by slipping can be expressed in a two-prong equation :

$$\begin{cases} T_S < R_g \\ T_d < R'_g \end{cases}$$

With $R'_g < R_g$

R_T and R_g (or R'_g) are respectively strip resistances of failure by breakage and by slipping.

In the case of works reinforced by quasi-inextensible strips, observations on the RICHARDSON tests and finite elements calculations (DHOUIB et al., 1987) allow us to retain the logarithmic spiral hypothesis (D = H/2). In this framework, we can consider :

i - A widening of the active zone, or :

$$D' = D + d = (1+m).H/2$$

ii - A deepening of this zone, or :

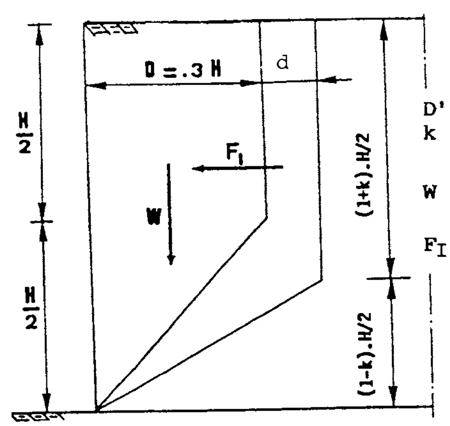
$$(1+k).H/2 = (1+2/3 \ m).H/2$$

The inertia force is thus calculated (see Figure 5).

$$F_I = m. W = \gamma . D'.H. \ (3 + k)/4$$

when m < 0,10

$$F_I = \ . H^2 \ (2 + 3 \ m)/6$$



$D' = D+d = (m+1) \ H/2$

$k = \frac{2}{3} m$

$W = \gamma \cdot \frac{D' \ H}{4} . (2k + 3)$

$F_I = m. W$

FIGURE 5 : CALCULATIONS OF THE INERTIA FORCE (LOGARITHMIC SPIRAL)
PSEUDO-STATIC METHOD MODIFIED (DHOUIB et al, 1987)

To give a comparative synthesis of different methods, we chart the inertia force (over $\gamma.H^2$) as a function of m. It is worth noting that the repartition of the inertia force that we propose falls between that of the pseudo-static and that of SEED and MITCHELL method (see figure 6).

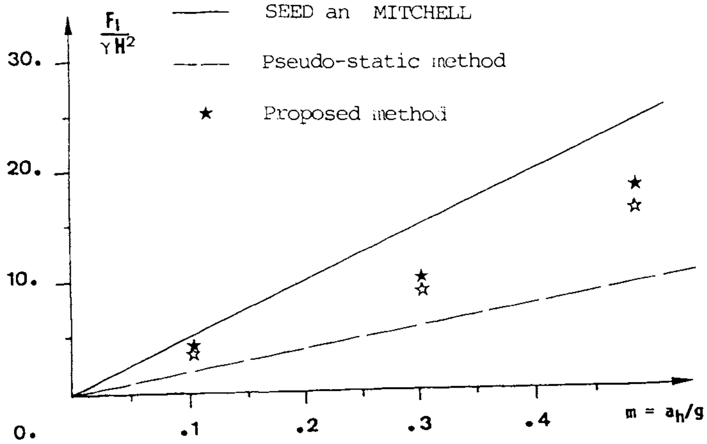


FIGURE 6 : Comparative evolution of the inertia force $F_I/\ \ H^2$

By examining the distribution of the dynamic latéral pressure as a fuction of m, we observe that it peaks at a distance of H/2 behind the facing (and not at m.H/2). This justifies an analogous distribution to that proposed by SEED ans MITCHELL.

5. CONCLUSION :

From experimental findings and comparative study, led by finite elements method, we note that the behaviour of reinforced earth is modified under dynamic actions. We retain :

. an increasing of the tensile force in the strips,

. a widening of the active zone, and

. a deepening of this zone.

After a concise study of the current design methods we propose a simple design method based on the pseudo-static and SEED and MITCHELL Methods. The comparative study ends this design proposal.

REFERENCES :

BASTICK M., SCHLOSSER F. "Comportement et dimensionnement des ouvrages en terre armée", C.R. Génie Parasismique, Paris (1985).

CHIDA S., MINAMI K.,"Reinforced Earth Technique : its Outline and Laboratory Test", August (1980).

DHOUIB A. "Contribution à l'étude du comportement des sols renforcés sous chargement statique et dynamique : Application aux ouvrages en terre armée", Thèse de Doctorat, LILLE (1987).

DHOUIB A., ROBINET J.C. : "Domains of Behaviour and Behaviour of reinforced soils" ; International Conference Series on Advances in Numerical Methods in Engineering : Theory and Applications", NUMETA (1987).

JURAN I. : "Comportement et dimensionnement des ouvrages en sols renforcés", Thèse d'Etat, Paris VI, Septembre (1987).

RICHARDSON G.N. : "The Response of Reinforced Earth walls to Vibratory Loading", Thesis for the Degree Master of Sciences in Engineering, Los Angeles, (1974).

SCHLOSSER F., NGUYEN THAN LONG : "Comportement de la Terre Armée dans les ouvrages de soutènement", Congrès de Mécanique des Sols, Moscou, (1973).