On Effective Methods of Introducing Diagonal Braces to Green Houses' Frames

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On Effective Methods of Introducing Diagonal Braces to Green Houses' Frames

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Abstract

This report describes of the method of evaluating the effect of bracings and the effective methods of introducing diagonal bracings to green houses' frames, from results analysed by F.E.M. (Finite Element Method) considering rahmen structural elements.

In analysis, two types of green houses are modelded which are gabled and semi-circular types. And statical and dynamical methods of evaluating the effect of bracings are proposed.

One of the objects introducing braces is to restraine displacements of frames. But by this restraining, stresses are induced in members and make safety of materials to decrease. The stiffness of structures becomes larger if braces act effectively.

From the characteristics of displacements, safety of members and fundamental frequencies, effective methods of bracings to green houses' frames are evaluated. Following conclusions were obtained;

1) For gabled and semi-circular houses, it is desired that braces are placed such as one end of a brace is connected to the supporting point of a column and the other to the eave or the top of a roof.
2) The methods proposed in this paper can be used to solve the problem of optimum design of a green house frame.

I. Introduction

Author have studied characteristics of the response of green houses' frames to various loads i.e., wind load and snow load. Green house frames are, in general, light weighted and deformable, and so types of house frames affect considerably to the structural safety.

In employing types of house frames, it is important to consider weather and surrounding conditions. However, although house frames are one of important objects of investment in plant and equipments, simple and low cost frames are employed and so the structural safety are frequently reduced.

In this paper, the methods of bracings for house frames are discussed analytically. Generally, there are no strict methods of introducing braces to house frames and so empirical methods are used. And so, sometimes, unuseful braces are founded. In analysis, F.E.M. (Finite Element Method) considering rahmen structural elements is used, and to types of green house frames, i.e., gabled type and semi-circular type are considered.

In evaluating of the effective method of bracings, statical method and dynamical method are introduced which take displacements, safety facters, or natural frequencies. However, the failure of a frame is not described and so, the effect of bracings is discussed from state of elastic deformation of frames.

II. Investigating Methods and Analytical Models

In analysing statical response and dynamical response of house frames, the finite element method considering rahmen structural element is used.

1) Statical Methods

One of the objects to introducing braces in frames is to restrain horizontal and vertical displacements of frames. Due to this restraining, stresses are induced in members of frames and the safety of them may be diminished.

In this study, certain constant unit load is applied at one point of frame horizontally and vertically and computed displacements are compared with each members. And it is considered that the smaller displacements are, the larger the effect of bracing.

On the safety of materials, relationships between stresses and safety facters are investigated from AISC manuals. That is as follows;

(i) Firstly, by first-order elastic analysis, bending moments and shearing forces are calculated.

(ii) From these results, following equationsare acertained,

$$\sigma_{ba} \leqq \sigma_Y / F.S. \quad \cdots\cdots (1)$$

$$\sigma_{ba} \leqq \sigma_{cr} / F.S. \quad \cdots\cdots (2)$$

(iii) And from following equations, the related equations of beam-column are investigated.

$$\frac{\sigma_c}{\sigma_Y / F.S.} + \frac{\sigma_b}{\sigma_{ba}} \leqq 1.0 \quad \cdots\cdots (3)$$

$$\frac{\sigma_c}{\sigma_Y / F.S.} + \frac{C_m^* \sigma_b}{\sigma_{ba}[1-\sigma_c/\sigma_e]} \leqq 1.0 \quad \cdots\cdots (4)$$

where $\sigma_c = P/A$ ...... (5)

$$\sigma_b = M_{max} / S \quad \cdots\cdots (6)$$

$$\sigma_{ca} = P_{cr} / A \; (F.S.) \quad \cdots\cdots (7)$$

P : Axial force A : Section area

P_{cr} : Central buckling load for beam-column with no bending mement.

In applying those equations, following parameters are determined from AISC manuals for frames with normalsteel members (A 441 steel).

σ_{ca} = 1.480 kg/cm^2, or $\sigma_{ca} / \sigma_Y = 0.422$

σ_e = 2.200 kg/cm^2, or $\sigma_e / \sigma_Y = 0.626$

Cm^* = 0.85 for no restrain to horizontal displacement and then, euqation (3) and (4) are translated as follows,

$$\frac{\sigma_c}{\sigma_Y} + \frac{\sigma_b}{\sigma_Y} = 0.6 \quad \cdots\cdots (8)$$

$$3.97\left(\frac{\sigma_c}{\sigma_Y}\right) + 1.42\left(\frac{\sigma_b}{\sigma_Y}\right) = 1.0 \quad \cdots\cdots (9)$$

These are corresponding to maximum bending moment and axial force computed by first-order elastic analysis.

In this report, equation (9) is translated as follows in order to investigate the effect of restraining displacements.

$$3.97\,(\sigma_c) + 1.42\,(\sigma_b) = \sigma_Y = F' \quad \cdots\cdots (10)$$

Though σ_Y is yielding strength of material, $\sigma_Y = F'$ is taken as a safety factor of one member which the maximum bending moment and axial force are introduced by constant unit load.

From the change of F'_i/F'_0 (F'_0 for no bracing and F'_i for i-th bracing pattern). the effect of bracings is discussed and so it is considered that the smaller the value of F'_i/F_0' is, the larger the effect of bracings is.

2) Dynamical Methods

The effect of bracings may be discussed from dynamical method based on the eigen-value problem. In general, the multi-degree of freedom equation is as follows;

$$M\ddot{X} + C\dot{X} + KX = F(t) \quad \cdots\cdots (11)$$

where M : Mass Matrix
C : Damping Matrix
K : Stiffness Matrix.

In the eigen value problem, $F(t)$=0. When $X=X_0e^{ipt}$ is assumed,

$$(p^2M - pC_i - K)\,X_0 = 0. \quad \cdots\cdots (12)$$

As this equation is a complex value problem, it is needed to be devised to solve it. In the case of rahmen structures, the damping matrix C may be neglected, and so the following eigen value problem is discussed,

$$|\,K - p^2M\,| = 0, \quad \cdots\cdots (13)$$

where p is a natural frequency.

It may be considered that the larger this natural frequency is, the larger the total stiffness is. From the ratio of frequencies p_i/p_0 (p_i and p_0 are fundamental frequencies for house frames with any bracings and no bracings respectively.), the effect of bracings may be investigated.

3) Analysing Models

In this study, two types of green houses are considered which are gabled and semi-circular types. Fig.-1 shows bracing methods and scales. All models have same L-type steel members which cross area is 3.89cm^2, unit weight is $7.86 \times 10^{-3}\text{kg/cm}^3$, moment of second order is 9.04cm^4, and elastic modulus is 2.1×10^6 kg/cm^2. In statical analysis, unit load (1 ton) is applied at eaves of gabled house and at same position of semi-circular house, horizontally and vertically respectively.

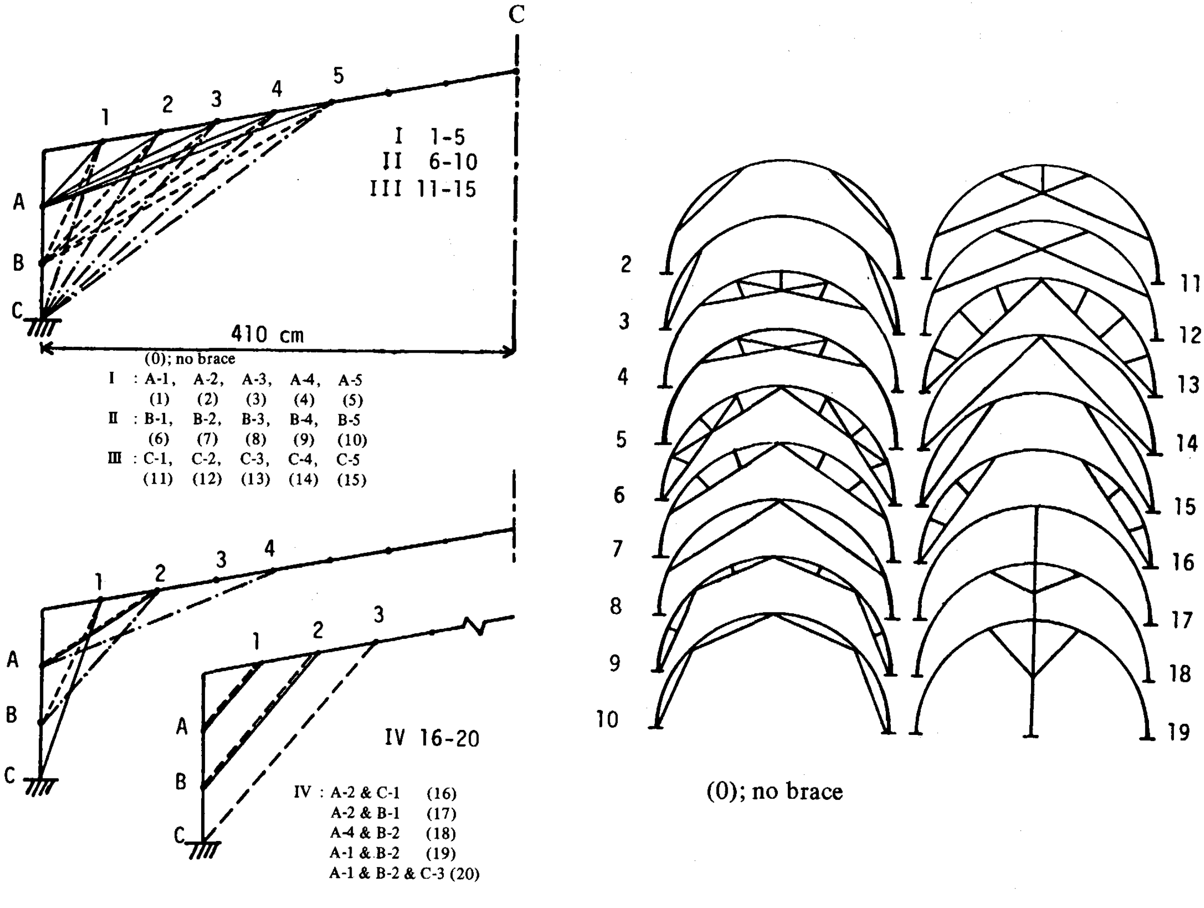

Fig.-1 House Models of gabled type (the left) and semi-circular type (the right)

III. Considering of Results

1) On the case of gabled type

Fig.-2 shows the realtionships between horizontal and vertical displacements when an unit load is applied to each direction. Numbers in this figure are corresponding to numbers of gabled houses' models in Fig.-1.

From this result, it is said that methods of bracings such as No.10 and No.15 are more effective than others. These methods are those which combine B to 5 and C to 5 in Fig.-1.

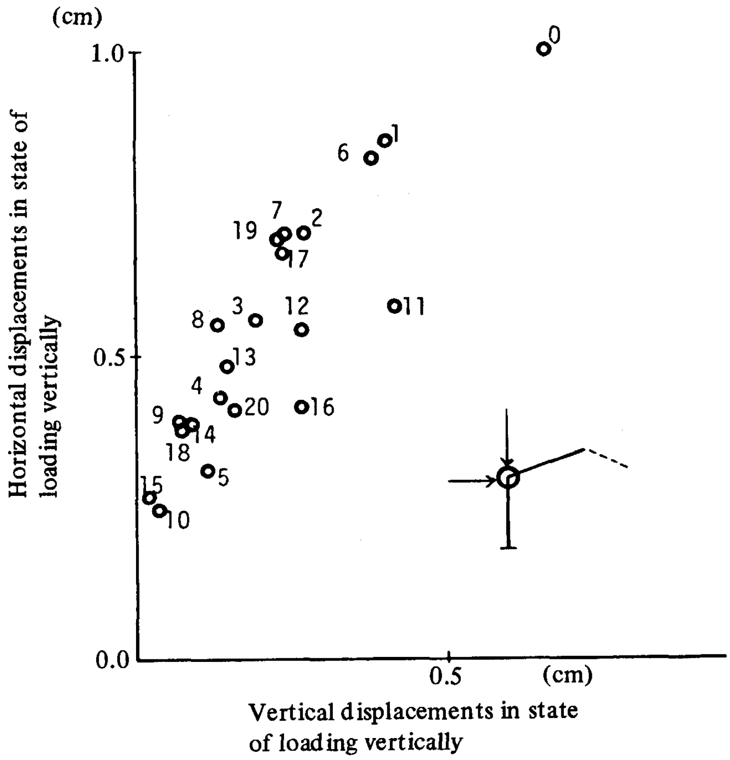

Fig.-2 The relationship between horizontal and vertical displacements for gabled types

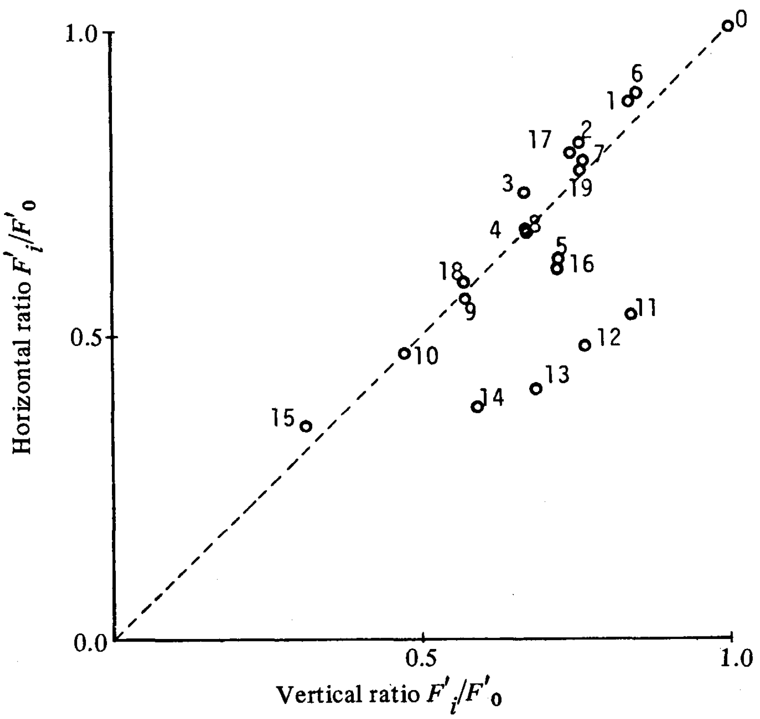

Fig.-3 The relationship between horizontal and vertical ratio F_i/F_0 for gabled type.

It is generally said that the larger amounts of braces are, the larger the stiffness of a structure is. And so, in the dynamical investigating method, the ratio of each bracing length to its main member's length is introduced as one parameter.

Fig.-4 shows the relationships between the length ratios and natural frequencies. In the bracing methods showed in this report, the ratio of the length which is described previsously is not a continuous papameter, but discrete papameter of which values are from 0.20 to 0.80.

If the value of the ratio is assumed as 0.50, the methods of bracings that take the largest natural frequency are those which are combined A-2 and C-1 members. This case is corresponding to No.16 in Fig. 2 and Fig. 3.

Nextly larger natural frequencies are obtaned in the cases of No.10 and No.15.

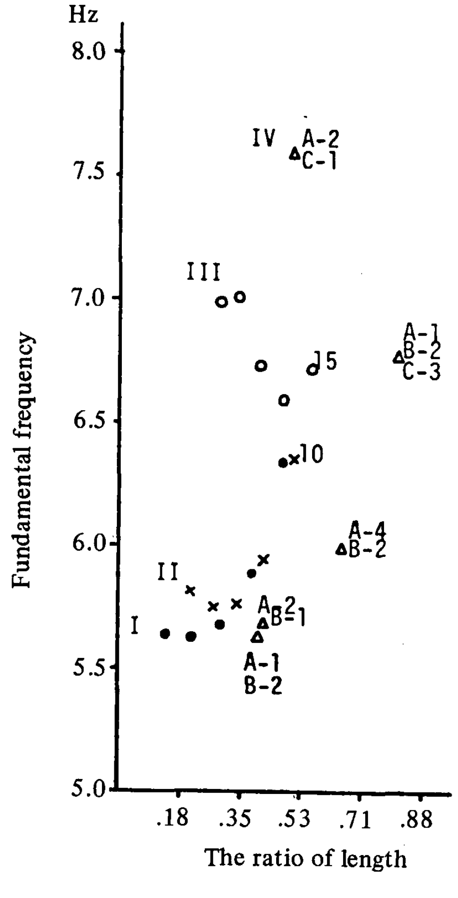

Fig.-4 The relationship between fundamental frequency and the ratio of length for gabled type

From total consideration, it is concluded that the desirable methods of bracings are those such that the end of a brace is situated nearly at the supporting point in a column and the other end is placed nearly at the ridge of a roof.

2) On the case of semi-circular type

In this case, results are similarly discussed such as the case of gabled type, Fig.-5 shows the relationships between horizontal and vertical displacements.

It is founded that the effective methods of bracings for semi-circular type frames are the cases of No.6, No.13 and No.14.

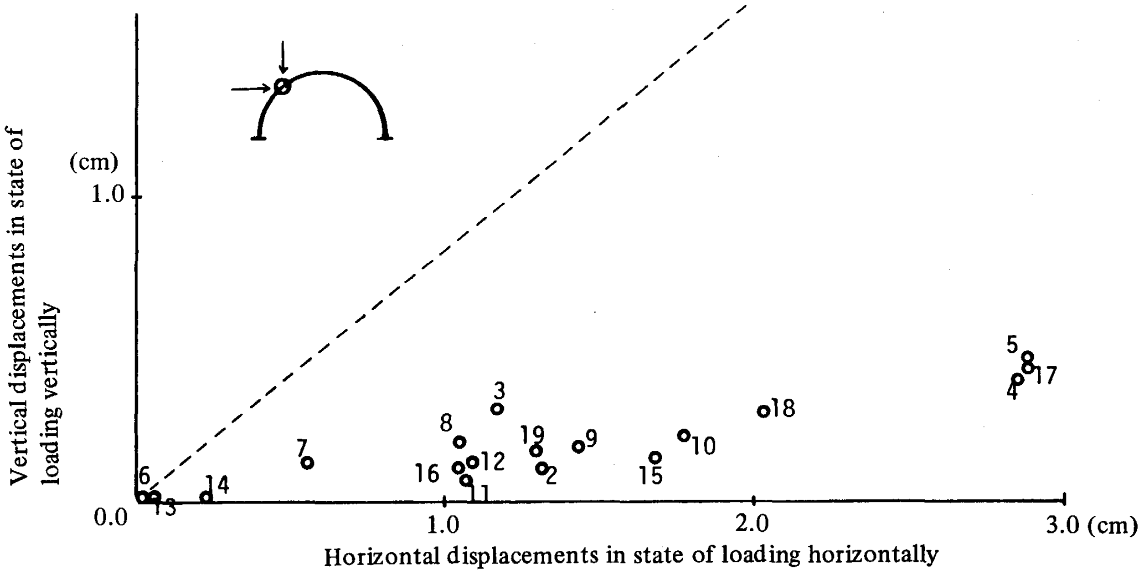

Fig.-5 The relationship between horizontal and vertical displacements for semi-circular type

Fig. 6 shows the relationships between horizontal and vertical F'_i/F'_0, to each directionally loaded case. It is founded that the cases of No.6, No.13 and No.14 show the excellent effect of bracings.

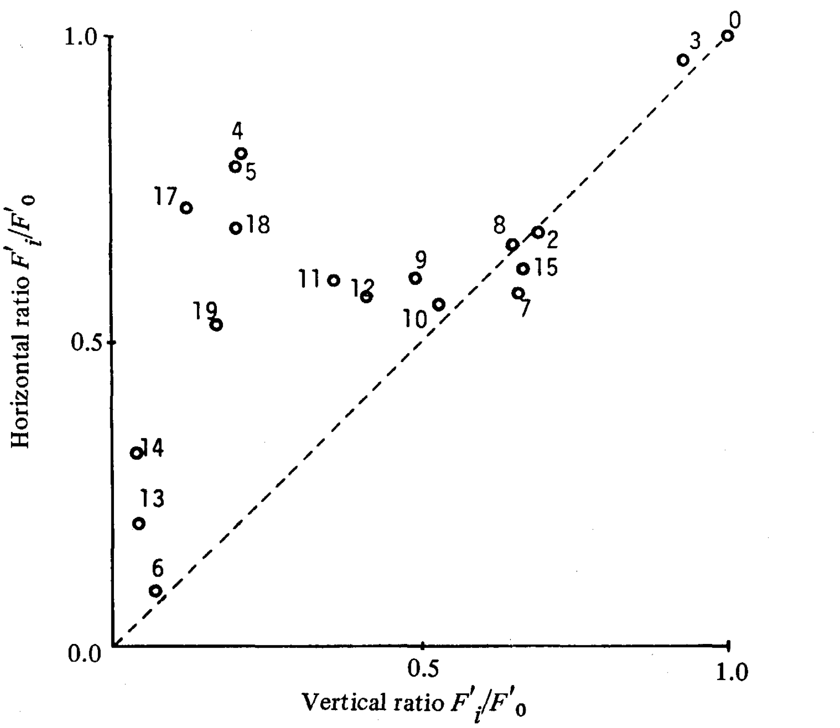

Fig.-6 The relationship between horizontal and vertical ratio F'_i/F'_0 for semicircular type

Fig. 7 shows the relationships between natural frequencies and the length ratios. In this figure, the case of No.6 takes the largest value of natural frequency and next case is No.13. At 0.50 of the length ratio, the cases of No.14 and No.7 are to be more effective methods of bracings.

These cases such as No.6, No.13 and No.14 are composed of a fundamental pattern of No.14. It is considered that the effective methods of bracings for semi-circular types are those which one end of brace is placed at the supporting point and the other end is placed nearly at the top of a frame.

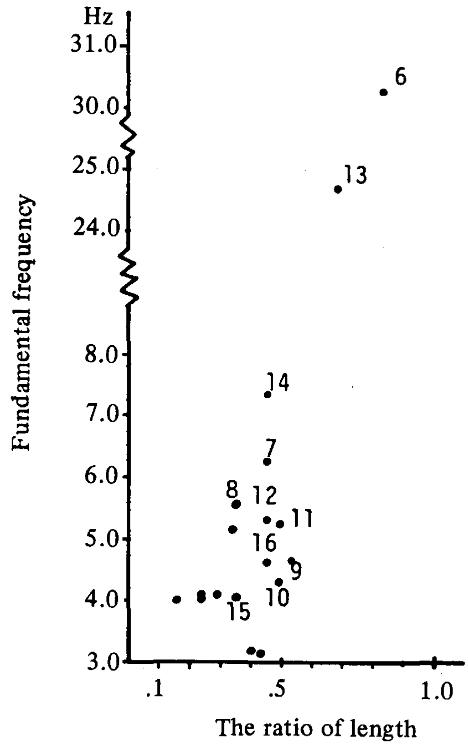

Fig.-7 The relationship between fundamental frequency and the ratio of length for semi-circular type

IV. Conclusions

Generally, the methods of bracings are not well discussed and are employed by empirical ways. However, as showed in this paper, the effect of bracings is considerably affected by the length ratios and its introducing methods etc..

In this paper, statical and dynamical investigating methods are proposed and effective methods of bracings are founded as follows;

1) For gabled houses, it is desired that braces are placed such as one end is connected to the supporting point of a column and the other to the eave of a roof.
2) For semi-circular houses, it can be said as above 1).

As the length ratio is not defined, it is not able to determine the most effective method of bracings. But it was founded in this paper that effective methods of bracings for green houses can be obtained analitically if some conditions such as green house's scales, typed, the length ratio of a brace to a main member and material conditions etc. are given.

V References

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