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## 10. Aseismic Design of Railway Structures

In the Niigata Earthquake in 1964 and the Tokachi Off-shore Earthquake in 1968, railway structures of the Japanese National Railways suffered serious damage mainly due to large ground displacement. Photos 1 and 2 show examples of damage due to a recent earthquake.

In the case of a railway structure, the effect of earthquakes should be considered from both view-points of the structure's strength and its permissible displacement for the safety of running trains. The J.N.R. has made efforts to establish an adequate aseismic design method in recent years and along with the development of the seismic response analysis by the aid of computers, a new specification for aseismic structure design has been drafted of late. It has the following characteristics.

According to the period of natural frequency of a structure, the method to check the seismic effect thereupon is classified into three categories.

In the case of structures of natural period of less than 0.3 sec, the design seismic coefficient is estimated by multiplying the basic horizontal seismic coefficient, which is usually 0.2, by two coefficients varying according to the region to which it belongs and the kind of ground on which it is constructed. The design seismic inertia force acting on the substructure is obtained as the product of the design seismic coefficient and the mass of the superstructure.

In the case of a structure of natural period between 0.3 sec. and 2 sec, a somewhat modified method is adopted. The design seismic coefficient is estimated by multiplying the design seismic coefficient obtained from the above-mentioned method by a corrective coefficient based on the dynamic characteristics of the structures and the ground (see Fig. 1).

A dynamic analysis is applied in principle to the structures of natural period of more than 2 sec. Such a case takes place, however, only in a very long or tall structure or a structure constructed on a very weak ground.

On the basis of tens of dynamic tests, the relation between the natural period and displacement of a structure under a horizontal force corresponding to one-tenth of the gravity acceleration was obtained as graphically displayed in Fig. 2.

The relative displacement between the surface and the base layer is arrived at according to the combination of the thickness of soil layer below the footing bottom or the caisson top and the N-value of soil as shown in table 1, and is then taken into consideration in the design of the substructures mentioned below.

The above-mentioned specific grounds are further classified into three kinds as follows; Layer A, which has an invariable deformation modulus regardless of difference in the vertical position, Layer B, in which the modulus increases in proportion to its depth, and Layer C, which consists of two strata of different deformation moduli.

A different function is assumed for the deformation mode due to shearing vibration for each of the above-mentioned layers.

The stresses in substructures resulting from their forced deformation, caused by the shearing deformation of the surface soil layer, are added to those due to the seismic inertia of the superstructures. Fig. 3 shows the deformation patterns of the ground and piles.

In the regulation the permissible relative displacements between the upper slabs of adjacent viaducts where the rail-track is laid are given for safety against derailment of high-speed trains.

This displacement is assumed to be caused by a snakelike motion displacement of the surface layer in the cases of the afore-mentioned specific layer grounds and by the phase difference between piers in the case of ordinary ground.

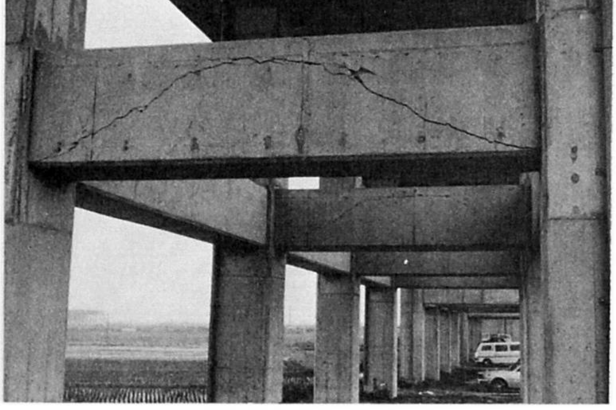

*Photo 1 Damage in beam of concrete viaduct*

*Photo 2 Damage in shoe*

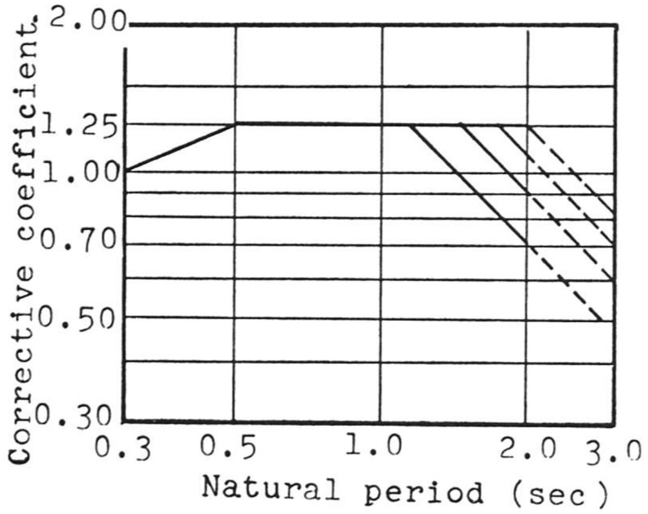


*Fig. 1 Relation between natural period and corrective coefficient*

*Table 1 Combination of thickness and N-value*

| Cohesive Soil Ground | | Sandy Soil Ground | |
|---|---|---|---|
| Minimum Thick. | Maximum N-value | Minimum Thick. | Maximum N-value |
| 2 | 0 | 5 | 5 |
| 5 | 2 | 10 | 10 |
| 10 | 10 | - | 15* |
| - | 8* | | |

*) Displacement of more than 3 cm

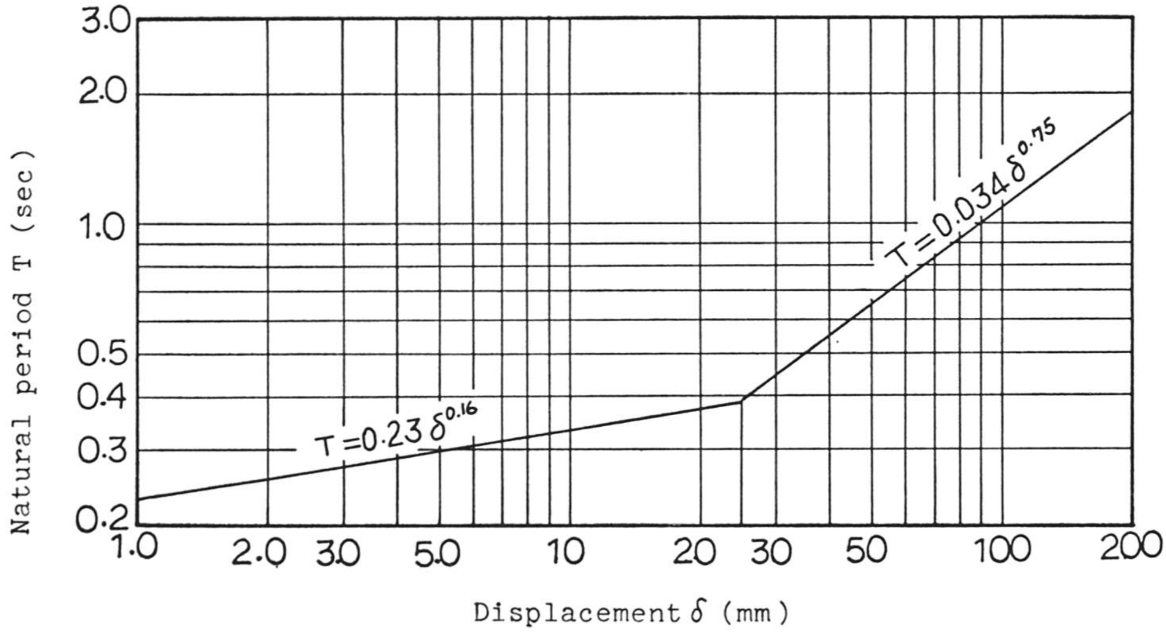


*Fig. 2 Relation between natural period and displacement*

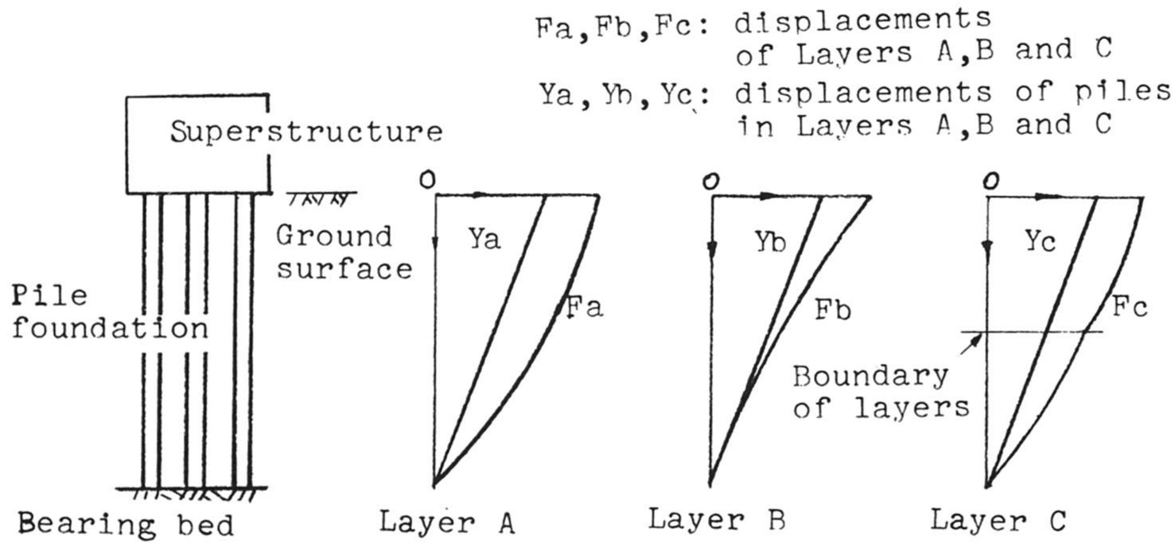


*Fig. 3 Deformation patterns of grounds and piles*