RETAINING WALLS IN SEISMIC AREAS

by

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SYNOPSIS

The dynamic earth pressures on retaining walls due to seismic disturbances are predicted by a general formulation and finite element solution. Considerations of preliminary compaction suggest that the wall-soil interface will remain continuous in the vibration. Subsequent analysis indicates a wide range of dynamic pressures and distribution depending upon geometry and material properties. One important conclusion is that present static amplification formulas have very little validity.

INTRODUCTION

Several methods are available to estimate the lateral earth pressure behind retaining walls due to earthquake loading. These include the dynamic amplification of an existing static pressure formula, experiments using vibration tables, and recently the utilization of the theory of elasticity. These do not, in general, consider the separate physical and mechanical properties of the wall and soil and thus neglect their interaction.

The dynamic lateral earth pressure will be affected by the wall motions, backfill characteristics, and the nature of the given vibrations. For a complete solution of the problem, it is essential that these factors be properly included.

This paper deals with the formulation of a mathematical model for a wall-backfill foundation system in which the physical and mechanical properties of both the soil and the structure are considered in the evaluation of the vibrational characteristics and seismic response. The method of solution used is the finite element method, which leads to computed values of stress, strain and deformation within the system.

FINITE ELEMENT MODEL

As the finite element model idealizes a continuum as a system of finite elements interconnected at a finite number of nodal points, the moduli and unit weight can be varied for different elements to represent different properties. Thus it is well suited to the study of the interaction problem between the soil, the wall, and the foundation which have different material properties.

The model studied here is composed of a retaining wall fixed at its

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base, backed by a horizontal elastic stratum which rests upon a rigid but movable base (e.g. rock). The model has been idealized by a number of interconnected rectangular finite elements, and the number of elements which give a reasonably accurate solution has been determined. A typical problem is considered as composed of the series of elements shown in Fig. 1. The material comprising the wall-soil system is assumed to be linear and elastic with internal viscous damping characteristics.

LOADING

Drenick[I] has suggested that the choice of a sample earthquake can be approached by seeking the least favorable among all foreseeable *excitations. This is different from the usual approach which imposes a* "typical" earthquake onto a structure. The Drenick approach is ideal in this comparative parametric study because it makes the results generally useful and not applicable to one situation only.

It is assumed in this work that the dynamic loading will have an input acceleration of a maximum of 0.1g. To conveniently characterize the nature of the excitation, it is assumed to be sinusoidal. Assuming that the frequency of the excitation is not bounded, then the maximum response will occur when the frequency of the excitation equals the natural frequency of the system. This means that all cases studied here will have sinusoidal input accelerations with a maximum of 0.1g. and with a frequency equal to the natural frequency of the system. Thus, a comparison between the different cases, each in its least favorable aspects, can be made. Also, only the first mode shape is considered for each case solved because the first mode (a shear mode) gives the maximum pressure on the wall and makes for a clearer comparison.

DYNAMIC PRESSURE

The oscillatory nature of the dynamic problem will ensure separation between wall and soil unless the residual static compression is greater than the dynamic tension and hence interface continuity is maintained. Thus, knowing the static pressure is a prerequisite to determining the behavior of the system. These static pressures are dependent on the compaction procedures. The residual lateral pressure developed by compaction has been computed. It has been found that compaction develops wall pressures and deflections many times greater than when the soil is uncompacted. This residual pressure in values and distribution can accommodate such dynamic tension pressure and maintain interface continuity.

Uncompacted loose soil will be compacted in vibration of the backfill soil. This produces settlement of the ground surface and the linear assumption used in this analysis will not be valid.

[I] Drenick, R. F., Model-free Design of Aseismic Structures, Journal Eng. Mech. Division, Proc. A. S. C.E., Vol. 96, No. EM4, 1970.

PARAMETER STUDY

Wall Flexibility:

Three different wall thicknesses of 1.25 ft., 2.0 ft., and 4.0 ft. were used. The backfill soil for all cases has a length of 10H; H is 20 ft. The damping ratio is 20% for all cases. The natural frequency of the system was found to increase a small amount with the increase in the wall thickness. It was found that the pressure on the 4 ft. wall approached the case of an infinitely rigid wall, and the corresponding deflection was very small compared to the 1.25 ft. thick wall. On the other hand, for the 1.25 ft. wall the pressure was markedly decreased near the upper part of the wall and increased near the lower part of the wall (Fig. 2). Thus a redistribution of the pressure, causing a lowering of the point of application of the resultant force occurred. It can be concluded the more flexible a cantilever wall,the less moment it will be subjected to during dynamic excitation.

Soil Modulus:

The effects for four soil stiffnesses were studied. The wall was 2.0 ft. thick for all cases. It was found that the increase in the soil stiffness resulted in an increase in the natural frequency. This change was significant and influenced the response. It was concluded that the stiffer the soil, the less deflection the wall will have in the dynamic case, and the less moment it will be subjected to.

Length of Backfill:

Backfill lengths of 2H. 5H and 10H were used. The wall and soil properties were the same for all cases. It was found that as the backfill length increased, the natural frequency decreased; the dynamic pressure decreased with an increase in the backfill length. For the 2 and 5H cases, the dynamic pressure and deflection were almost the same, but for the 10H case the pressure was reduced by about 40%. The system behaved as one with infinite length of fill for fills greater than 10H. In this case, the dynamic wall pressure was unaffected by the fill length.

Shape of Backfill:

Two cases were solved, one for a backfill in the shape of a horizontal soil layer and the other with a backfill in the shape of a wedge. It was found that the shape of the backfill has a marked effect on the natural frequency. The dynamic pressure due to a soil wedge was about 60% smaller than for a soil layer.

In summary, the lower bound of the dynamic pressure was for a backfill in the shape of a wedge and the upper bound was the pressure of a backfill with a length of 2 to 5H. The value of the pressure for the upper bound was about five times the lower bound. This means that no general rules can be offered for determining the dynamic pressure at this stage of knowledge. Each problem must be examined on its own merits, and all its characteristics must be represented in the solution.

CONCLUSION

Retaining walls in seismic areas will be subjected to a dynamic pressure, which will vary markedly depending on the properties of both the soil and the wall, their geometry, and their loading. The behavior of the system will depend on the existing static pressure which is a function of the compaction. Thus the solution of a problem requires first the prediction of the existing static pressures and then, by using a method which could introduce all the characteristics of the problem, the determination of the dynamic pressure. Finally, the dynamic and static pressures must be summed algebraically.

The results obtained give no encouragement for the continuing use of the static amplification procedures.

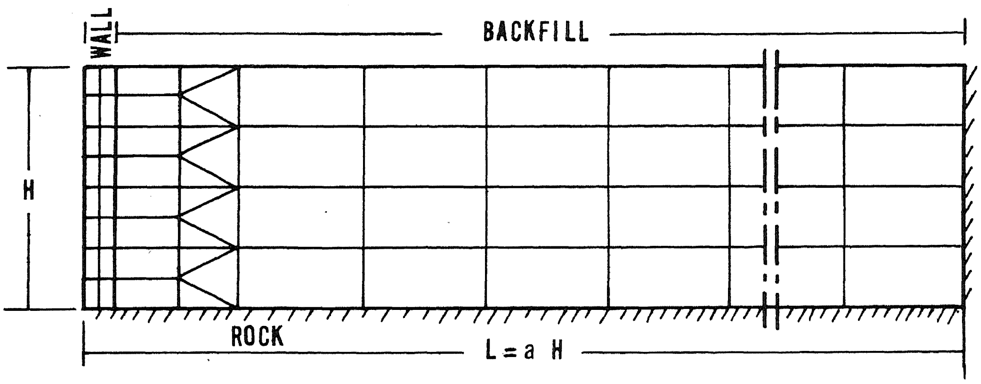

FIG. 1 FINITE ELEMENT IDEALIZATION OF SOIL-WALL SYSTEM

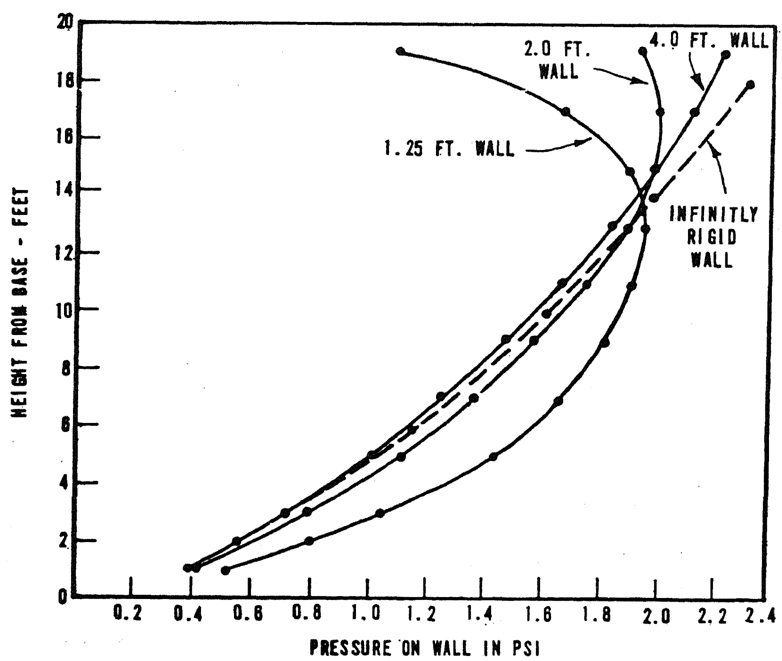

FIG. 2 EFFECT OF FLEXIBILITY OF THE WALL