A PROPOSAL FOR EARTHQUAKE RESPONSE ANALYSES OF LONG STRUCTURES AND ASEISMIC DESIGN CRITERIA OF PIPE LINES

by

Akio SAKURAI I, Chizuko KURIHARA II and Tadashi TAKAHASHI III

SYNOPSIS

Earthquake response analysis method of long structures are discussed in reference to the characteristics of seismic wave propagation. The aseismic design criteria by ground strain during earthquakes are proposed, following the conclusions of response analyses on pipe lines.

THE SEISMIC WAVE PROPAGATION

During earthquakes, long structures such as pipe lines, long bridges and large building foundations etc. will behave in different ways compared with tall structures such as buildings, towers and chimney, because the long structures suffer not only the inertia foces but also the foces due to ground deformation or the foces due to the seismic wave propagation.

Fig. 1 is the displacement records which were observed by the seismographs distributed on the ground surface and placed each other apart 30 metres on a straight line. It is observed from the records that: 1) S (shear) wave propagation which is incident perpendicularly from subsoil upon the surface of ground is recognized at the first of the record. 2) The disturbance of each displacement at the second phase is induced by the non-homogeneity or the inclination of underground layers. 3) The surface wave propagation at some delayed phase are recognized.

This propagation characters are ascertained by the seismic wave observation in the downward direction under the ground and are connected to observed ground strains and dynamic stresses of piles and underground pipe lines during the MATSUSHIRO Earthquake swarm (1) (2) (3).

THE RESULTS OF RESPONSES ANALYSES

Modification and amplification of earthquake ground motion in surface ground layers are researched and the results are: 1) The computer technique based on the shear wave propagation and multi-reflection theory for phase I were examined. The method give good agreement to the observations and give good estimation of seismic forces considering locality of surface ground layers. 2) Then the disturbance in phase 2 can also be evaluated (2) (3).

I Senior Research Engineer, Chief of Earthquake Engineering Section No. 1, Foundation and Earthquake Engineering Department, Technical Laboratory, Central Research Institute of Electric Power Industry, 1646 Abiko Abiko City, CHIBA, JAPAN.

II Research Engineer, ditto

III Chief Research Engineer, ditto

The response analysis method on multi-input systems is proposed (3) (4) (5). The results are : 3) Not only the input acceleration but also the input velocity and displacement are required in the analysis. 4) It is essential items to evaluate quasi- static behaviours especially for underground structures because of less effects of inertia force. It is the same for reactions of each support.

The derived velocity and displacement from the acceleration record are required in the analysis. 5) The incompleted integration method are proposed in order to eliminate considerable drift induced by observation and digitalized processes (6).

The ground strains during earthquakes are firmly consistent to the aseismic stability of underground pipe lines. As the precise evaluation of ground strain have to follow the results from 1) to 3), the conventional evaluations are proposed (4). 6) The strain ε for surface seismic wave is given as

$$\varepsilon = V / v \qquad \text{..... (1)}$$

where v is seismic wave velocity and V is velocity amplitude. The maximum V derived from famous strong acceleration records by the incompleted integration is nearly 7 cm/sec, or 11 cm/sec for alluvium and 5 cm/sec for rock by another research. 7) The shear strain γ in phase 1 is connected with stability of pile like structures and with estimation of liquifaction in saturated sandy layers. γ is given as

$$\gamma = \frac{1}{2V}\left[V(t+z/v) - V(t-z/v)\right] \qquad \text{..... (2)}$$

Fig. 2 is the distributions of for famous earthquakes normalized maximum acceleration at 100 gal. The envelope of γ is given as Fig. 3 per 100 gal at the surface. The coefficient 3.4 of γ_0 in Fig. 3 may, of course, adopt to round number 5. 8) The weakness of ground defined by ground strain during earthquakes is proposed as

$$W(H,v)=(2k/\pi)\cdot(H/v) \qquad \text{..... (3)}$$

where $k=\varepsilon_0/\varepsilon$ and ε_0 is induced structural strain.

THE ASEISMIC DESIGN CRITERIA OF PIPE LINES

Following the results above mentioned, it is the essential point that the aseismic stability of pipe lines depend not on the force but on the deformation of ground during earthquakes. Then the aseismic design based on the philosophy of earthquake proof or resistance does not suitable, and the design based on the philosophy of earthquake avoid is recommended. The following items have to be proposed in the aseismic design criteria of pipe lines.

1) Utility Purpose and Philosophy of Design, considering the acceptable range exerted on civil life if damaged and cost.
   Petroleum ? gas ? sanitary ? electric cable ?,
   days needed to repair ? construct in city or field ?

2) Decision of Design Earthquake
the design base earthquake (D.B.E.) and the safety inquiry earthquake (S.I.E.)
acceleration ? velocity ? or deformation ?

3) Research of Ground Weakness
the subjects to research, root selection

4) Structural Design
allowable strain of pipe materials Ea
if the D.B.E. beyond as

$$\text{Acc. of D.B.E.} \qquad Ea/W(H,S) \qquad \text{.....} \ (4)$$

material selection, structural details for decreasing the transmissible ratio k in Eq. (3)

5) Back Up Systems for The S.I.E.
back up systems as softwear and hardware, countermeasures of disaster prevention, bake up systems for emergency use observation of seismic motion for back up systems, automatic stop valve

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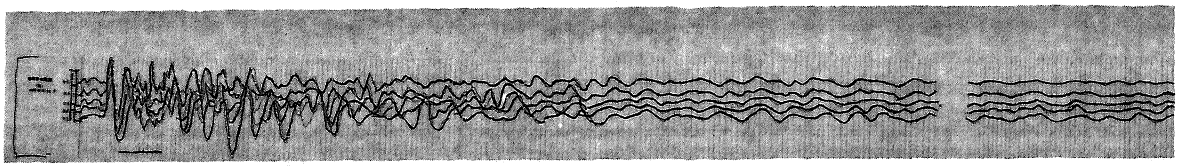


Fig.1 A record of ground displacements at the surface

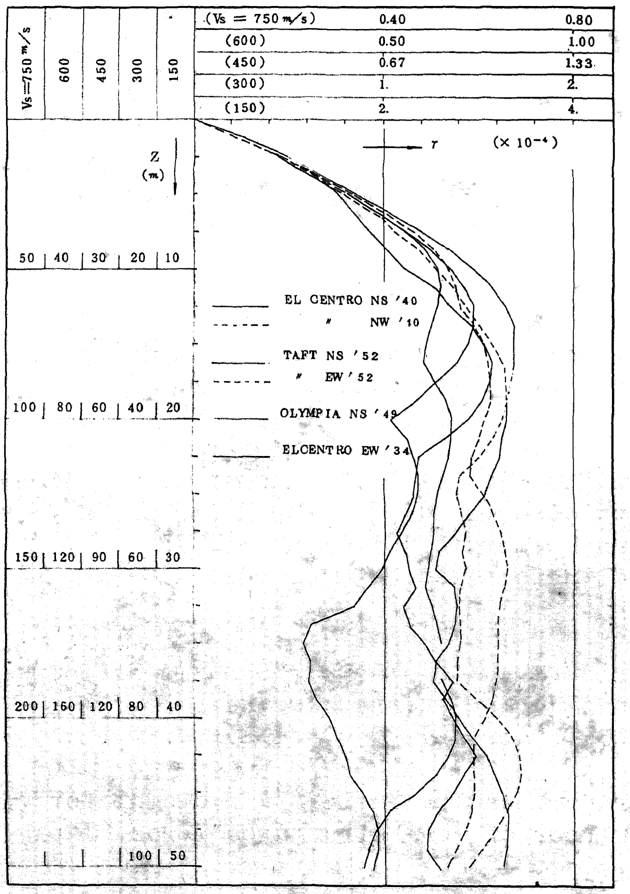
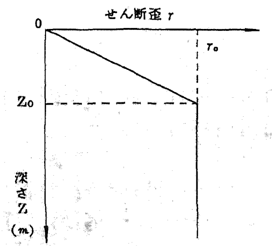


Fig.2 Distribution of shear strain during famous earthquakes



$$Z_o = 10^{m} \times \frac{v_s\,({}^{m}\!/_{s})}{150\,({}^{m}\!/_{s})}$$

$$\gamma_o = 3.4 \times 10^{-4} \times \frac{150\,({}^{m}\!/_{s})}{v\ ({}^{m}\!/_{s})}$$

Fig.3 Envelope of the shear strain