Morphology of diagonal structural systems

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Summary

In this paper, we systematize various types of diagonal structural systems, including trusses, from the viewpoint of structure and form. First, based on the concept that a diagonal structural system consists of fundamental elements, we outline unit models as minimum elements. Then, in order to classify the patterns of constitution of the system, we present the formation flow of a three-dimensional structure and the application of a diagonal structural system to such a structure.

Keywords: diagonal structural system; unit model; truss; conceptual design.

1. Fundamental elements of diagonal structural system

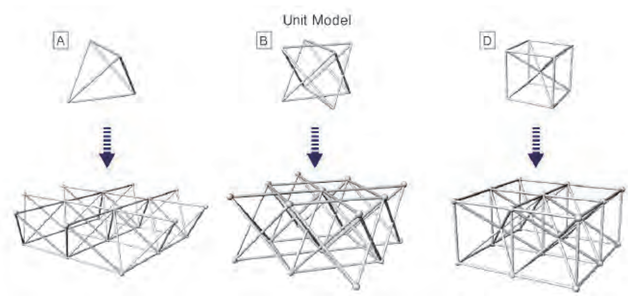

Fig. 1: Repetition of each unit model

To consider the structures and forms of diagonal structural system, unit model is available. Thus far, Kubota has investigated the systematization of truss systems, which are typical 2-D diagonal structural systems. We show formation flow of 3-D unit models and define structure (A), (B), and (D) as minimum units of a 3-D diagonal structural system as shown in Fig.1. Various forms of such a system can be developed by transformation, repetition, and combination of the unit models.

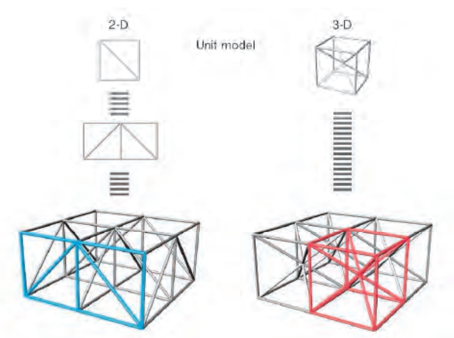

Fig.2: Examples of composition of 3-D diagonal structural system

We discuss the mechanical characteristics of 3-D unit models. Note that diagonal members transmit shear forces, whereas chord members transmit bending moments. In 2-D unit models, diagonal and chord members lie in the same plane on which a load acts. Thus, shear forces and bending moments are transmitted to the same plane when a load acts on these structures. However, in 3-D unit models, diagonal members and chord members do not exist simultaneously in the same plane on which a load acts. This implies that shear forces and bending moments are transmitted to a different plane. We wish to emphasize that this is the most important difference between 2-D unit models and 3-D unit models. Although 3-D diagonal structural systems have various types of forms, they have two types of composition, namely, 2-D unit model composition and 3-D unit model composition, as shown in Fig.2.

2. Constitution of diagonal structural system

A 3-D structure is formed by expansion of a 2-D structure, various parts of which become diagonal elements. Fundamental 2-D structures are span systems of bridges shown in Fig.3.

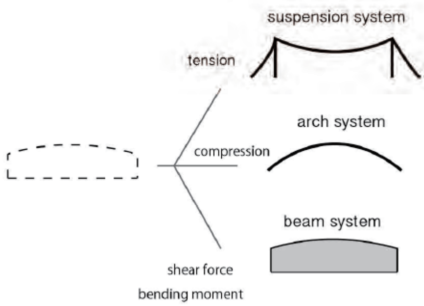

Fig. 3: Systematization of span systems

There are three methods for developing a 3-D structure from a 2-D structure, revolution, translation, and ruled. In addition, there are two types of sectional expansion, namely, continuous and discontinuous expansion. Thus, the form of a 3-D structure depends on the span system, the method and direction of development of the 3-D structure, and the expansion method. Next, let us consider the parts of a structure to which a diagonal structural system is applied. We illustrate the patterns of application of a diagonal structural system to a 3-D structure in Fig.4. Various forms can be developed by combining these patterns.

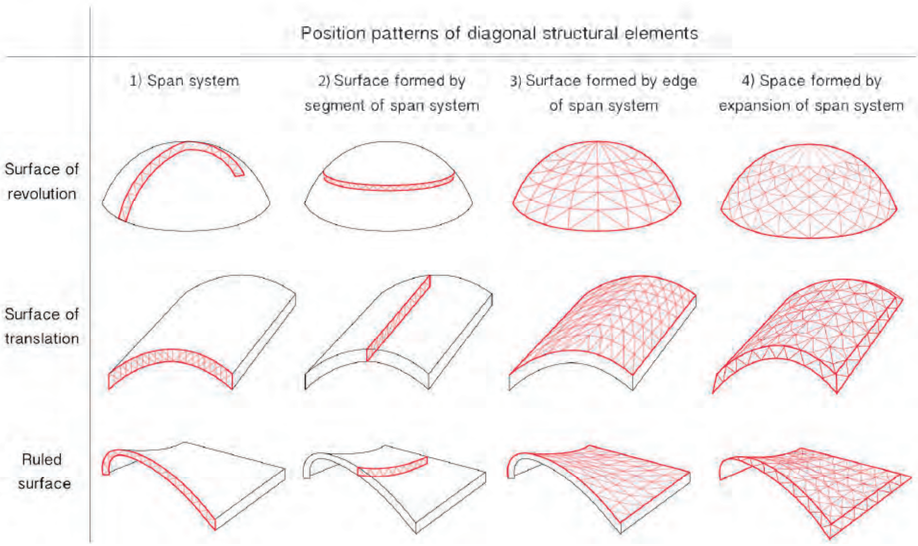

Fig. 4: Patterns of application of diagonal structural system to 3-D structure

3. Conclusion

In this paper, we outlined the structure and form of diagonal structural systems. In particular, various forms and constitutions were systematized. By focusing on the fundamental elements and the routes of shear forces and bending moments in 3-D structures, we defined minimum structures as 3-D unit models, to which the shear forces and bending moments are transmitted in different planes. Then, various constitutions of diagonal structural systems and patterns of application of a diagonal structural system to a 3-D structure were systematized.

This study could provide the fundamental principles for designing a wide variety of bridges and architectural structures that comprise diagonal structural systems.