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An Empirical Formula for Seismic Test of Telecommunication Equipments

Young Hoon Lee, Bong Jin Kang, and Won Ho Kang

***Abstract*—**Antiseismic property of telecommunication equipment is very important for the grasp of the damage and the restoration after earthquake. Telecommunication business operators are regulating seismic standard for their equipments. These standards are organized to simulate the real seismic situations and usually define the minimum value of first natural frequency of the equipments or the allowable maximum displacement of top of the equipments relative to bottom.

Using the finite element analysis, natural frequency can be obtained with high accuracy but the relative displacement of top of the equipments is difficult to predict accurately using the analysis. Furthermore, in the case of simulating the equipments with access floor, predicting the relative displacement of top of the equipments become more difficult.

In this study, using enormous experimental datum, an empirical formula is suggested to forecast the relative displacement of top of the equipments. Also it can be known that which physical quantities are related with the relative displacement.

***Keywords*—**Empirical formula, First natural frequency, Seismic test, Telecommunication equipments.

I. Introduction

STABILITY of telecommunication equipments against earthquake is one of the most important things when it occurred. In the seismic situations, it is essential to keep communications network operate normally to induce rapid evacuation before earthquake happens and to grasp the damage and execute restoration after it happened. So each telecommunication business operator applies particular seismic standard to their equipments. The most popular seismic standards are Telcordia standard [1] and ETSI EN standard [2]. And, in Korea, all the telecommunication equipments must be tested following the national standard established in 2009.

Seismic standards of telecommunication equipments are usually regulating normal communication status and no physical damage of equipment after earthquake, the lower limit of the first natural frequency of equipment and the upper limit of relative displacement of top of equipment. Because earthquake wave has high energy level in the frequency range of 1~6 Hz, the first natural frequency of telecommunication equipments need to be larger than certain value. And the relative displacement of top of the equipments should be smaller than particular value in order that equipments do not bump against each other.

Y. H. Lee is with Samsung Electronics Co,. Ltd. (phone: +82-31-279-2328; e-mail: yh3515.lee@samsung.com).

B. J. Kang is with Samsung Electronics Co,. Ltd. (phone: +82-31-279-; e-mail: bongjin2.kang@samsung.com).

W. H. Kang is with Samsung Electronics Co,. Ltd. (phone: +82-31-279-; e-mail: wonho78.kang@samsung.com).

Telcordia standard suggest that the first natural frequency of equipment must be larger than 2 Hz and is recommended not to be smaller than 6 Hz. Also it proposes that the relative displacement of top of equipment must not to exceed 75 mm. Korea national standard also suggest the same criteria of displacement with Telcordia.

II. Seismic Test and Simulation

The usual seismic test of telecommunication equipment is carried out following the process shown in Fig. 1.

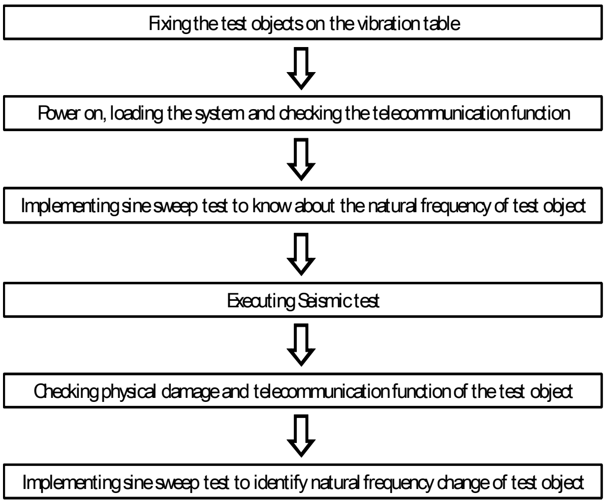
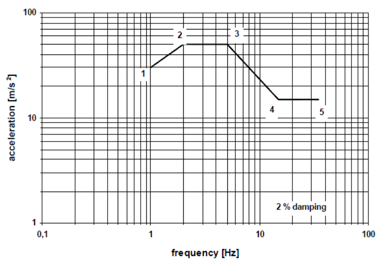
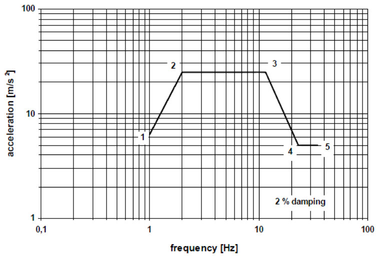


Fig. 1 The seismic test process of telecommunication equipments

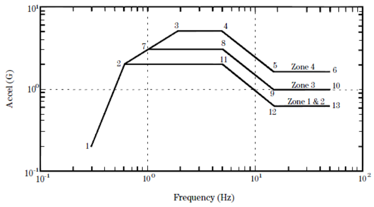
In general, seismic test conditions are provided in the form of response spectrum and these spectra are called as required response spectrum (RRS). In the test, test response spectrum (TRS), which is over the RRS, is induced into the test equipment for about 30 seconds. Each seismic standard is defining RRS and it can be shown in Fig. 2.



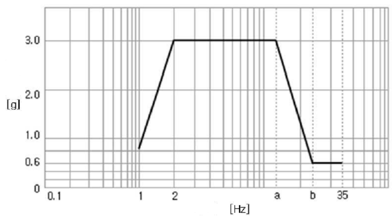
(a) ETSI EN 300 019-2-3



(b) ETSI EN 300 019-2-4



(c) Telcordia GR-63-Core



(d) Korea national standard

Fig. 2 Required response spectrum of each seismic standard; (a) ETSI EN 300 019-2-3, (b) ETSI EN 300 019-2-4, (c) Telcordia GR-63-Core, (d) Korea national standard

The way of fixing the test equipment to the shaking table needs to follow the same method or at least similar way of installing the equipment in building. In Telcordia standard, test equipments need to be set up on the shaking table directly. In Korea national standard, weight distribution frame should be installed on the shaking table for the test of outdoor telecommunication equipment and frame for simulating access floor should be set up on the table to test indoor equipment. The three types of test figures are given in Fig. 3.

(a) type Ⅰ (b) type Ⅱ (c) type Ⅲ

Fig. 3 Three types of test figures; (a) type Ⅰ, (b) type Ⅱ, (c) type Ⅲ

Before executing the seismic test, several methods can be used to confirm the fulfillment of seismic standard of the equipment. Among those methods the most general thing is finite element analysis [3]-[4]. Using mode analysis about the finite element model of the equipment, the natural frequency can be obtained. And through the transient analysis of finite element model of the equipment, stress, from which we are able to predict the deformation or mechanical damage of the equipment, and the relative displacement of top of the equipment can be found.

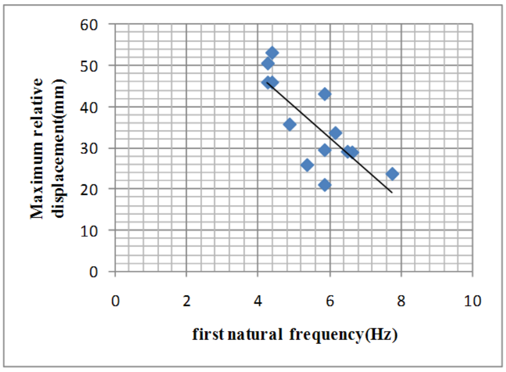
From more than thirty times of seismic test experience of us and previous studies [5]-[6], it could be concluded that the finite element analysis results about natural frequency can predict the test result well within 10 % error.

But it was found that the gap between the finite element analysis results and the test results of relative displacement seems not to be small. Sometimes the analysis results are different from the test results more than two times. To obtain more accurate analysis result, contact effect among the parts within the equipment need to be considered while executing transient finite element analysis. But there is no such a simulation tool for now. Therefore, another method is necessary to forecast, the displacement of equipment top relative to bottom, more accurately.

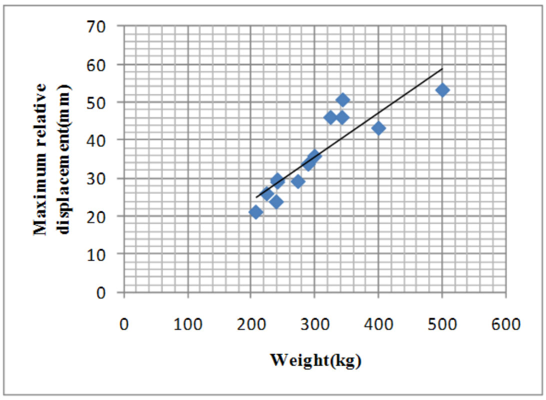
III. An Empirical Formula Suggestion

In this paper, an empirical formula for the prediction of the relative displacement would be suggested especially for the indoor telecommunication equipments which use the particular frame for simulating the access floor when it is tested. The thirteen test cases were used to establish the formula.

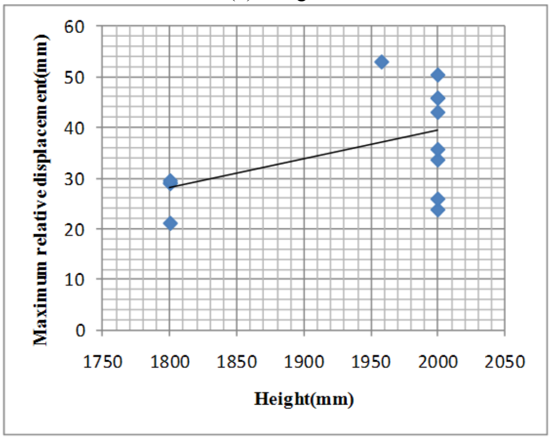
Factors, which are related with maximum relative displacement, were extracted. The relationships between these factors and maximum relative displacement are shown in Fig. 4.



(a) First natural frequency



(b) Weight



(c) Height

Fig. 4 Dependency of maximum relative displacement on (a) first natural frequency, (b) weight, (c) height of test object

As shown in Fig. 4 the maximum relative displacement is proportional to the weight and the height of the equipment. And it is inversely proportional to the first natural frequency of the test object. From the analysis about these relations and the test datum, we came to set a variable C defined in (1). And from Table I, it could be found that the value of variable C keeps certain range while test case changes.

$$C = \frac{(D \cdot \sqrt{f})}{((M_1 + M_2) \cdot (H_1 + H_2)^2)} \quad (1)$$

D : *Maximum relative displacement*

f : *First natural frequency*

M_1 : *Weight of equipment*

M_2 : *Weight of the frame simulating access floor* $(= 70\ kg)$

H_1 : *Height of equipment*

H_2 : *Height of the frame simulating access floor* $(= 600\ mm)$

As it can be shown from Table I, the maximum difference of values of variable C is about 40%. On the other hand, as we mentioned above, the difference between finite element analysis results and seismic test results could be over 200 % for the relative displacement value. Therefore, using the empirical formula composed of variable C and its range of value to predict the relative displacement will be more effective than predicting the relative displacement by transient finite element analysis.

TABLE I
CHANGES OF VARIABLE C ACCORDING TO TEST CASES

No.	Maximum relative displacement(mm)	Value of variable C
1	23.76	3.16E-08
2	33.63	3.43E-08
3	28.94	4.15E-08
4	29.1	3.74E-08
5	45.84	3.55E-08
6	50.43	3.72E-08
7	45.84	3.44E-08
8	35.7	3.15E-08
9	21.09	3.19E-08
10	53.01	2.98E-08
11	43.04	3.28E-08
12	29.5	3.97E-08
13	25.89	3.01E-08

In this study, it is suggested to follow the process like below to predict the relative displacement of indoor telecommunication equipment which is seismic tested with the frame simulating access floor. At first, using mode analysis method for the finite element model, first natural frequency could be obtained within 10% error. Then the weight and height of the test object could be checked easily. Finally, using these values and variable C, we can predict the relative displacement value. If we consider the 10% error of natural frequency and 40% error of empirical formula, the relative displacement can be obtained within 50% error.

IV. CONCLUSION

We proposed an empirical formula to predict the relative displacement of top of telecommunication equipments. Datum and test results of indoor equipments which are tested with simulating access floor were used to obtain this formula. And this is more accurate than using transient finite element analysis. It is clear that inductive empirical method has its limit but it is also definite that this empirical formula is useful.

It is thought that the empirical formula of this paper should be remedied through more test datum. Also further studies should be followed to reveal the reason why the empirical formula, variable C does not have a non-dimensional form.

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