論　文　の　要　旨

題　目　Analysis and Optimization Approach of Scissors-Type Bridge based on Equilibrium Equations
(平衡力学理論に基づくシザーズ型展開橋の解析と最適化アプローチ)

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Natural disasters often result in destruction of facilities and residents. It is of the utmost importance to repair the damaged bridges in the disaster area, because this allows for quick evacuation and relief activity to local communities. In the case of emergency situation, collapsed bridges in important traffic routes are rebuild by emergency bridges. However, there are many restrictions within the disaster area regarding the creation of large construction yards and the use of heavy industrial machines. Therefore, even if the prefabricated bridge is used for restoration in the emergency situation, it takes several weeks or more until it is in a usable state due to the above limitations. In order to resolve these construction problems, the author has been suggested a new type of deployable bridge with scissor mechanism (herein called scissors-type bridge). The bridge has a compact size in its undeployed state and can be transported easily to where it is needed. Its quick deployment makes this type of bridge useful in areas struck by natural disasters by enabling vehicles to cross terrain that is impassable.

This thesis aims at proposing an analytical method for the scissors-type bridge and evaluating its effectiveness based on several structural experiments and numerical analyses. Furthermore, in order to improve the performances of this bridge, the author suggests the reinforced scissors-type bridge based on its optimization approaches with quantitative evaluations.

In Chapter 1, the thesis began with introduction of background with regards to the existing emergency bridges, scissor structures and achievements in the previous research, and then it was described aims and constitution of this thesis.

In Chapter 2, historical background for computing method of scissor structure was summarized, and then the analytical approach was proposed based on the coupling equilibrium equations on a-unit of scissor member. The proposed method allowed for an understanding on basic mechanical properties of the scissors structure from case studies. For example, it was found that sectional forces in the structure which are axial force, shear force and bending moment were changed depending on the expansion angle, and the bending stress was the most important ones in the scissor structure.

In Chapter 3, the computing method proposed in Chapter 2 was extended to more general formulations in order to apply chained scissors-type bridge. The author developed a scissors-type pedestrian bridge (prototype) experimentally, and made clear the basic structural properties such as

stress distribution and displacement according to the difference boundary conditions. The validity of analytical values by the equilibrium equations is evaluated with structural experimental values. It was clear that present method ensures a good consistency to evaluate frame member and displacement of the prototype.

In Chapter 4, a simple design concept of frame member for the scissors-type bridge was shown focusing on the dominant sectional force of bending moment at pivot parts. Then, trial design was conducted by use of practical design values which were obtained from bending test with an aluminum alloy member. The author made clear the design parameters and its relativity via the trial design, and showed the design results for the longest layout of the bridge.

In Chapter 5, a full scale scissors-type bridge (MB1.0) with lower deck which allows for a small vehicle to pass across was developed to demonstrate the possibility of this structural form and its analytical method based on equilibrium equations. The author carried out a vehicle loading test to the MB1.0, and confirmed that the main frame and the deck boards were within admissible stress levels with a maximum loading weight of 13.6 kN. Furthermore, it was possible to build the theoretical and numerical model of the MB1.0 with moving load with a margin of error less than 5% when compared with experimental values on the safe side.

In Chapter 6, the reinforced scissors-type bridge with additional member was proposed, and its utility was made clear based on the equilibrium equations for statically - indeterminate scissors structure. It was found that by applying reinforcing member, sectional forces distribution was close to typical truss structure. Moreover, it was clarified numerically to the effect of reinforcement by differences layout pattern of the strut members using the MB1.0 in Chapter 5. The author showed effective reinforcing patterns focusing on vertical strut member and proposed optimal reinforcing procedure to reduce the construction time in site.

In Chapter 7, several optimization approaches were proposed with the combination of the two software ABAQUS and Mathematica in order to improve the bridge's performance. The author showed two optimization problems, limit load and weight minimum problems, by several reinforcing layout and availability of the prestressing force. By optimization procedures, the limit load capacity of the reinforced MB1.0 improved more than 10 times but also the weight of the frame member also reduced about 50 % from initial state. Furthermore, the reinforcement of the prestressing also confirmed its effects. These solutions were allowed to mention that the scissors-type bridge performance could be improved with optimal reinforced members and prestressing forces.

Chapter 8 contains the conclusions obtained in Chapter 2 to 7.