Knowledge-based Structural Design System of Steel Deck Slab for Beginners

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SUMMARY:
This paper describes a development of a new structural design system for beginner education. The object of this research is structural design of deck structural slab. This system was developed based on a new design concept. This system provides a designer with multiple solutions and has a mechanism in which the designer determines just one design solution suitable for a design out of these multiple solutions by oneself. The designer can compare and examine with solutions in a design. Moreover, because data-flow programming language DSP was used for this system, a problem of black box can be solved. Therefore, a design beginner can raise one's design sense and skill by means of this system. A performance test of deck structural slab was executed using this system. Thereby, useful data for beginners was obtained.

Keywords: Steel structure, Deck slab, Design system, Education

1. INTRODUCTION

There was an affair of "Structural Calculation Forgery Problem" known as a serious problem in the construction industry 2005 in Japan. After that, the Building Standard Law was revised and the qualification of structural design specialty was established newly. Thereby, the importance of structural design has been recognized again. Moreover, the younger age group is decreasing in number with an aging society. Therefore, excellent structural designers are immediately required. Now, consistent structural calculation software using a computer is generally used in the building structural design. The software is used also for beginner education. However, the contents of information are black boxes in order that the software performs processing automatically. Moreover, a designer cannot determine a solution by oneself in order that the designer can obtain only a single solution under one condition. Beginners cannot raise their design sense in short term from the above things.

In this research, a new structural design system for beginner education was developed with respect to deck structural slab that is applied for training of structural design of the beginners among several sub-structural members in a building. Moreover, a performance test of deck structural slab was executed using this system in order to obtain knowledge of structural design for the beginners.

2. CHARACTERISTICS OF DECK STRUCTURAL SLAB

The object of this research is structural design of deck structural slab. The deck structural slab is one of secondary members such as sub-beams, purlins in a frame. The secondary members are structural components that do not resist against the seismic force like girders and columns. Design of the secondary

members can be performed in a short time. Moreover, that is not needed a lot of knowledge and is used for beginner education. Deck structural slab was chosen for an exercise of structural design for the beginners or students.

The deck structural slab is shown in Figure 1. The deck structural slab is one type of steel deck slabs. In spite of the fact that deck structural slab also consists of concrete plates and steel decks, this slab supports gravity load by only the steel decks. Since the slab allows neglecting process design of the concrete, a complicated calculation process is excluded. In addition, this type of slab is lightweight and strong structure and makes a fabrication of the slab easy. Thereby, structural design of this slab is used for small-scale steel buildings. Structural design of deck structural slab is enough suitable for beginner education.

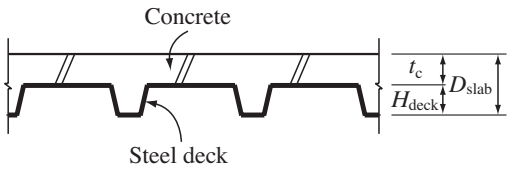

Figure 1. Deck structural slab

3. CONSTRUCTION OF STRUCTURAL DESIGN SYSTEM

3.1. Computer Language for Design Calculation

Data-flow programming language DSP was used to develop this system. DSP is developed for design calculation by Nagasawa et al., which has a function of generate and test. The program code in DSP language is written in individual spread sheet that contains functional processes. A bunch of spread sheets works for a design calculation. A program module can execute stand-alone or perform with some other modules under cooperation. On the other hand, a work can be divided into several classes is unified. A calculation processing is not exception. Design specification is usually described like a mathematic textbook, in which some equations are written first followed by notation. Data-flow programming language is convenient to code like the textbook without consideration of processing order. Therefore, a program can be developed comparatively easily and a user can grasp the inside of a module easily.

In past research, it was asserted that the transparency of the contents of process is required and a program description with data-flow programming language has guaranteed the transparency of information. It is thought that a system using DSP is effective in beginner education.

3.2. Development of The System

The central portion was developed by means of DSP, as the foregoing paragraph also described. The design was performed under the design standard. Where, a new design concept was used for this system. It consists of design space and designable space. The design space and the designable space are shown in Figure 2. All of design solutions include solutions applicable to a design and solutions inapplicable to a design. In the conventional design, a designer determines whether one solution can be designed out of these design solutions. The design space was defined as all set of the design solutions applicable to a design and the designable space was defined as a subset that reduce the number of the design solutions from the design space. This system provides the designer with multiple solutions that exist in the designable space. This system has a mechanism in which the designer determines just one design solution suitable for a design out of these multiple solutions by oneself. Because the designer can compare and

examine with these multiple solutions in a design, a design beginner can raise one's design sense and skill.

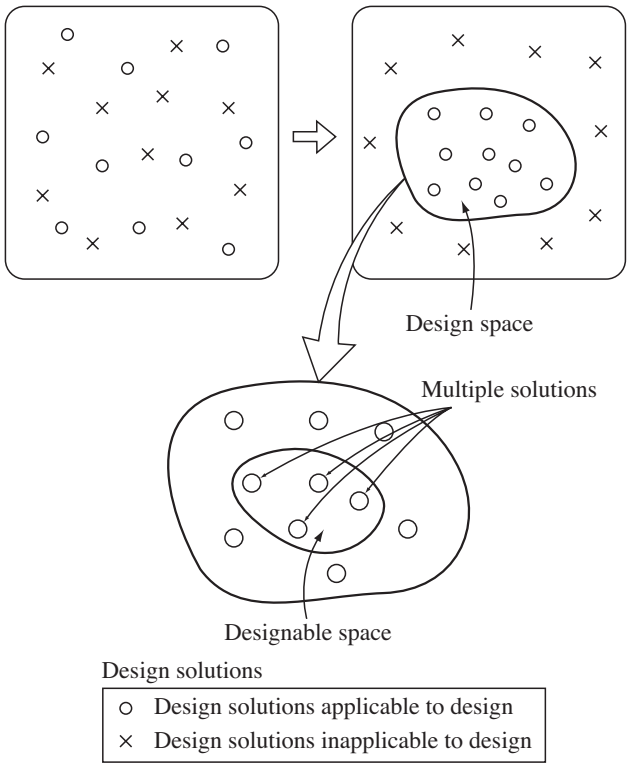

Figure 2. Design space and designable space

4. PERFORMANCE TEST OF DECK STRUCTURAL SLAB

4.1. Purpose

Deck structural slab is generally used for small-scale steel buildings, as mentioned above. However, in an actual design, a design beginner does not know how long steel decks can span between beams or girders located both ends of the slab. It is difficult for the beginner without empirical knowledge to get the suitable design solution. Thereby, performance of deck structural slab was tested and a design judgment material that helps the design judgment was sought by means of this system.

Where, limit span length L_d was sought as the design judgment material. L_d is a span length of limit that can build the slab across. Since L_d gives the boundary of the design space, a designer can know the extent of the design space by L_d. It is expected that providing a beginner with L_d lead to support of beginner education.

4.2. Method

The specimen for the test by this system is one slab surrounded with four steel beams as shown in Figure 3. There are ditches in a steel deck and they pass in X-direction. Since the direction of the strong side of the steel deck is X-direction, L_d takes the value of the limit span length in X-direction. A test was conducted using this system. The span length in X-direction was changed every 0.1m and the number of design solutions was sought out of the served steel deck data in a catalog. Since the number of design solutions shows the extent of the design space, L_d was sought. The relation of L_d between the number of design

solutions was demonstrated with a graph and a performance evaluation of deck structural slab was concluded by this graph. The input data for the test is shown in Table 1.

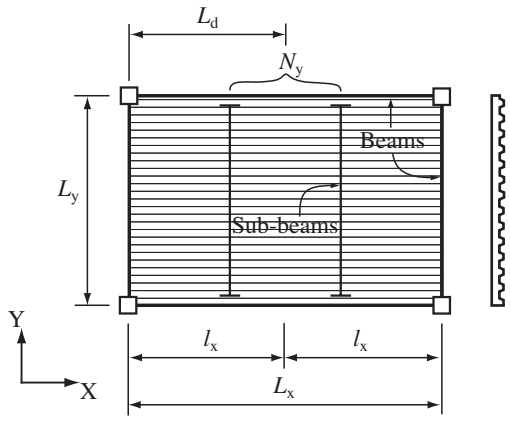

Figure 3. Test specimen

Table 1. Input data

Span length in Y-direction			L_y (m)	3.6
Number of sub-beams			N_y (number)	1
Load		Live load (Completed)	L_{L1} (N/m^2)	2900
		Live load (Under construction)	L_{L2} (N/m^2)	1470
		Floor finish load	L_F (N/m^2)	700
Material data	Steel deck	Young's modulus	E_s (N/mm^2)	205000
		Allowable stress for temporary loading	f_t (N/mm^2)	235
	Concrete	Specified design strength	F_c (N/mm^2)	18
		Thickness	t_c (mm)	60

4.3. Test Result

Four indexes are prepared for the test of structural design of a slab. They are represented by height of steel deck, the number of sub-beams, thickness of concrete and design evaluation measure.

4.3.1. Height of steel deck

L_d of deck structural slab was examined. The relation of L_d and the number of design solutions is shown in Figure 4. The number of design solutions is decreasing suddenly when L_d is about 2m. Thereby, deck structural slab is suitable for a design of small-scale slabs that is about 1-2m. H_{deck} shown in a figure is height of a steel deck when a design became impossible. The more the number of the design solutions decreases, the longer the value of H_{deck} becomes. In order words, the longer the value of H_{deck} becomes, the longer the length of limit span L_d becomes. Therefore, it is shown that H_{deck} has a great influence on L_d.

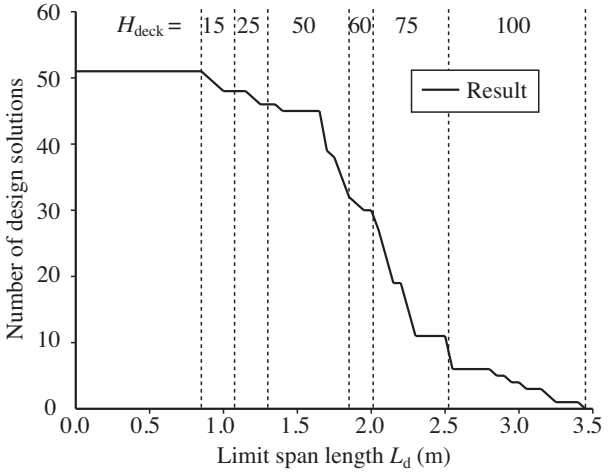

Figure 4. Height of steel deck and limit span length

4.3.2. Number of sub-beams

Sub-beams are arranged in Y-direction of the slab surrounded with four beams. A designer has to determine the suitable number of sub-beams N_y according to the design. However, it is difficult for a beginner to determine it. Where, the influence that N_y has on L_d was examined. The calculation result (N_y=1) of the preceding clause was compared with the calculation result of N_y=0 and N_y=2.

The relation of the value of L_d between the number of design solutions is shown in Figure 5. The number of design solutions increases most when N_y is 1. Thereby, L_d takes the maximum value in the case that N_y is 1. It is because that maximum bending stress of a steel deck becomes the smallest in the case that N_y is 1.

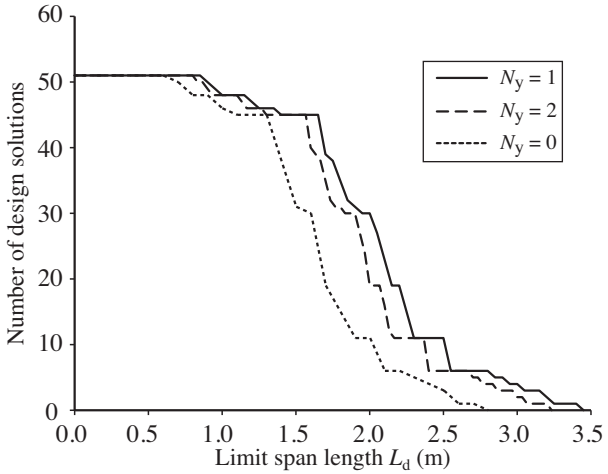

Figure 5. Number of sub-beams and limit span length

4.3.3. Thickness of concrete

Thickness of concrete t_c is the measured value between the upper face of the slab and the top of the steel deck. t_c has a great influence on thickness of the slab. However, it is difficult for a beginner to determine the pertinent value of t_c. Where, the influence of t_c has on L_d was examined through a series of design calculation. The result in the case that t_c=60 was compared with that in the case that t_c=120 and t_c=180.

The relation of L_d between the number of design solutions is shown in Figure 6. The larger thickness t_c becomes, the less the number of design solutions is. Thereby, thickness of concrete affects limit span length as load.

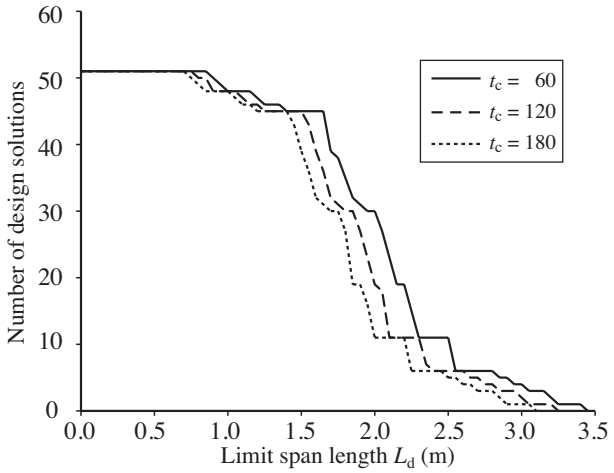

Figure 6. Thickness of concrete and limit span length

4.3.4. Measure of design evaluation

In this system, a designer cannot know why solutions inapplicable to a design cannot be designed. That is, the designer cannot know measure of design evaluation. This shows what evaluated a design. It is important for the beginner to know this. Where, measure of design evaluation was examined. Three indexes were prepared in the examination of deck structural slab design. They are bending stress, deflection and eigenfrequency. These were expressed to three kind of evaluations by means three indexes as shown in Table 2. Evaluation 1 is the calculation result of the preceding clause.

Three evaluations were investigated and compared. The relation of L_d between the number of design solutions is shown in Figure 7. The number of design solutions takes the least value in the case that the evaluation type is 1. Thereby, examination of eigenfrequency has a great influence on L_d. Eigenfrequency is greatly concerned with amenity. In the case of deck structural slab, a problem of amenity is the most important.

Table 2. Evaluation

Examination items	Evaluation		
	1	2	3
Bending stress	True	True	True
Deflection	True	True	False
Eigenfrequency	True	False	False

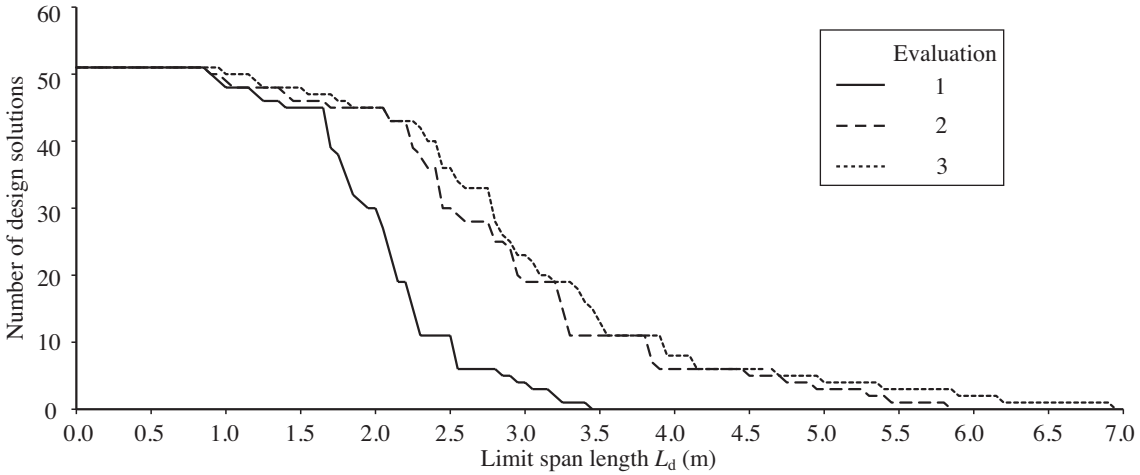

Figure 7. Measure of design evaluation and limit span length

5. CONCLUSIONS

This system was developed based on a new design concept. This concept does not exist until now and it was effective in beginner education. A performance test with respect to deck structural slab was executed using this system. The view acquired below is described.
The acquired view is as follows:
1. Span length that is about 1-2m is suitable for a design of deck structural slab.
2. Limit span length is greatly influenced by height of a steel deck.
3. Limit span length becomes the longest when the number of sub-beams is 1.
4. Thickness of concrete affects limit span length as load.
5. The examination that governs design evaluation is mainly eigenfrequency.

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