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Parametric Study on Seismic Ties of Boiler House

Etude paramétrique d'attaches anti-sismiques d'une chaudière

Parameterstudie über seismische Verbindungsglieder in einem Kesselhaus

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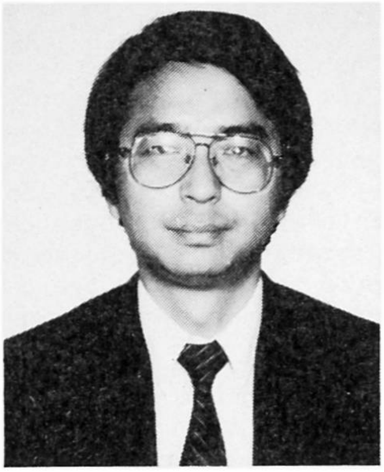

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SUMMARY
The seismic ties of the boiler house of a thermal power station have the function of fastening the boiler body to the boiler house. In particular, the mechanical properties of the seismic tie are expected to exert significant influence on the seismic response of the boiler and boiler house system. This paper evaluates quantitatively the influence the seismic tie exerts on the seismic response of the boiler house. This evaluation reflects the parametric study carried out by varying the mechanical properties (gab, yield strength and initial rigidity) of the seismic tie.

RÉSUMÉ
Les attaches anti-sismiques d'une chaudière dans une centrale thermique ont pour fonction de fixer le corps de la chaudière au bâtiment. Il est admis que dans le cas d'un séisme important, les caractéristiques mécaniques des attaches anti-sismiques ont une influence remarquable sur le comportement du système de la chaudière et du bâtiment. Cette étude concerne l'évaluation quantitative de l'influence de différentes caractéristiques mécaniques des attaches anti-sismiques sur la réponse sismique du bâtiment de chaudière.

ZUSAMMENFASSUNG
Die seismischen Verbindungsglieder in Kesselhäusern von Heizkraftwerken dienen der Befestigung des Kessels am Kesselhaus. Das Verhalten bei schweren Erdbeben kann jedoch dadurch beeinträchtig werden, daß das Erdbebenverhalten des Systems zusammen mit dem Kesselhaus stark beeinträchtigt wird. Die Studie schätzt diesen Einfluß quantitativ aufgrund einer Parameterstudie unter Veränderung der mechanischen Eigenschaften des seismischen Gliedes (Fugenbreite, Nachgiebigkeit, Anfangsfestigkeit) ab.

1. INTRODUCTION

The boiler house of a thermal power station is the structure that supports the power generating boiler by means of the top girder. The boiler weight of the Takehara Thermal Power Station Unit No. 3 amounts to 12,000 tons and accounts for 40 percent of the total weight of the boiler house as a whole. Its configuration is outlined in Figure 1. The boiler is fastened to the boiler house by means of a device called a seismic tie. This device has the function of restraining the boiler in the boiler house to prevent excessive shaking during an earthquake. On the other hand, the seismic tie is devised so that the boiler remains free with regard to deformation caused by its deadweight and by heat on ordinary condition (refer to Figure 2).

It may safely be said that the function of the seismic tie has been neglected thus far in connection with the aseismic design of the boiler house, irrespective of the static or dynamic design method adopted in this connection. In other words, the boiler house formerly was given an aseismic design by assuming that the seismic tie has infinite rigidity, and that an earthquake force due to the boiler is transmitted to the boiler house through the seismic ties as they share. The mechanical strength of the seismic tie was previously determined from the earthquake force they have to bear. Furthermore, the rigidity of the boiler itself was neglected for aseismic design of the boiler house.

It must be remembered, however, that the boiler and the boiler house have vibration characteristics very different from each other if they are regarded as independent vibrating systems. It is obvious, therefore, that the mechanical properties of the seismic tie exert a significant influence on the force working on the both in the case of an earthquake, since the both are coupled each other by the seismic ties.

In this paper the author carries out a parametric study of the mechanical properties of the seismic ties in a coupled vibration model of boiler and boiler house whose validity was proved by a simulation analysis of earthquake response for the boiler house of Takehara Thermal Power Station Unit No. 3. The study aims to improve aseismic design method for the boiler house as a structure. The flow of this study is shown in Figure 3.

2. PARAMETRIC STUDY

2.1 Analytical Model

The analytical model used for the sake of this parametric study is a sixteen-lumped-mass model. This is obtained by simplifying the accurate model (pseudo-three-dimension model) that consists of representing each member of the columns, beams and braces of the boiler house as well as the boiler itself and the seismic tie with finite elements. In this model the boiler is supported at the top of the boiler house by means of a hanging spring. Boiler weight is represented by mass concentrated at each floor. Boiler rigidity is represented by elastic springs valuating the axial and bending rigidity. On the other hand, the seismic tie is represented as a nonlinear spring taking into consideration of such factors as the gap and the yielding. The coupled vibration model of boiler and boiler house mentioned in the foregoing is called a seismic tie model (refer to Figure 4(a)).

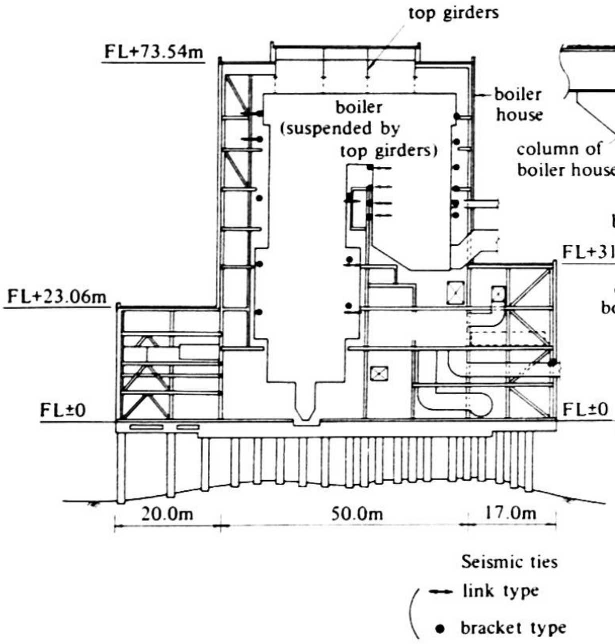


Fig. 1 Section of Boiler House (Takehara Thermal Power Station Unit No. 3)

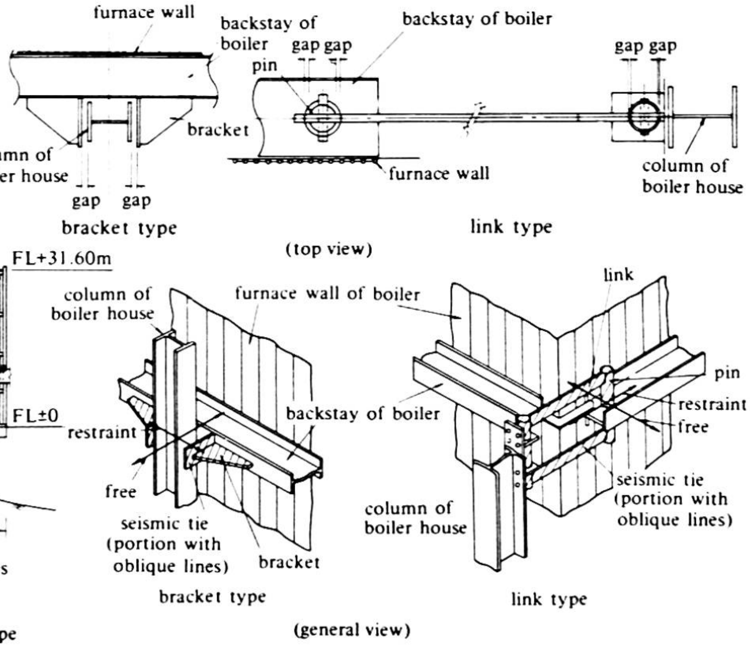


Fig. 2 Structure of Seismic Ties

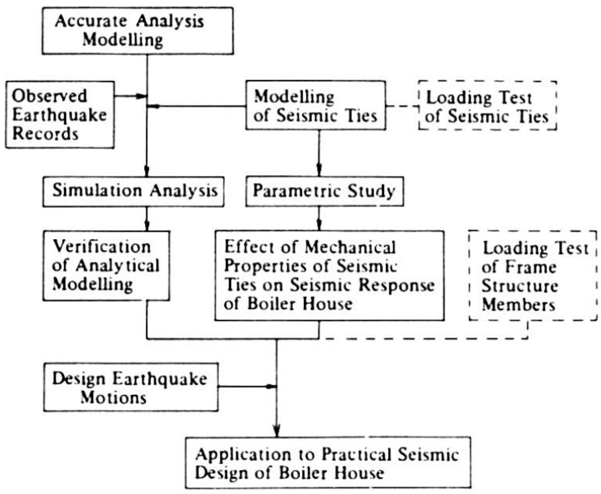


Fig. 3 Flow of Study

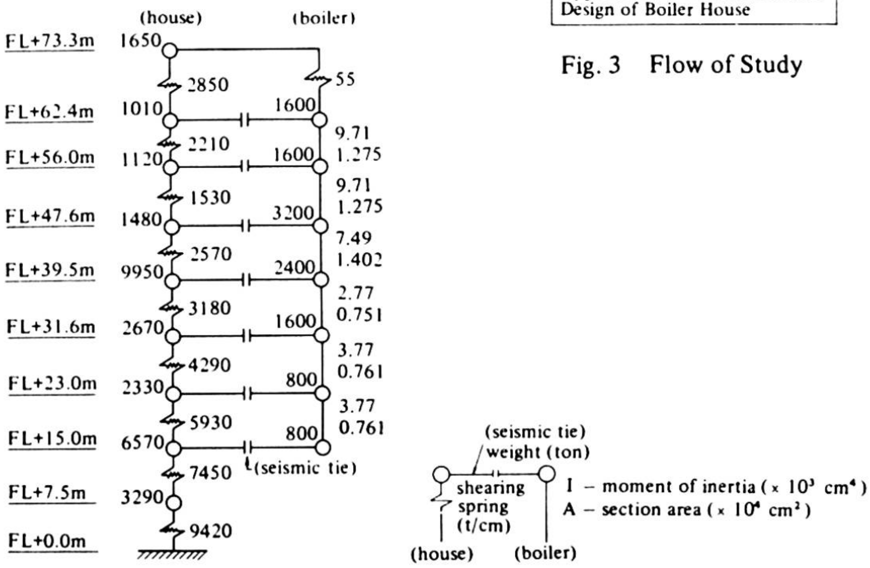


Fig. 4 (a) Analytical Model (Seismic Tie Model)

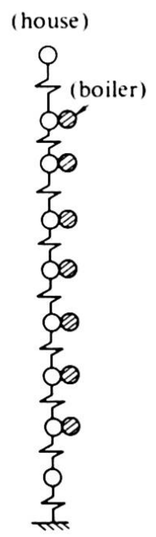


Fig. 4(b) Analytical Model (One-Body Model)

A conventional model, called a one-body model hereafter, is illustrated in Figure 4(b) that is for comparing with the results of the above-mentioned seismic tie model. This is obtained in the same manner as above except that the mass point corresponding to the boiler weight is added to the mass point at each floor, i.e. with seismic ties of infinite rigidity and neglecting rigidity of the boiler itself.

2.2 Parameters

Two distinct types of seismic ties, classified in terms of their hysteresis characteristics, are taken into consideration in this study.

(1) Gap-slip type (in which the gap widens concurrently with the plastic deformation. It corresponds to the bracket type shown in Figure 2).

(2) Gap-bilinear type (in which the gap continues to remain constant after the yield. It corresponds to the link type shown in Figure 2).

The hysteresis characteristics of each type are shown in Figure 5.

The initial gap amount, the initial rigidity and the yield strength are selected as the main parameters representing the mechanical properties of these two types of seismic ties. These parameters are varied as shown in Table 1, based on the value actually adopted in the Takehara Thermal Power Station Unit No. 3 as standard one. When one parameter is varied, the standard value is adopted for the other two parameters.

2.3 Earthquake Response Analysis

The earthquake response analysis is carried out by adopting the El Centro 1940 (NS) as input ground motion and by normalizing the maximum acceleration at 200 gals. As for distribution of max. response shear force of boiler house and max. response relative displacement between boiler and boiler house, Sendai 038 (NS) by Miyagi Ken Oki earthquake of July 12, 1978 is applied for supplement. 3 percent of internal viscous damping is assumed to occur in correspondence to the first natural mode of the boiler house.

2.4 Results

The parametric study by means of the earthquake response analysis was carried out in conformity with the conditions mentioned in Sections 2.1 through 2.3 above. The results obtained are outlined as follows.

2.4.1 Influence of the analytical model and the hysteresis characteristics

(1) Distribution of the Maximum response shear force for each story of the boiler house

Figure 6 shows the distribution of the maximum response shear force of the boiler house. Comparing the gap-slip type and gap-bilinear type seismic ties in terms of hysteresis characteristics, there is no much difference in the distribution of the maximum response shear force. It is, therefore, concluded that there is no difference attributable to the hysteresis characteristics.

On the other hand, the maximum response shear force of the seismic tie model is reduced to 60 percent through 80 percent of the response of the one-body model in both cases (gap-slip type seismic tie and gap-bilinear type seismic tie).

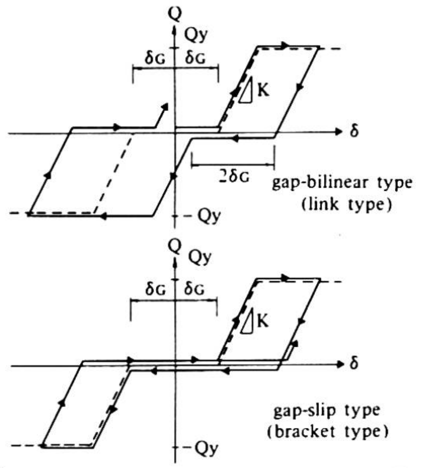
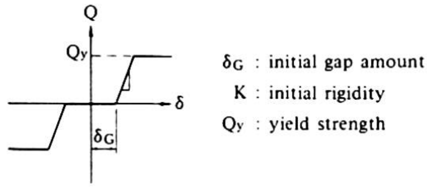


Fig. 5 Hystereses Models of Seismic Ties

	S.V ×1/3	Standard Value (S.V)	S.V ×5/3
δG (cm)	0.3	0.9	1.5
* K (t/cm) (total value)	2400	7200	12000
* Qy (ton) (total value)	1200	3600	6000



* total value of all seismic ties

Table 1 Parameters of Study

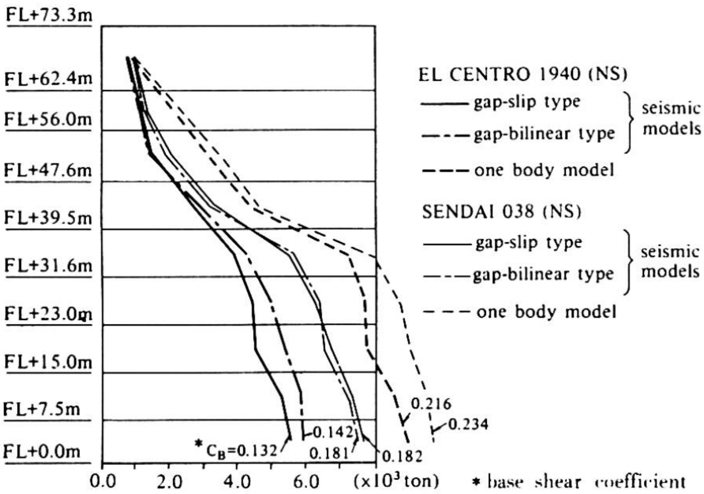


Fig. 6 Distribution of Max. Response Shear Force of boiler house

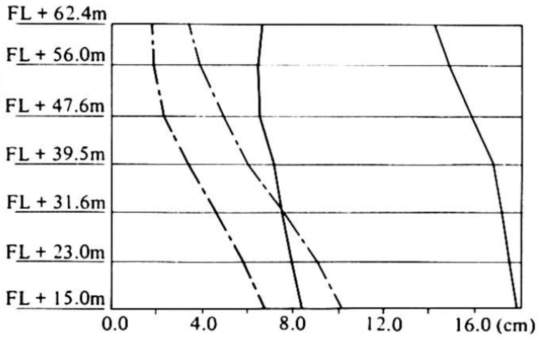


Fig. 7 Max. Response Relative Disp. between Boiler and Boiler House

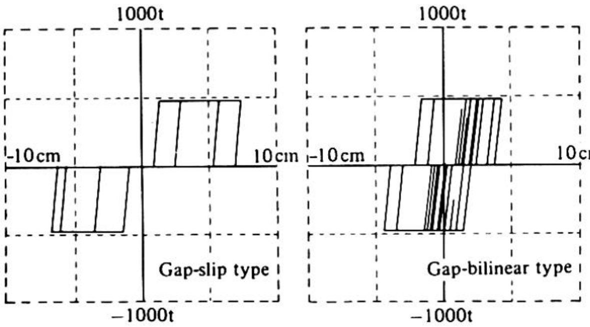


Fig. 8 Hystereses of Seismic Ties by Analysis

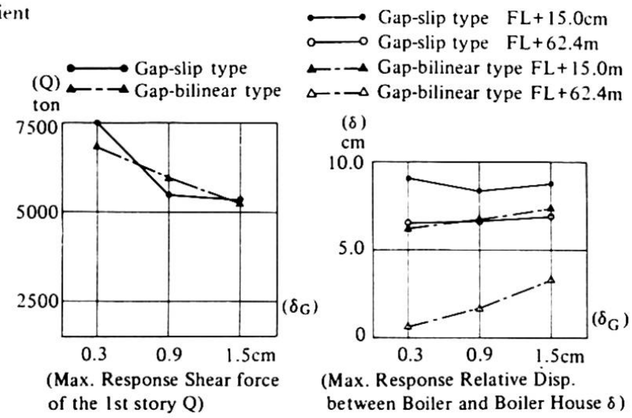


Fig. 9 Effect of Initial Gap Amount (δG)

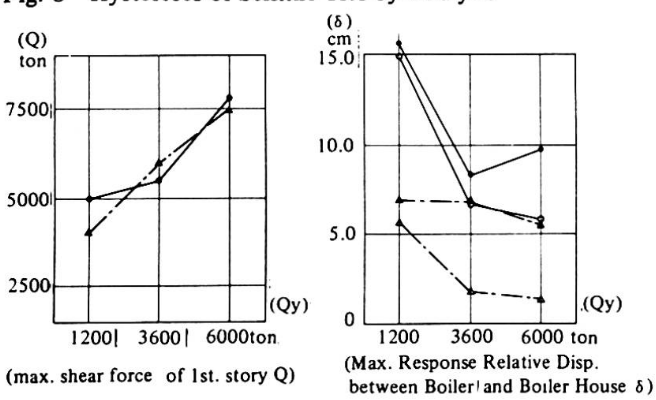


Fig. 10 Effect of Yield Strength (Qy)

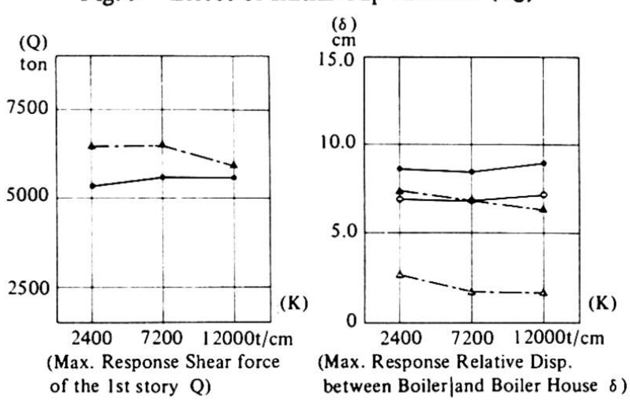


Fig. 11 Effect of Initial Rigidity (K)

(2) Maximum response relative displacement between boiler and boiler house

Figure 7 shows the maximum response relative displacement between boiler and boiler house. As can be seen, the relative displacement occurring in the gap-slip type is approximately twice as much in the gap-bilinear type.

The said difference occurs because whereas in the gap-bilinear type seismic tie the gap remains constant, in the gap-slip type seismic tie the gap increases concurrently with the progress of yield. And this characteristic is clearly explained by the hysteresis loop of the seismic tie of FL + 31.6 shown in Figure 8 as an example.

2.4.2 Influence of the mechanical properties of the seismic tie

(1) The maximum response shear force occurring in the first story of the boiler house and (2) the maximum response relative displacement between boiler house and boiler when the mechanical properties of the seismic tie are varied - with the El Centro wave adopted as input ground motion - are shown in Figure 9 through 11.

(1) Maximum response shear force in the first story of the boiler house

The larger the initial gap the smaller the maximum response shear force, and the smaller the yield strength the smaller the maximum response shear force. The relationship is practically linear. When the initial gap δ_G is 1.5 cm the extent of reduction is approximately 10 percent as compared with the standard value (δ_G = 0.9 cm). When the yield strength Q_y is 1200 t the extent of reduction is of the order of 30 percent compared with the standard value (Q_y = 3600 t). It is presumed that the said fact occurs because of the increasing hysteresis damping effect. This is attributed to the frequent response in the plastic range resulting from the lower value of the yield strength. Differences in the initial rigidity seem to exert practically no influence.

(2) Maximum response relative displacement

Contrary to the tendency mentioned above, the larger the initial gap the larger the maximum response relative displacement, and the smaller the yield strength the larger the maximum response relative displacement. A quite large relative displacement caused by plastic deformation occurs when the yield strength Q_y is 1200 ton. Differences in initial rigidity seem to exert practically no influence in response relative displacement as well as in response shear force.

3. CONCLUSION

Seismic ties are useful for reducing earthquake force of boiler house as well as for restraining the large relative displacement between boiler and boiler house during an earthquake by providing appropriate mechanical properties such as gap amount, yield strength and ductility. For evaluating the effect above-mentioned properly, analysis model representing the mechanical properties of seismic tie such as seismic tie model is essential.