New Steel Structural Design Tools Based on Knowledge Processing for Introductory Education

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SUMMARY:
This paper describes on a design tools with the new concept that was recommended previously by authors. Secondary structural members such as slabs in a steel building are usually designed by hand to learn the design rules. Therefore, senior engineers give them such problems for education or training. As for design of steel deck floor, the designer has to choose only one type of slab with steel deck out of three types. It is rather difficult for the beginners to achieve it. Because each type of slab is different from others and there is plenty of variation with respect to shape and size of the floor. The new structural design system developed in this research gathers a sub-set of suitable solutions with respect to a problem. As for design of steel deck floor in Japan, a demonstration was conducted on some problems with the system, following an explanation of the concept.

Keywords: Design tool, Structural design, Education, Steel deck slab, Comparison design

1. INTRODUCTION

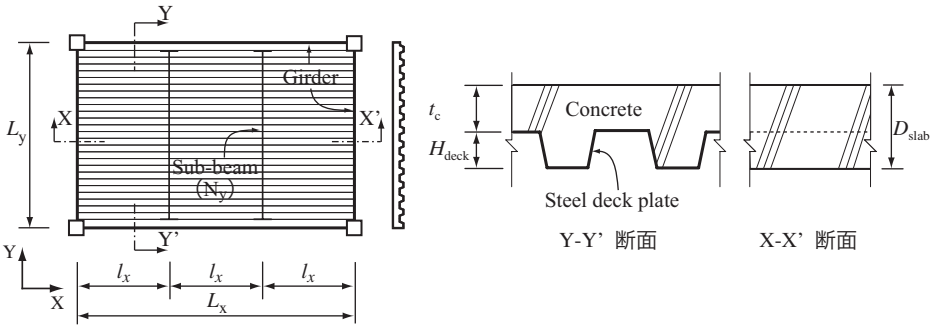
The beginners in the structural design field usually calculate the structural frames by hand under education, and get skilled gradually. Generally, the structural engineers assume some sizes of members and calculate with them, and judge if they are suitable or not. However, all members not necessarily decided in the first trial.

Then the designers have to try once more calculation with some another sections if the sections chosen previously were not right solution. For example, they have to spend much time if they repeated the same works. Instead, they can spend the time for study of evaluation of design solutions, if they could use computer-assisted design system.

The authors developed a structural design system with the new concept. The system is oriented introduction education. A subject of design for the beginners is a secondary structural member, because it is suitable for first training for structural design. A steel deck slab for secondary steel design is shown in Fig. 1.1. The structural system is developed for design calculation of the slab as shown in Fig. 1.1. The plan and the section of the slab are illustrated as Fig. 1.1. (a) and Fig. 1.1 (b) respectively.

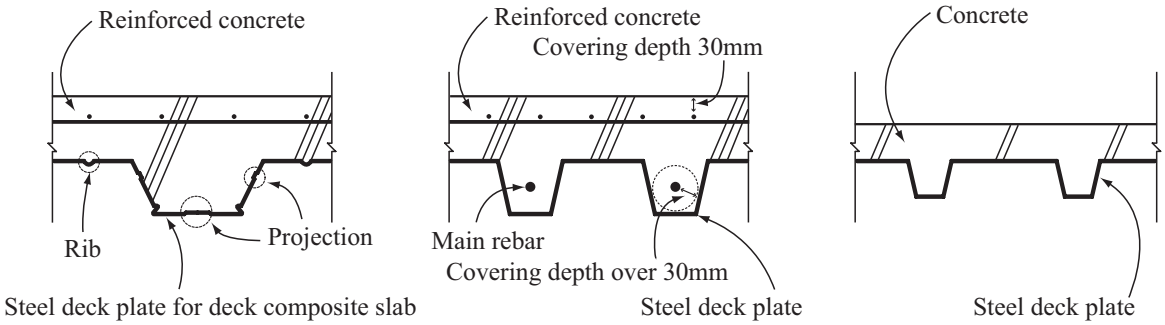
Three types of steel deck slab are shown in Fig. 1.2. Each type has some good points depending on the size, the proportion, or use of the slab in the floor. As for design of steel deck floor, the designer has to choose only one type of slab with steel deck out of three types. However, there are two major problems of the following. The first is the fact that there are differences in idea of design among the three types. Therefore, the beginners need to understand and learn the method of design each deck slab type for get the skill. The second thing is the fact that they do not enough time to get knowledge of selection of the deck slab that is suitable. Therefore, it is too difficult for them to choose the rational slab type.

This paper proposes the new structural design system that gets solutions out of the slab types. The solutions can be compared with each other by means of method of the comparison design. Therefore, the designers can understand characteristics of slab types through their work with the system. Consequently they are effective to understand that the rearing of the sense and the estimate method of solutions.



(a) Floor plan of a steel deck slab (b) Section of a steel deck slab

Figure 1.1. Composition of steel deck slab



(a) Deck composite slab (b) Deck compound slab (c) Deck structural slab

Figure 1.2. Sections of steel deck slabs

2. STEEL DECK SLAB

2.1. Proportioning and Examination of Section

The designer carries out proportioning and examination of section in accordance with the design standard of steel deck slab. The examination on stress and deflection of the slab is done with respect to both the loads under construction and the loads post construction as follows. First, a steel deck plate under construction should be examined because it must stand for not only self-weight but also the load as weight of concrete, which does not yet finish hardening. Namely, concrete under construction cannot bear the load. Therefore, the load of post construction consists of the both weight of steel deck and the weight of concrete. Second, the examination of both steel deck and concrete is done for the situation of post-construction. There are three types of steel deck slab, and they must be examined by means of its design rule.

2.1.1. Design of slab under construction

Structural design of steel deck slab under construction must be done with respect to the following two items.

1) Bending stress; only steel deck plate
2) Deflection; only steel deck plate

2.1.2. Design of slab post construction
Structural design of steel deck slab post-construction must be done with regard to the following four items.
1) Positive bending stress; steel deck plate and rebar in reinforced concrete at the center of the slab
2) Negative bending stress; rebar in reinforced concrete at the end of the slab
3) Deflection; at the center of the slab
4) Natural frequency

2.2. Deck Slab Types

2.2.1. Deck composite slab
Deck composite slab is shown in Fig. 1.2 (a). The slab of this type supports the loads both deck plate and concrete. Steel deck plate because of its good properties of material can support both tensile and compressive forces, and concrete supports only compressive force under bending moment caused by floor load. The slab of this type has corrugated steel plate with embosses and ribs for prevention against exfoliation of concrete from steel plate.

2.2.2. Deck compound slab
Deck compound slab is shown in Fig. 1.2 (b). The slab of this type is a hybrid plate with reinforced concrete and corrugated steel plate. They act independently against bending force caused by the floor loads. The rebars are placed in a ditch of deck plate for getting high performance of reinforced concrete plate. This structural element supports the loads by both reinforced concrete and deck plate after the concrete finish hardening.

2.2.3. Deck structural slab
Deck structural slab is shown in Fig. 1.2 (c). The slab of this type is just deck plate itself, and supports by the loads only deck plate. Therefore, concrete on the deck plate is only play a role of weight.

3. THE DESIGN SYSTEM OF STEEL DECK SLAB

3.1. Structure of System

This paper demonstrates a new structural design system. The system is made up with three design systems developed for each slab type by the authors. In addition, a concept of comparison design is implemented in the new system. Therefore, it makes the designer can easily choose a suitable slab type out of three structural types of steel deck slab through their handling the system with evaluation of solutions. There are plenty of variations with respect to shape and size of the floor. The design evaluations of steel deck slab are given as follows.
1) Bending stress / allowable stress
2) Deflection
3) Weight of deck slab per one square meters
4) Depth of steel deck slab
5) Natural frequency

The comparison design makes a designer skillful because the system provide them useful information for the their decision of unique solution out of a lot of candidates. There are some points of view of decision of the solution through comparison with three types of slab. They are economic efficiency, characteristic

of structure and the constructability. The beginners can study the difference of each slab type by using the system that has the functions. They can know the peculiarity of slab type.

The system of the comparison design is shown in Fig. 3.1. The design system shows the designer the solutions that are obtained from design with respect to each slab type at the same time. The candidates are plotted, which were obtained from the systems for three all slab types, in the figure. The evaluation is performed with graph by the designer. The graph has two axes of evaluations, and all solutions scatter on the coordinate system.

Eventually, the most suitable solution is plotted on the up and right place in the graph field when the two good evaluations take the up and right directions whatever type of slab. The evaluations of the solutions vary in conjunction with personal skill of the designer. Therefore, the designer has to make decision through the comparison design by each evaluation, and was hoped for still more study.

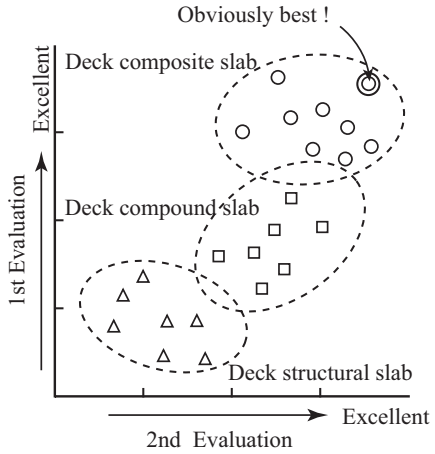


Figure 3.1. Function of comparison design

3.2. Graphical User Interface of The System

This system utilizes the Excel for an easy familiar with the users. Moreover, the designers can visually and intuitively use the system for evaluation of the solutions. Fig. 3.2 shows the block diagram of the system. First, a user inputs the necessary information about the design. Second, the system indicates the processing design. Finally, the user selects one solution, and decides the suitable solution through graphical user interface (GUI) of the system.

Fig. 3.3 shows output data of the system. Here, the system is introduced the concept of comparison design which is realized. It is shown a table and seven graphs on the computer display. As mentioned in the section 3.1, the design of the deck slab has many items of the design evaluation. However, the beginners cannot evaluate using the items at the same time. The system provides the user the designable space, which is defined by the authors with respect to a problem. Here, it has six graphs that are took weight of deck slab for the y-axis and bending stress per allowable stress, deflection and depth of deck slab for the x-axis for the coordinate system. In the addition, it has a graph that takes depth of deck slab for y-axis and natural frequency for the x-axis. The reason why natural frequency is included in the evaluations is important in livability as well as other items are corresponding with safety. It is possible that frequency of deck slab is bad for livability and working conditions. It is a case of an obstacle for a precision machine has dislike vibration. Therefore, the system has to judge from a synthetic that is included usability.

The solutions are plotted on the graphs. The user knows the solutions that keep up with each graphs and a

table by selecting with the solution. The user can understand a relationship between items of evaluation that are drawn on the display. Thus, he or she can design a structure such a steel deck slab with comparison design system.

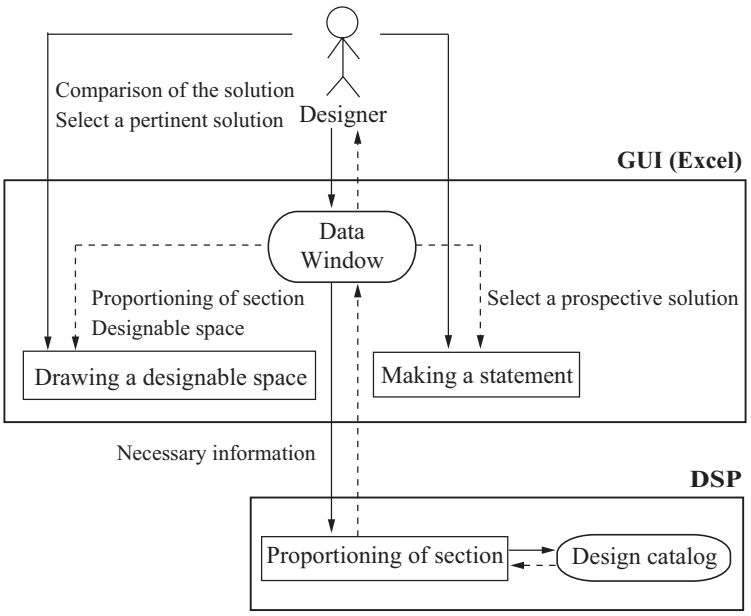


Figure 3.2. Block diagram of the system

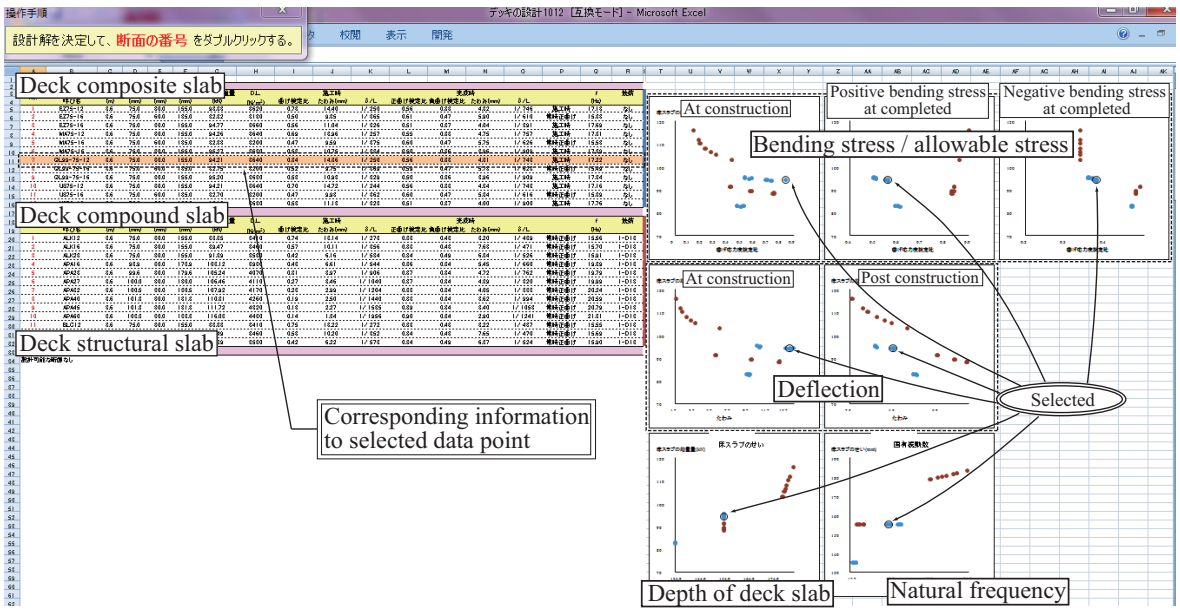


Figure 3.3. Output data of the system

4. AN ACTUAL EXAMPLE OF DESIGN

This chapter describes performance and evaluation of design with some examples.

4.1. Design Condition

Table 4.1 is shown as necessary input data for design of a steel deck slab. A restriction for designable space was set in order that the number of solutions is reduced for the user. Here, the value of ratio of bending stress to allowable stress should be within a range of 0.6 to 1.0. The system takes input data and the restriction. The system outputs the solutions that were calculated in light of the design standard with design catalog of steel deck plates.

Table 4.1. Input data

Size of steel deck slab		Length of X-direction	L_x (m)	3.6, 7.2
		Length of Y-direction	L_y (m)	3.6
The number of steel sub-beams			N_y (number)	1
Load		Live-load at completed	L_{L1} (N/m^2)	2900
		Live-load at construction	L_{L2} (N/m^2)	1470
		Weight of finish	L_F (N/m^2)	700
Material	Deck plate	Young's modulus	E_s (N/mm^2)	205000
		Allowable stress	f_t (N/mm^2)	235
	Concrete	Specified design stress	F_c (N/mm^2)	18
		Thickness	t_c (mm)	60, 120, 180
	Rebar	Specified design stress	F_r (N/mm^2)	295

4.2. Evaluation of The Solutions

In this section, the evaluation of the solutions is showed. An example is designed under the conditions that L_x is 3.6 m (Slab A) and 7.2 m (Slab B). Slab A represents rather small slab and can be designed with all slab types. However, it is difficult for Slab B to be designed with deck structural slab because the slab is rather large one. The following is what investigated on the solutions for each item of the evaluation.

4.2.1. Bending stress per allowable stress and deflection

Fig. 4.1 is shown as the relationship between weight of deck slab (W_{slab}) and the ratio of bending stress to allowable stress (σ_b / f_b). In addition, the relationship between W_{slab} and deflection (δ) is shown in Fig. 4.2. According to Fig. 4.1, the solutions of the deck composite slab and the deck compound slab are distributed in the area of large value under construction or upon positive bending stress at completed for σ_b / f_b. Moreover, the solutions of the deck structural slab are distributed in the area of large value upon negative bending stress at completed for σ_b / f_b. According to Fig. 4.2 (a), the deck compound slab of Slab B is decided the solutions in part of deflection under construction. Consequently, the beginners can know item of evaluation that is decided.

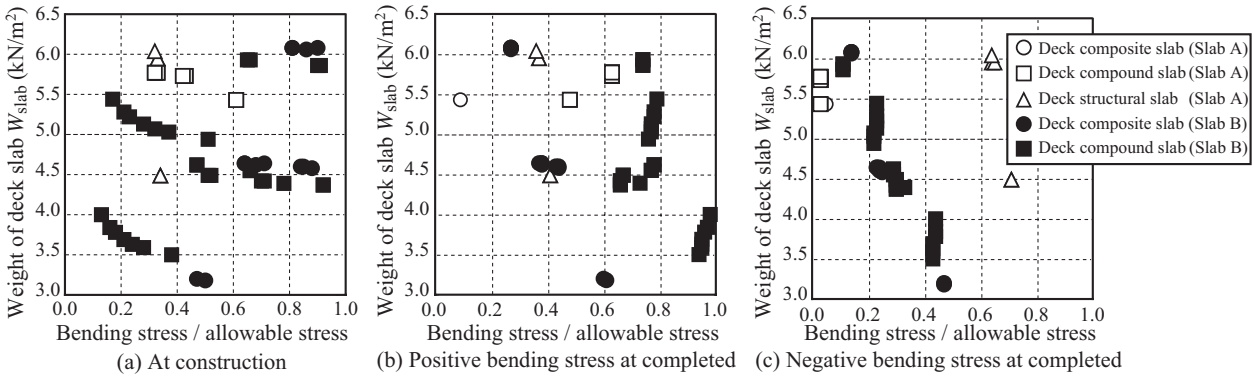


Figure 4.1. Bending stress per allowable stress

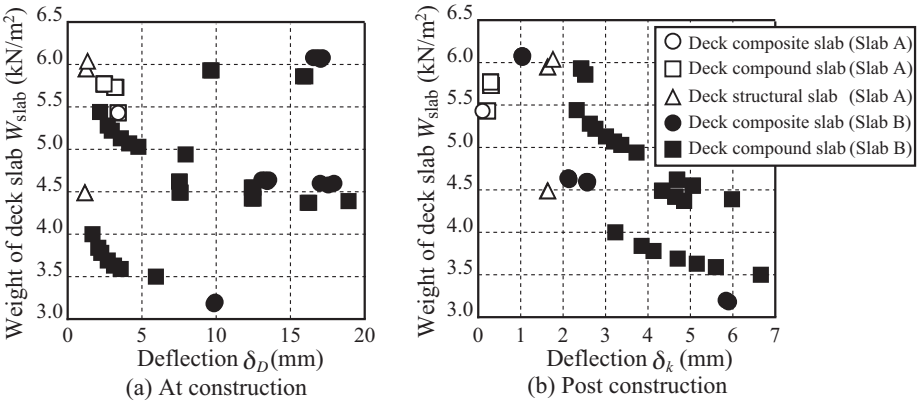


Figure 4.2. Deflection

4.2.2. Depth of deck slab

Fig. 4.3 is shown as the relationship between W_{slab} and depth of deck slab (D_{slab}). According to Fig. 4.3, W_{slab} is proportional to D_{slab}.

In case of Slab A, the deck structural slab is the suitable solution upon W_{slab} and D_{slab}. The solution was compared with tem of such as W_{slab}, the solution of the deck compound slab can be designed with smaller weight than that of deck structural slab. Because H_{deck} of the deck compound slab is larger than that of the deck compound slab.

Furthermore, in case of Slab B, the deck composite slab is the profitable solution upon W_{slab} and D_{slab}. Although, the solution is compared with those of such as D_{slab}, the solution of the deck composite slab is lager than that of the deck compound slab upon W_{slab}. The deck composite slab uses deck plate with wide ditches, and it was compared with the deck compound slab. As a result, the deck composite slab needs much more volume of concrete than other types.

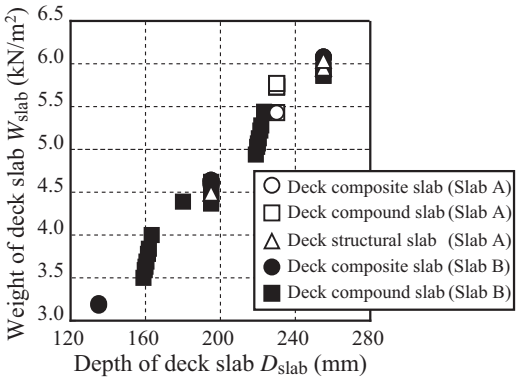


Figure 4.3. Depth of deck slab

4.2.3. Natural frequency

Fig. 4.4 is shown as the relationship between D_{slab} and natural frequency (f). According to Fig. 4.4, in case of Slab A, the deck structural slab has the smallest f among all deck slabs. The deck slab of this type has smaller value of f than other types in case that this is larger D_{slab} than others. Moreover, as for Slab B, the deck composite slab has a little larger value of f than the deck compound slab when D_{slab} is the same.

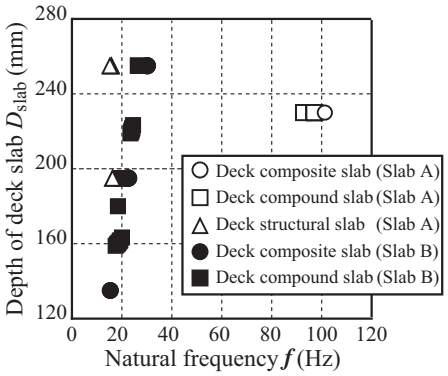


Figure 4.4. Natural frequency

5. CONCLUSIONS

The system described in this paper can provide designer, who are under introduction education, the solutions about the steel deck slab having three slab types. This system introduced the concept of comparison design in a computer-assisted design. The designers can define judgment of design with this system. They are urged decision of the solutions. The structure of the system is effective for education of the beginner.

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