DYNAMIC PROPERTIES OF HIGHWAY BRIDGES

by

Eiichi Kuribayashi[I] and Toshio Iwasaki[I]

SYNOPSIS

This paper presents the results of dynamic tests on some thirty highway bridges constructed in Japan during this decade, and summarizes their dynamic properties such as mode shapes, resonant frequencies, damping characteristics. The tests were conducted on foundations, pier columns, or complete bridge structures at various stages of construction, by applying lateral forces due to harmonic excitors or other equipments. From the study a relation between natural periods and damping ratios is evaluated for bridge structures. Also relations between heights of substructures above crests of foundations and natural periods, and between orders of natural modes and damping ratios are investigated.

INTRODUCTION

In the study of structural behavior to seismic excitation it is essential to evaluate structural dynamic properties, such as mode shapes, natural periods, and damping characteristics. To this aim numerous dynamic tests were performed on actual bridge structures.

In the following the results of the dynamic tests are described.

RESULTS OF DYNAMIC TESTS ON HIGHWAY BRIDGES

Between 1958 and 1969, some thirty highway bridges were tested dynamically. Most bridges experimented are common ones in Japan and designed in taking into account lateral seismic coefficients of 0.15 to 0.3 (average 0.2). The tests were conducted usually with excitation small in comparison with those expected during major earthquakes, by applying lateral forces caused by centrifugal-type excitors. For some bridges several experiments were carried out at various stages of construction (foundations, pier columns or complete bridges).

Fig. 1 indicates a relationship between natural periods and corresponding damping ratios (fraction of critical) for all meaningful data. In the figure Group A denotes results of fundamental modes for ordinary bridges, while Group B denotes those of 1st to 3rd modes for bridges with pier columns higher than 25 m above the crests of foundations. Data in Fig. 1 are classified on the basis of structural type (foundation, substructure, overall structure), and also data in Group A are classified into two on the basis of foundation type (pile, caisson).

The natural period-damping ratio relation for only Group B is shown in Fig. 2, in which numerals indicate orders of natural modes

[I] Public Works Research Institute, Ministry of Construction, Japan.

and data for one structure are linked by a solid line.

Fig. 3 indicates the relationship between heights of piers and fundamental natural periods, for lateral movements of overall structures, together with the corresponding results for isolated piers.

As for mode shapes of highway bridges the following properties can be generally found. Caisson foundations and footings made of reinforced concrete behave as rigid bodies, and their modes are mainly rocking. Piles behave as elastic beams embedded into soil deposits, and their modes are of flexural deformation. Modes of pier columns are flexural and sometimes shear type. Bridge superstructures move as rigid bodies in the direction of bridge axis, while behave as flexural girders in the transverse direction.

CONCLUSIONS

From the studies on dynamic properties of bridge structures in lateral motions, the following can be concluded.

(1) Fundamental natural periods range 0.07 to 1.0 second for foundations, 0.1 to 1.3 seconds for isolated pier columns, and 0.3 to 1.2 seconds for complete bridge structures. It seems probable that fundamental periods get longer, as substructures become high, or as subsoils surrounding the foundations become soft, and also that fundamental natural periods for bridges with bent piers or steel piers are longer than those with reinforced concrete piers.

(2) It is revealed that fundamental normal modes for ordinary bridges which have comparatively low substructures, are usually of deformation of foundations, such as rocking motions or translation motions, and that damping ratios for those structures vary inversely proportional to the natural periods. The following formula is obtained.

$$h = 0.02/T$$

where h denotes damping ratios expressed as fractions of critical damping, and T represents natural periods in seconds for various sections of bridge structures. It seems reasonable that for the cases most of the vibratory energy will dissipate into the surrounding soils through the foundations.

(3) On the other hand, fundamental normal modes for bridges with substructures higher than about 25 m above the crests of foundations, are of elastic (primarily flexural) deformation of pier columns, and the damping characteristics are different from the above. Damping ratios for these bridges are comparatively small, ranging 0.005 to 0.03 regardless of natural periods, and the mean value is 0.013. It seems that for the cases dissipation damping through foundations is very small, and structural damping is the principal damping. Furthermore, although damping ratios for these bridges seem to vary inconsistently with orders of normal modes, it is seen that damping ratios do not change considerably as far as a few lowest modes of highrise bridges concern.

(4) Since rigid foundations embedded into deep soils have short natural periods and large damping capacities, deep foundations seem effective in providing bridge structures with appropriate structural resistance to seismic disturbances.

REFERENCE

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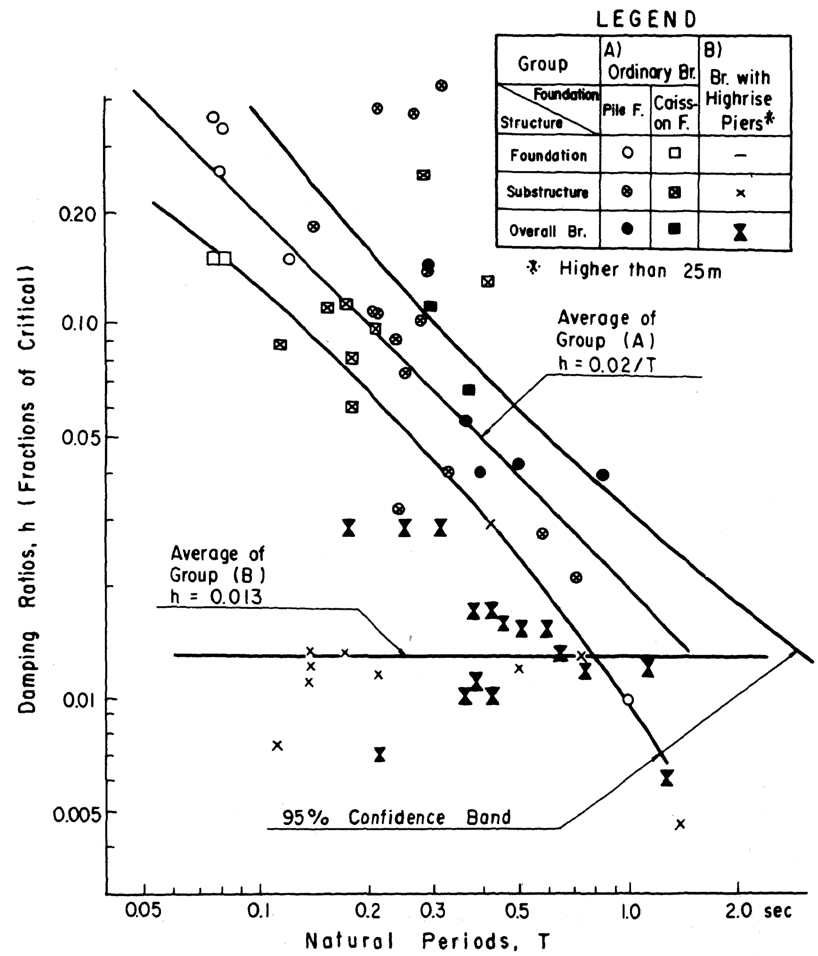

Fig. 1 Relationship Between Natural Periods and Damping Ratios for Bridge Structures

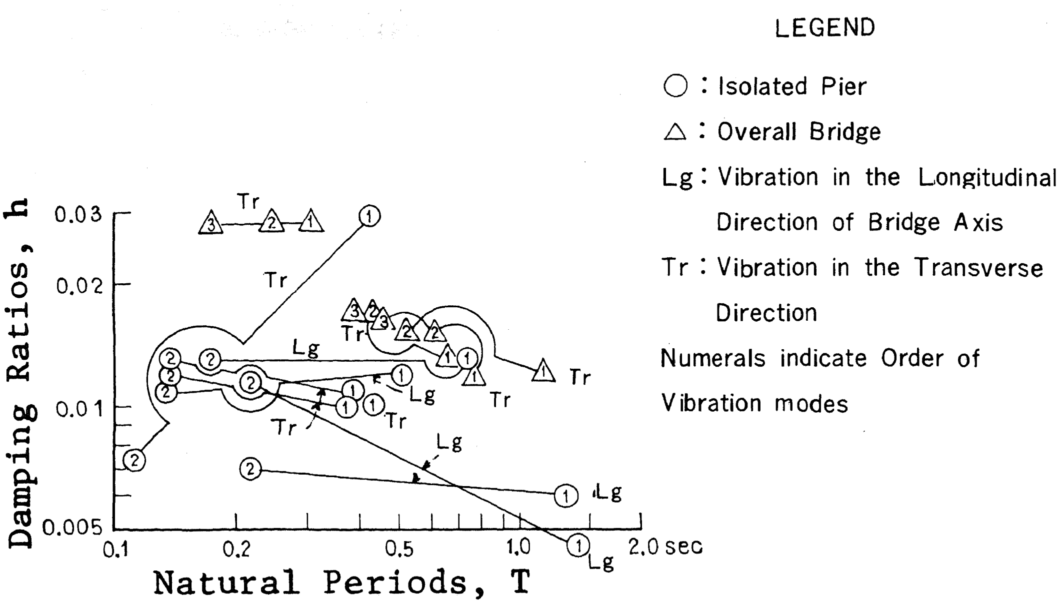

Fig. 2 Relationship between natural period and damping ratio for bridges with highrise piers

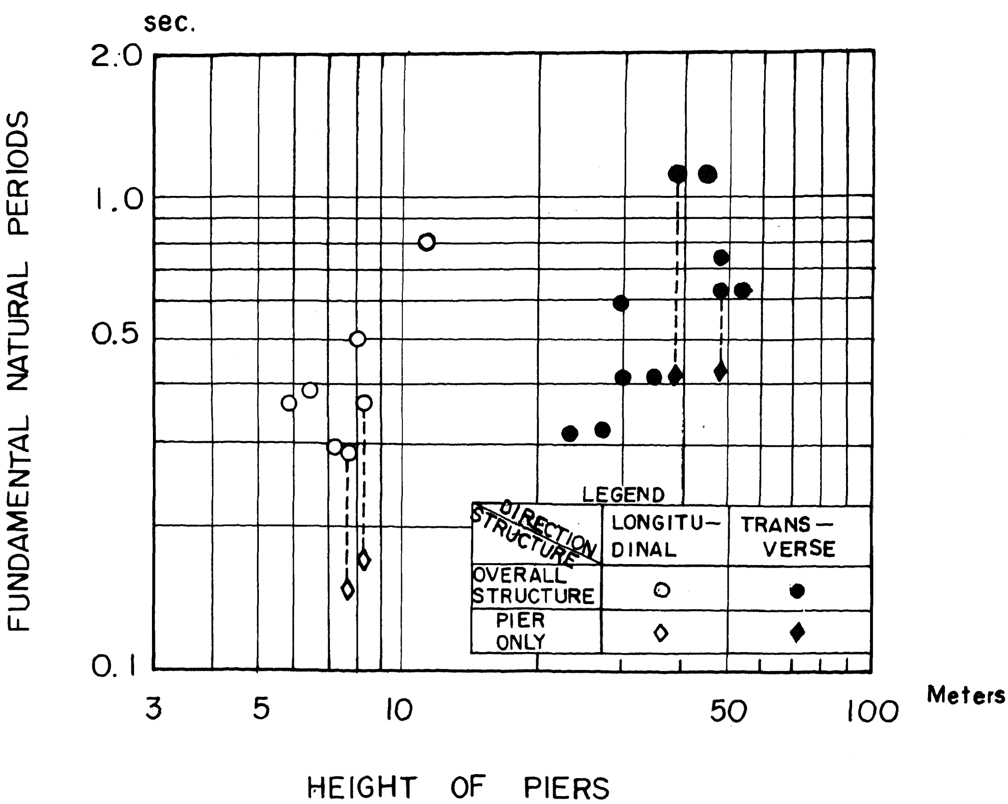

Fig. 3 Relationship between height of pier and fundamental natural period