Acquisition of designable space for planar steel frames

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Abstract

This paper describes a methodology for the acquisition of designable space for planar steel frames. Here, the designable space is obtained out of the universe which contains the all sets applied for a structural design of a building. A designer takes some sets of solutions simultaneously using a new concept design system, although he or she gets only one set of solutions with the conventional method. The new concept design system was developed taking the knowledge system and data flow system into account.

For a convenient structural design system for unskilled engineers and students, a new concept needs to be introduced to the conventional structural design system. It is a laborious process for beginners to become skilled in structural design because it often takes a long time to find the rational solutions to design problems.

The new concept for a structural design system is developed with Excel and DSP. Excel is used for the development because it is the most popular spreadsheet type application and uses the programming language VBA. DSP is the special computer language which is developed by Nagasawa and possesses a high potential for writing design codes. This system has the capability to get designable solutions simultaneously. This is proof of the new concept as an acquisition of designable space. A demonstration was conducted as to how a designable space moves in the whole design space.

Keywords: structural design, computer assisted design, design space.

1 Introduction

This paper describes on both a concept of acquisition of designable space and a methodology for the acquisition of a pertinent solution for planer steel frames. A

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structural design system of arbitrary shape steel planar frame based on a knowledge system was developed in this study. The system is different from other conventional structural design systems in the concept and the architecture of processing. Conventional structural design systems often force the beginner into a laborious process of finding the rational or best solution. Consequently it is difficult to become proficient with these systems in a short time, although the systems are used as effective tools by structural design experts. This study is aimed at developing a system that advances structural design skills for structural design beginners. There are various knowledge-based expert systems for structural design [1], although they are not suitable for the beginners.

2 Designable space and pertinent solution

2.1 Acquisition of design solution

An action of the structural design is to select a unique rational or reasonable data set (called a *pertinent solution* in this study) applied for the structural design of a building from all designable data sets (called a *design space* in this study). However, there is a lot of designable data sets in the design space. It is inefficient to calculate all sets at one time, because it would take too long to achieve. Therefore, some design solutions (called *designable space* in this study) under constrained conditions are acquired from the design space and a pertinent solution is acquired by moving the designable space into the design space [2]. In the study, a pertinent solution is distinguished from the optimal solution. A pertinent solution is selected by the designer's decision, although the optimal solution can be calculated automatically.

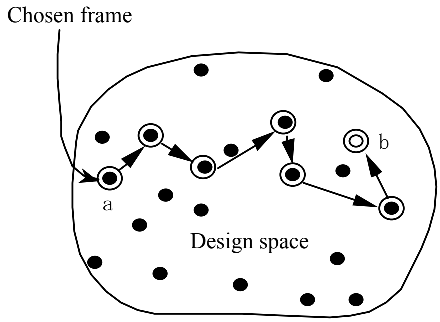

Figure 1: Pertinent solution search in a conventional structural design system.

2.2 A comparison of the new concept with the conventional method

A model depicting the pertinent solution search in a conventional structural design system is shown in Figure 1. In the pertinent solution search in a conventional structural design system, a designer takes the first prepared frame (a, in Figure 1) and examines the frame for structural design using the result given by the system. When the designer is satisfied with the frame the design process is finished at this step. If not, designer has to select other frame from the design space and examines it. In this way, he or she implements a pertinent solution search from doing a rundown.

On the other hand, there is a model depicting a pertinent solution search described 2.1 and shown in Figure 2. In this process, a designer takes the first prepared frame (a, in Figure 2) in the same way as in Figure 1 and he or she acquires some designable frames (designable space) constituted by members that have a close dimension to that of the member that constitutes the assumed frame at a time. When the designer reasons that the point marked b is the best frame fulfilled design condition, the design process is finished at this step. If not, the designer makes point b the new assumed frame and implements an acquisition of new designable space. At this time, if the designer reasons that point c is the best frame fulfilled design condition, this design process is finished. However, if this is not the case, the designer repeats the previous step with the same methodology and acquires a pertinent solution (d, in Figure2).

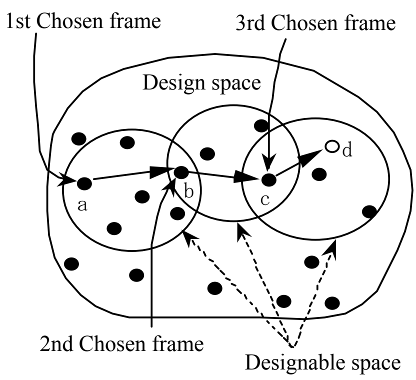

Figure 2: Pertinent solution search in the new structural design system.

3 New concept design system

3.1 Development of a new concept steel structural design system

A new concept structural design system, that is achieved by the design process concept as described in Chapter 2, for steel planar frames was developed in this study. The system is applied to arbitrary shape steel planar frames. The system was developed with Excel and DSP. Excel is the most popular spreadsheet type system, which uses the Visual Basic for Applications (VBA) programming language, and is able to handle figure or graphics on the sheet. It is convenient for dealing with arbitrary shape frame design. On the other hand, DSP is a special computer language that was developed by Nagasawa and possesses a high potential for scripting design codes and also has a generate-and-test method function [3]. These are the reasons why Excel is used for the development.

Structural member design in a steel frame is based on the specification for steel structure design in Japan [4]. The expression of equations and notations described in the specification generally has the form shown in Figure 3. However, if those in Figure 3 are coded in the conventional computer language such as Basic or Fortran, the description sequence of program code must be deferent from the sequence shown in Figure 3. Also, a large amount of labor to develop whole system is necessary for systems programmed in Basic or Fortran.

$$\frac{\sigma_c}{f_c} + \frac{{}_c\sigma_b}{f_b} \leq 1 \qquad (6.1)$$

and

$$\frac{{}_t\sigma_b - \sigma_c}{f_t} \leq 1 \qquad (6.2)$$

where

$$\sigma_c = N/A$$

$${}_c\sigma_b = M/Z_c$$

$${}_t\sigma_b = M/Z_t$$

Figure 3: Expression of equations and notations in design specification.

On the other hand, DSP is a spreadsheet type application and it uses the concept of data flow. This means a programmer doesn’t have to take care of the sequence of program code. Therefore, not only a usual computer programmer but also a designer, who is not familiar with program coding, can develop a system by themselves, and he or she can rapidly respond to changes to the design specification.

4 Outline of the system

4.1 Graphical user interface of arbitrary shape steel planar frame

It is necessary that there is a graphical user interface (GUI) for a system user to design an arbitrary shape steel planar frame for visualization. In the study, Excel is used for the GUI of the system. It is the reason why Excel is taken for the development is that it is the most popular spreadsheet type application and uses the VBA programming language. Also, it can handle graphics on the sheet. It sets some buttons and menus to be able to implement the selection and change for input and output by the mouse. An outline of an arbitrary shape frame is

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drawn at upper left of Figure 4, and information of structural members and load conditions is also included. A demonstration of the methodology for acquisition of pertinent solution is shown in Figures 5 and 6.

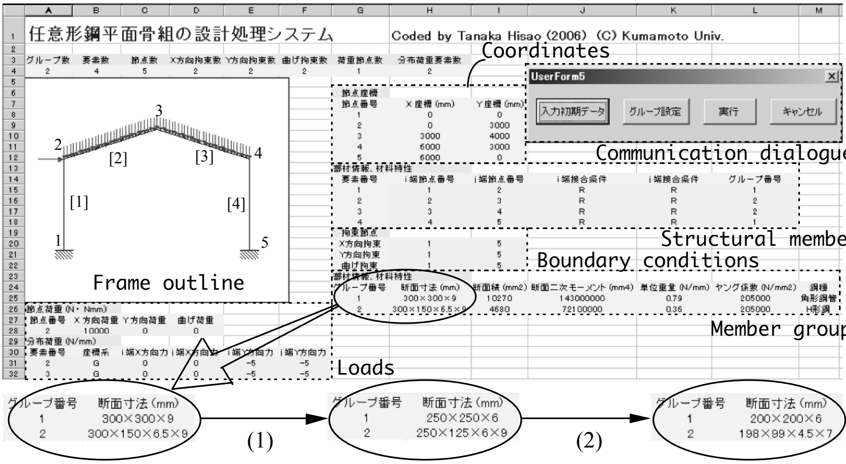

Figure 4: View of spreadsheet and process of change of members.

An example process of the methodology is described below. One set of structural members such as beams and columns of which the frame consists is prepared for the first structural analysis and examination of all the members. From this the first acquisition of designable space is achieved, as shown in Figure 5. The vertical axis in this graph is the total weight of the frame, which is designable, and the lateral axis is member height, which is variable for the design. Constrained conditions are shown in (1) of Table1. The first chosen member for examination is plotted as a point (a) in Figure 5. A change of members for the improvement of the design solution is implemented by clicking on another design solution in this designable space. For example, when the lightest frame (b) in Figure 5 is selected, the previous data of each member in the frame is replaced by new value. As a result, all members are refreshed on the data input sheet, shown in Figure 4.

When the designer needs another improved solution, the rewritten members are applied for the next structural analysis and those are examined with the structural design code. Also the designer takes new constrained conditions shown in (2) of Table 1 for getting lighter designable members. As a result, the designer gets the new designable space shown in Figure 6. When Figure 5 is compared to Figure 6, it is shown that the designable space moved in the design space. More rational reasonable solution for him or her is acquired by selecting a design solution (c) which is the minimum lightweight data set in designable space shown in Figure 6.

This agrees with the process shown in Figure 2, where the pertinent solution is acquired by moving the designable space in design space.

Table 1: Constrained condition for acquisition of designable space.

	Item	Colum (Square steel tube)	Beam (H-section)
(1)	Height	350 - 250 mm	350 - 250 mm
	Width		200 - 100 mm
(2)	Height	250 - 0 mm	250 - 0 mm
	Width		150 - 0 mm

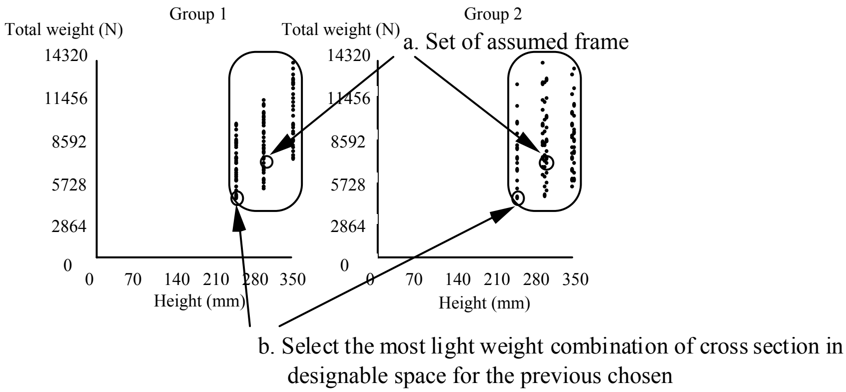

Figure 5: Acquisition of designable space (1).

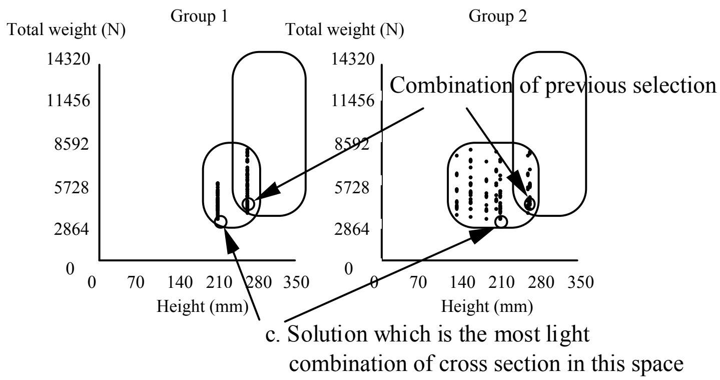

Figure 6: Acquisition of designable space (2).

4.2 Constitution of the system

The structure of the system is shown in Figure 7. In the system, the selection or consideration of design solutions are implemented by human decision for a human-driven design style, although calculation is implemented by computing system. The visualization of the designable space is a noteworthy aspect of the system that makes comparing data of members easier for designers.

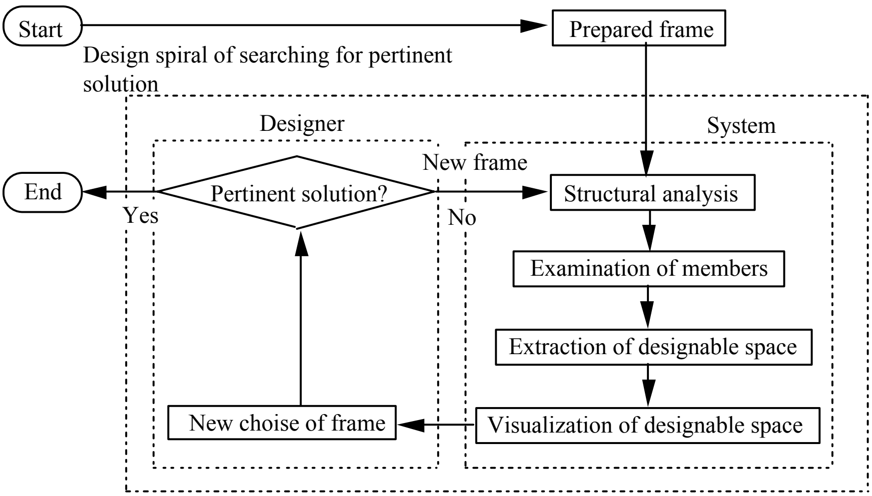

Figure 7: Design procedure of structural design system for arbitrary shape steel planar frame.

5 Conclusions

In this paper, the visualization of designable space in the structural design system for arbitrary shape steel planar frames based on a knowledge system was introduced. This system with new concept means that the unskilled structural designer can easily obtain the pertinent solution out of many designable data. This is a proof of the new concepts capability for the acquisition of designable space. A demonstration was outlined for how a designable space moves in the whole design space.

Acknowledgement

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