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MULTI-VARIANT STATISTICAL ANALYSIS FOR THE NATURAL PERIODS AND DAMPING RATIO OF ACTUAL EXISTING BUILDING STRUCTURES

Yoshihiro TAKEUCHI, Yoshio HIKIMOTO, and Masayuki WATANABE

1) Professor, Dept. of Architectural Eng., Osaka Institute of Technology, Osaka Japan
2) Engineer, Dept. of Eng. Development, Konoike Construction Co., Osaka Japan
3) Staff, Dept. of Architectural Eng., Osaka Institute of Technology, Osaka Japan

SUMMARY

Fundamental natural periods and damping ratios of actual existing building structures are discussed in relation to the structural characteristics, such as a height of structure, an aspect ratio, a ratio of structural material, and et.al. 130 natural periods of the high rise buildings and natural periods of the moderate buildings are used to analyze. A brief formula of evaluating fundamental natural period is investigated by the methodology of multi-variant statistical analysis. The explanation items in the analysis are constructed by 12 objective variables which are describe effectively the structural characteristics of buildings. On the basis of these analytical results, this study intends to establish the appropriate brief formula of fundamental natural period, which can be generally used in the structural regulation of aseismic design.

INTRODUCTION

As to the structural regulation of aseismic design in many regions and countries of the world, it is very important problem to evaluate appropriately a fundamental natural period of tall building, which has been used to decide a base shear coefficient at the primary stage of aseismic design. In general, an evaluation formula of fundamental natural period is formulated semi-empirically as a simple linear function, the variable of which is a height of structure. At a present time, it is considered to be necessary and possible to establish more appropriate evaluation formula constituted with the effective structural factors for natural period, on the basis of many experimental data of dynamic characteristics of existing building structures. The purpose of this study is the quantitative and qualitative examination to the effects of various structural factors on evaluation of natural period of structure by the method of multi-variate statistical analysis and presentation of a reasonable approximation brief formula.

EXPERIMENTAL DATE OF ANALYSIS

The measured natural periods which are used as the objective variables in multi-variate statistical analysis are the evaluation values obtained by the various vibration tests on the final stage of construction of building structure. The total number of the measured natural periods of tall buildings and moderate buildings are 130 and 209 respectively, which have been collected in the recent eight years. On the other hand, as the fundamental data of structural factors for the objective variables, 12 items are selected from the various structural factors, such as a height of structure, total story number of structure, an aspect ratio, a shape of plan, a set-back ratio, and et.al.

METHODOLOGY OF MULTI-VARIATE STATISTICAL ANALYSIS

Fig.1 shows the fundamental relationship between the fundamental natural period and the height of building structure. As it is clear from this figure that, a fundamental natural period of building structure are influenced strongly by a height of building structure, an evaluation formula used in structural regulation of aseismic design in many countries is represented generally as a linear function with only a variable of height. In the regulation of present Japanese aseismic code, these linear relation are presented by a linear function with a variable of height of structure which has as a parameter the coefficient of structural ratio between the values of 0.02 and 0.03. This study discuss the formulation of more effective evaluation equation of fundamental natural period of building structure by the method of muti-variant statistical analysis, on the basis of the actual measured experimental data.

The method of the statistical analysis used in this study is based on two procedures such that are the multi-regression analysis and quantatification theory of I class. On the application of methodology of these multi-variant statistical analysis, the fundamental natural period which is formulated consequently to be a linear function with a variable of height of structure is not adopted directly as a objective variable because of the above-mentioned fact that the fundamental natural period is controlled remarkably by the variable of height. Instead of the natural period itself, the objective variable is defined as the residual value which is subtracted the factor of height of structure from the natural period. With regard to selection of the explanation factors, the twelve items are chosen from the various structural factors.

In order to examine the fundamental relation of natural period and several structural factors, the correlation coefficients matrix is calculated and shown in Table 1. In this table, it is pointed out that the factors of height, structural ratio, set-back ratio, aspect ratio indicate the large correlation to natural period. However, as these factors also show the large correlation each other at the same time, it is necessary to evaluate mutual relation among these structural factors by the multi-variant statistical analysis.

EXPLANATION FACTORS AND ITS CATEGORY INTERVALS

As the explanation factors to the objective variable in this statistical analysis, the following twelve items are selected from the various structural factors, 1) height of building structure from ground surface, 2) total height of structure, 3) total story number above ground surface, 4) total story number, 5) ratio of total height and width of basement (aspect ratio), 6) ratio of height from ground surface and width of basement, 7) ratio of height of steel construction part and height from ground surface (structural ratio), 8) ratio of height of set-back construction part and height from ground surface (set-back ratio), 9) a reciprocal of width of basement, 10) shape of plan, 11) shape of elevation, 12) constant value.

These explanation factors could be treated as either a continuous value or a discrete value in the analysis if the values of factors are well-distributed in each interval of category. From the viewpoint of resolution and stability of the analytical results in each category interval, only a factor of height of structure is determined to be a continuous value. Table-2 and Fig.2 show the classification and distribution of discrete values in some category interval, respectively.

ANALYTICAL RESULTS

The analyses for each structural factor are proceeded sequentially in order to reduce unefficient explanation factor and, in each step of these analysis, the evaluation results of multiple and partial correlation coefficient,ratio of variance of residual, and regression are examined in reference to the criteria of significant level by F-distribution. One example of the important analytical results is shown in Table-3. From this results, three factors of the structural ratio, the aspect ratio,and the set-back ratio indicate the large partial correlation coefficient, so that it is concluded that these three factors are considered to be the effective explanation factors in the formulation of evaluation equation of the fundamental natural period.

Fig.3 shows the residual distribution of criterion variable which indicates to remain or not any significant quantity in the residual in comparison with normal distribution.

Fig.4 (a), Fig.4 (b),and Fig.4 (c) show graphically the quantified quantities for the structural ratio, aspect ratio,and set-back ratio,respectively. The values of coefficients of linear function which is an approximate formula of fundamental natural period can be evaluated from the average gradient of broken lines shown in the figures. By using these coefficients of explanation factors,the following approximation formula can be introduced as a linear function of three effective factors.

$$T=0.018H+\begin{Bmatrix} 2.63(k-0.85) & ; k\geq 0.85 \\ 0 & ; k<0.85 \end{Bmatrix}+\begin{Bmatrix} 0.17(a-2.25) & ; a\geq 2.25 \\ 0 & ; a<2.25 \end{Bmatrix}+\begin{Bmatrix} 0.15(s-5.50) & ; s\geq 5.50 \\ -0.1 & ; s<5.50 \end{Bmatrix}$$

(k;structural ratio a ;aspect ratio s;SB ratio)

Estimation Equation of Approximation Formula

The mean square error and error ratio which are calculated as the residual error from the approximation formula are shown in the Table-4. It is clear from the comparison of right side column and left side column in the table that the formulation of three explanation factors improves the accuracy of approximation in contract with the case of formulation of one factor of height of structure.

CONCLUDING REMARKS

As the conclusion from these analytical results,the following three explanation factors are considered to be the most significant than the others except for the height of structure; 1) structural ratio, 2) set-back ratio, 3) aspect ratio. An effective brief formula of evaluating the fundamental natural period can be obtained by using these three factors.

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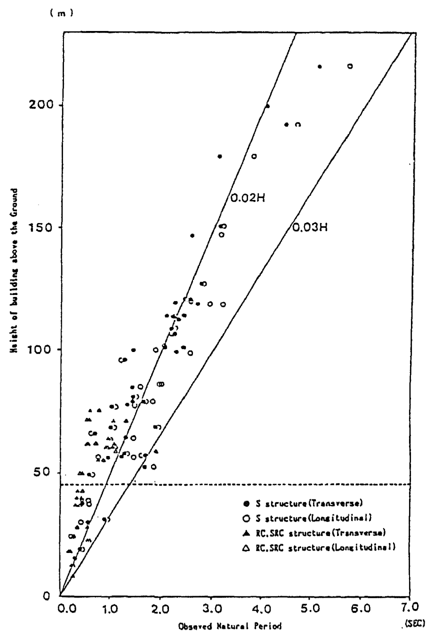

Fig.1 Height of Building from Ground Surface and Observed Natural Period

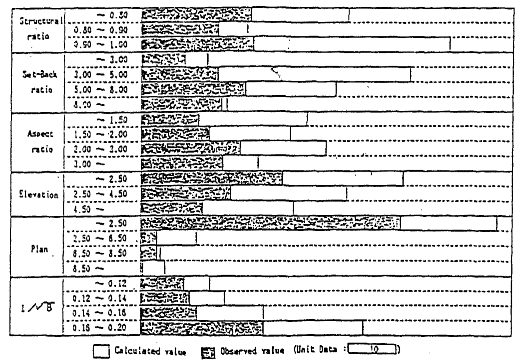

Fig.2 Frequency Distribution of Predictor Variable in Category Interval

Table-1 Normalized Correlation Coefficient Matrix

	Period	Height from ground surface	Structual ratio	Aspect ratio	Set-Back ratio	Elevation	1/√B	Plan
Period	1.000	0.922	0.346	0.366	0.669	0.107	0.118	0.132
Height from ground surface		1.000	0.252	0.276	0.636	0.106	0.166	0.049
Structual ratio			1.000	0.198	0.263	−0.039	0.090	0.008
Aspect ratio				1.000	0.315	0.026	0.042	0.112
Set-Back ratio					1.000	0.011	-0.099	0.115
Elevation		S Y M				1.000	-0.200	0.106
1/√B							1.000	-0.205
Plan								1.000

Table-2 Classification of Category Interval

Category	I	II
Structual ratio	~ 0.80 0.80~ 0.90 0.90~ 1.00	~ 0.80 0.80~ 0.90 0.90~ 1.00
Set-Back ratio	~ 3.00 3.00~ 5.00 8.00~10.00 10.00~15.00	~ 4.00 4.00~ 7.00
Aspect ratio	~ 1.50 1.50~ 2.00 2.00~ 3.00 3.00~	~ 1.50 1.50~ 3.00 3.00~
Plan	~ 2.50 2.50~ 6.50 6.50~ 8.50 8.50~	~ 2.50 2.50~ 7.00 7.00~
$\frac{1}{\sqrt{B}}$	~ 0.12 0.12~ 0.14 0.14~ 0.16 0.16~ 0.20	~ 0.14 0.14~ 0.17 0.17~
Elevation	~ 2.50 2.50~ 4.50 4.50~	~ 2.50 2.50~ 4.50 4.50~

Table-3 Multiple Correlation and Partial Correlation Coefficient

CASE		F-1'	F-2'	F-3'	F-4'	F-5'	F-6'	F-7'
Multiple Correlation Coefficient		0.526	0.672	0.661	0.657	0.593	0.631	0.592
Partial Correlation Coefficient	Height above the Ground							
	Structural Ratio	0.209	0.365	0.361	0.472	0.428	0.402	-
	Aspect Ratio	0.199	0.268	0.259	0.332	0.440	-	0.321
	SB Ratio	0.279	0.321	0.323	0.364	-	0.472	0.425
	1/√B	-0.002	-	-	-	-	-	-
	Shape of Elevation	0.092	0.174	0.189	-	-	-	-
	Shape of Plan	0.181	0.145	-	-	-	-	-
Evaluated Coefficient		0.021	0.018	0.018	0.018	0.018	0.018	0.018
Variance	Regression	0.672	1.684	2.016	2.602	2.454	3.550	3.896
	Residual	0.126	0.168	0.170	0.171	0.195	0.177	0.184
Variance Ratio		5.33	10.02	11.86	15.22	12.52	20.06	21.17
F-distribution Significance Level		3.72	4.42	5.65	8.56	19.48	19.48	19.48
Error Variance *		0.97	0.78	1.09	0.68	0.61	0.75	0.64

* Error variance evaluated from normal distribution.

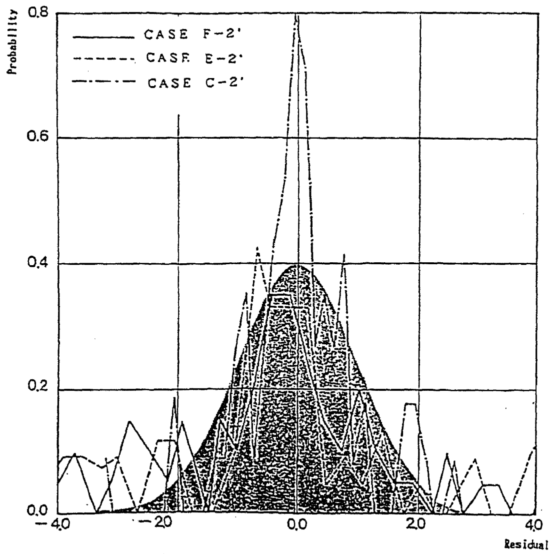

Fig.3 Residual Distribution and Normal Distribution

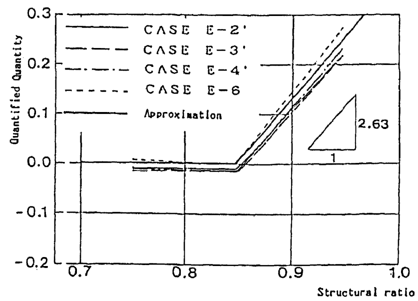

Fig.4(a) Quantified Quantity of Structure Ratio

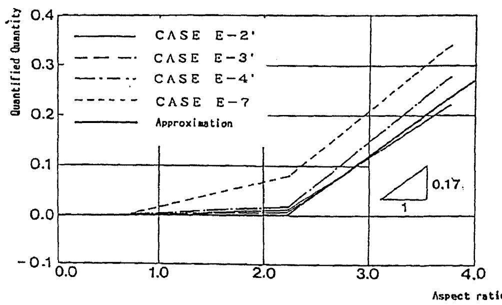

Fig.4(b) Quantified Quantity of Aspect Ratio

Table-4 Estimation Results of Approximation

Item		(1)	(1)+(2)	(1)+(3)	(1)+(4)	(ALL)
Mean square error		0.289	0.210	0.218	0.206	0.182
Error ratio	Mean error ratio	-0.003	-0.106	-0.037	-0.019	-0.156
	Maximum error ratio	0.402	0.430	0.402	0.518	0.328
	Minimum error ratio	-0.988	-0.988	-0.988	-0.806	-0.806
	Standerd deviation	0.323	0.318	0.320	0.278	0.276

(1)Height above the ground
(2)Structural ratio
(3)Aspect ratio
(4)Set-Back ratio

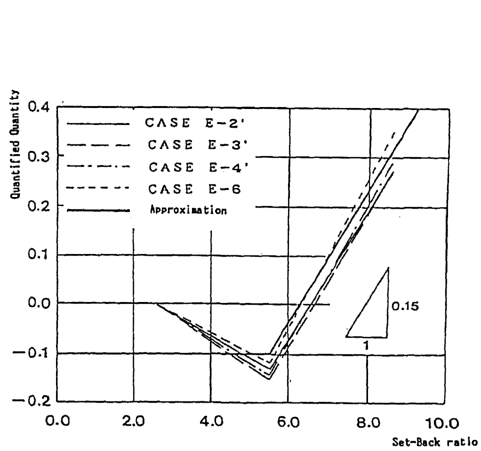

Fig.4(c) Quantified Quantity of Set-Back Ratio