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Simplified Inverse Building Stiffness Design for Nonlinear Surface Ground

○I.Takewaki, N.Fujii, K.Uetani

1. Introduction

An efficient stiffness design method for building structures is proposed in which nonlinear surface ground amplification and soil-structure interaction are taken into account in terms of equivalent linearization (see Fig.1). A sway-rocking shear building model with appropriate ground impedances derived from both finite element analysis and the equivalent linearization technique is used as a simplified design model and super-structure stiffnesses satisfying a desired stiffness performance condition are determined for a ground-surface response spectrum. The ground-surface response spectrum is transformed from the design response spectrum defined at the upper surface level of the engineering bedrock via the equivalent linearization technique and the one-dimensional wave propagation theory. In the process of the super-structure stiffness design, an improved and advanced inverse formulation is developed which regards the fundamental natural frequency of the interaction model as a principal design parameter. The reliability and accuracy of the proposed stiffness design method are examined by a two-dimensional finite element model. Inelastic response characteristics of the so-designed model are also investigated.

2. Design Problem

The design problem for the damage-initiation-limit level motion may be stated as : Find the stiffnesses of the super-structure that exhibits a specified distribution of the maximum interstory drifts to the design earthquake at the engineering bedrock surface.

3. Soil nonlinearity and equivalent linearization based on a new statistical approach

4. Foundation impedance

5. Advanced inverse stiffness design method

6. Design examples

7. Accuracy investigation

8. Response evaluation for safety-limit level motion

9. Conclusions

1. The proposed advanced inverse stiffness design method provides a simple and efficient design tool for designers to take into account the nonlinear surface ground amplification and soil-structure interaction. The stiffness design formula with the fundamental natural period of the interaction model as a principal design parameter enables the efficient evaluation of the lowest-mode damping ratio and the mean peak interstory drifts to design earthquakes with respect to the fundamental natural period.
2. The surface ground amplification for a rather stiff ground is larger in the shorter natural period range than that for a softer ground. In this natural period range, the building structure on a rather stiff ground requires larger story stiffnesses under the condition of a constant interstory-drift response level. On the other hand, in the longer natural period range the building structure on a rather soft ground requires larger story stiffnesses under the condition of a constant interstory-drift response level.
3. The statistical response evaluation of shear strains of soil layers provides a rational means in the equivalent linearization of soil properties. This method is reliable compared to the conventional technique which deals with a single wave for linearization.
4. The proposed simplified stiffness design method using a sway-rocking model is reasonably accurate regardless of its simplicity. This fact has been confirmed by a two-dimensional finite-element model
5. The building model designed by the present method exhibits a favorable E-P response to the safety-limit level motion.

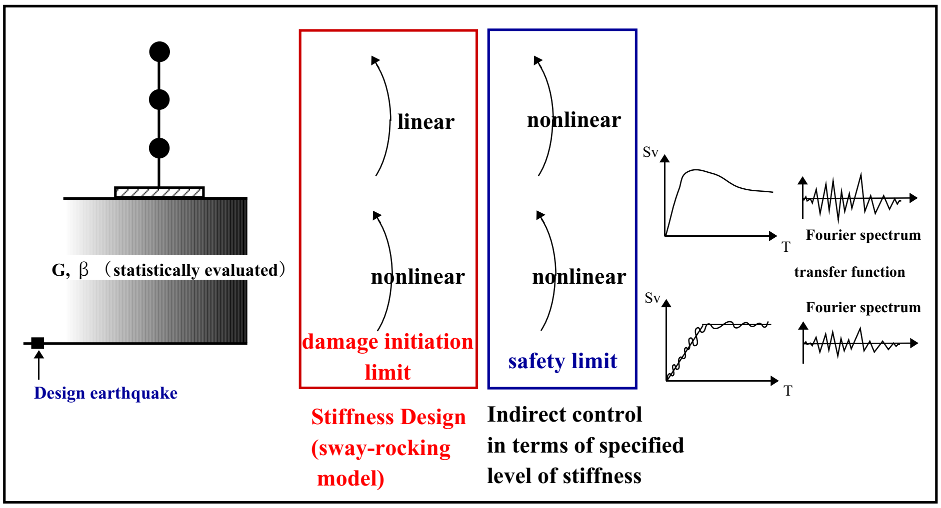

Fig.1 Framework of this research