V - 259 Nonlinear Prediction of Interactive Response of In-Plane Structures and Soil Continuum Under Shear

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Introduction

The soil and RC structures are basically designed as independent systems through the dynamic and static earth pressure. This is attributed to the insufficient knowledge concerning the interaction between the soil and RC structures especially in the elasto-plastic stages. Several researches were undergone on underground structures subjected to seismic loading [4]. In general, these researches considered lower stress levels close to the elastic range. In order to study the real behavior of underground structures for high nonlinearity in shear, the finite element program for nonlinear soil is combined with nonlinear RC finite element program "WCOMR" [3] to predict the behavior of RC structures surrounded by soil continuum. It was clearly proved through analytical results that the predictions of the nonlinear response of soil and RC structures under shear have good agreements with the results of experiments [1].

Description of The Program

The Computer Program "WCOMR" [3] is used for RC structures. It provides deformations, stresses, crack development and failure modes (crushing of concrete and reinforcement yielding) at each load step under reversed cyclic loads. In "WCOMR", the nonlinear constitutive laws of RC, which consists of the bond between reinforcement and concrete, compressive characteristics of concrete between cracks, shear transfer along cracks, and embedded set of reinforcing bars, is installed. The constitutive laws formulated with respect to the smeared crack RC model was systematically verified, as a result of which laboratory experimentation for in-plane members and structure can be replaced by numerical simulation [3].

The nonlinearity of soil is considered in terms of generalized path-dependent shear stress-strain (G) [2]. The volumetric change term, which is represented by bulk modules (K), is considered as elastic behavior. The soil element was estimated by combining both terms independently. Geometrical implications of the Massing's law [2], defining a relationship between the shapes of skeleton and hysteretic curves of nonlinear soil, are explicitly formulated as below, and shown in Fig.(1).

$$\sigma_{ij} = 2G\left(\varepsilon_{ij} - \frac{1}{3}\sum_{k=1}^{3}\varepsilon_{kk}\right) + 3*K\left(\frac{1}{3}\sum_{k=1}^{3}\varepsilon_{kk}\right) \qquad \text{where: } G = f(\bar{J}_2)$$

$$\bar{J}_2 = f(\varepsilon_{ij} - \varepsilon_{ij}^{(l)}) \qquad \text{(path-dependent)}$$

σ and ε represent the stress and strain along local axes, i and j. $\varepsilon_{ij}^{(l)}$ represent the strain at the turning point. $\bar{J}_2$ is the second strain deviator invariant.

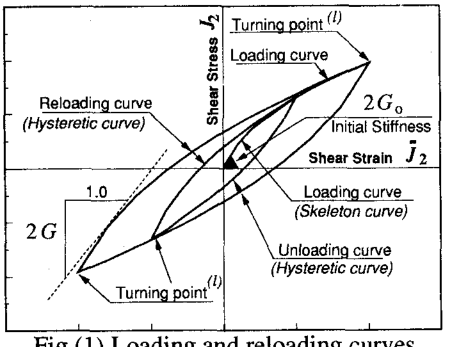

Fig.(1) Loading and reloading curves for the soil model

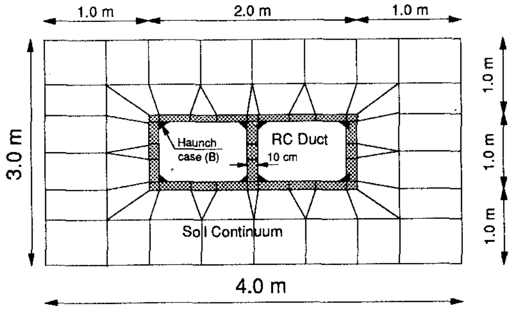

Fig.(2) 2-D finite element mesh of entire system

Experimental Outline

Two experiments [2] were carried out for RC duct surrounded by soil under reversed cyclic shear force as shown in Fig.(2). The thickness of RC wall is 10 cm for both cases But in case (B) the haunch is used at the corners of the duct to increase the stiffness of the duct. The total force acting on the system, the horizontal displacement of soil and RC were measured.

Description of The Analysis

The finite element mesh, composed of eight node quadrilateral elements, is used as shown in Fig.(2). The analysis is carried out for same reversed cyclic loading as was done in the experiments.

Discussion

Comparison between the experimental and analytical results for the mean shear displacement angle of RC (δ_d/h) with respect to the mean shear displacement angle of soil (δ_s/H) for both cases is shown in Fig.(3). Comparison between the experimental and analytical results for load-displacement relationship (F - δ_s) is shown in Fig.(4). These figures are drawn for envelope curve of the cyclic loading to simplify the comparison. Only one cyclic load at δ_s = 2.0 cm is shown for comparing the unloading and reloading behavior. The analytical results of mean shear displacement angles have perfect prediction with experiments. But in case of load-displacement relation, the analytical results successfully predicts the experimental results of case (A). But in case (B), the total force (F) is less in case of the analytical results for high displacement level.

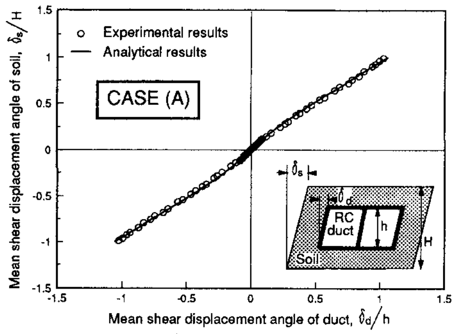

Fig.(3-a) Comparison between test and analytical mean shear displacement angles

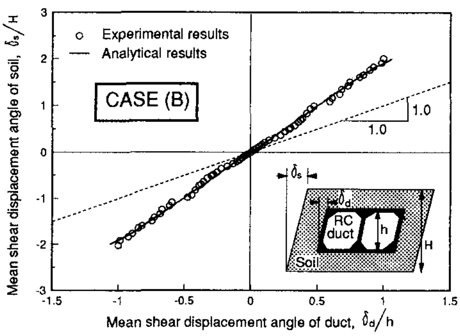

Fig.(3-b) Comparison between test and analytical mean shear displacement angles

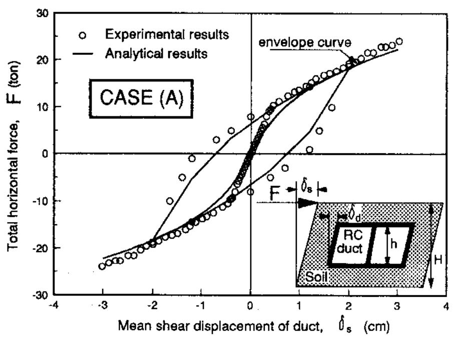

Fig.(4-a) Comparison between test and analytical load displacement relation

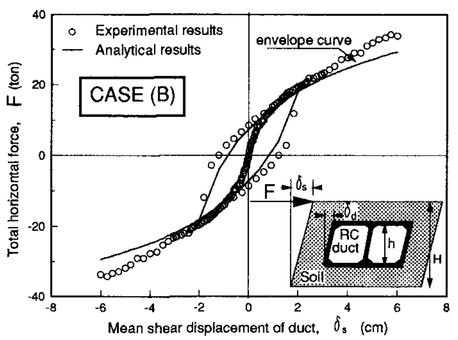

Fig.(4-b) Comparison between test and analytical load displacement relation

Conclusions

From the above discussion it can be concluded that the comparisons of the results of experiments and the above model of soil and RC show a fairly good agreement. By using this model, the response of RC in-plane structures surrounded by soil continuum under reversed cyclic loads and residual deformation can be predicted.

References

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