Structural Analysis and Experimental Study for realsized MB Travelable Vehicles

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Summary. Many natural disasters such as earthquakes, floods, torrential rains occur around the world, and we to undertake quick rescue actions. However, there are many recovery problems because of the occurrence of secondary disasters at each rescue worksite. So, from the previous study of optimal structures and control regulation of MFM[1]-[2], we propose a new type of foldable bridge with scissors structure called Mobile Bridge[3]. Applying scissors mechanism to bridge form, Mobile Bridge provides not only mobility but also good structural performance, because the whole bridge can be expand or fold quickly. In this paper, we discuss the vehicles passing test on the real scale Mobile Bridge in order to evaluate the design method and application limits.

Vehicle passing test using real-scaled Mobile Bridge

Development of the experimental Mobile Bridge

The schematic view of the experimental two units scissors model for a real sized Mobile Bridge (called as MB1.0) is presented in **Fig.**1. When deployment starts toward the opposite shore, the structural members are inclined gradually and the span is extended as shown in the **Fig.**1(a). Moreover, the MB1.0 is equipped with a foldable floor deck which follows the process of deployment. After the bridge is expanded, boundary conditions are changed from cantilever to simply-supported beam, and few vehicles can pass the bridge as shown in **Fig.**1(b). In operational state of the prototype MB1.0, the total length of the span is 7.0m and the height is 2.0m. The total weight of the MB1.0 considering the structural parts such as the main members, the shafts, the pins is 8.6kN. To reduce the dead weight, the main members of the frame and deck are made of aluminum alloy material. Moreover, the floor deck is reduced to two parallel narrow pieces on which wheel load acts.

Outline of vehicle passing test

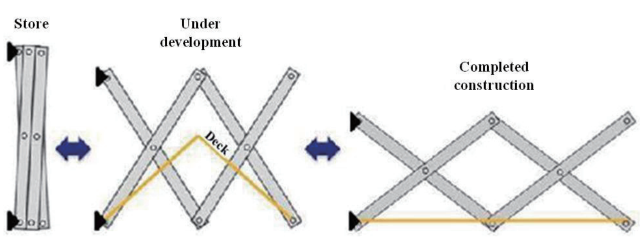
Two kinds of vehicles, STREET and AD van, were used for the vehicles loading test. The STREET is a light vehicle and the AD van is a standard-sized car. The STREET's (length*width*height) is (3195mm*1395mm*1870mm), while the AD van's (length*width*height) is (4370mm*1895mm* 1510mm). The weight of the STREET is 7.9kN and AD van is 12.3kN except the weight of driver.

The measurement was performed for five load cases. When the front wheel, the axle (defined here as the intermediate part of the front and the rear wheel), and the rear wheel came to a specific point and stopped, the value of the static strain was measured. The stop positions were the center of the deck for the first unit scissors and the central part of the MB1.0.

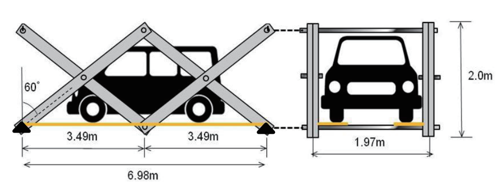
Verification of the 2D-frame analysis

AutoCAD Inventor made by Autodesk Company was used for this FE analysis. The analysis was possible by using internal program (ANSYS) which was embedded in the CAD. During the numerical simulations beam elements were used, and the analysis was performed for each position of the vehicle moving and stopping. This paper shows only selected cases in which the MB1.0 is loaded with a vehicle in the center of the span. The models are shown in **Fig.**2(a) and (b). In the full model including the deck, the dead weight consists of the main frames, shafts and the decks (Fig.2(a)). The simplified model depicted in Fig.2(b) is considered the stiffness of the deck.

In the full model, the wheel loads are applied to the deck in the position, in which the vehicle stopped as shown in **Fig.**2(a). The simplified model loads are modelled as equivalent nodal forces acting on the pins, as shown in **Fig.**2(b). The live load, as denoted by the red arrow acts according to the wheel loads, and the yellow arrow denotes the equivalent nodal forces. As a boundary condition, the shaft part of both-ends are fixed-pin supports.

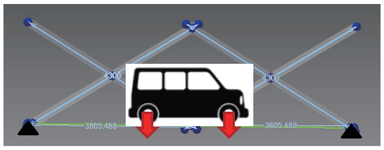


(a) Expanding action

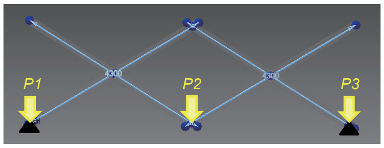


(b) In-service state

Figure 1: Outline of the experimental MB1.0

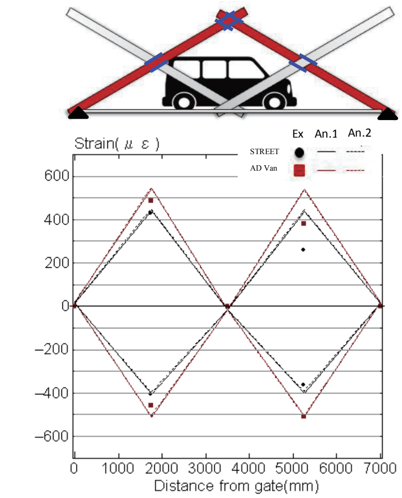


(a) The full model

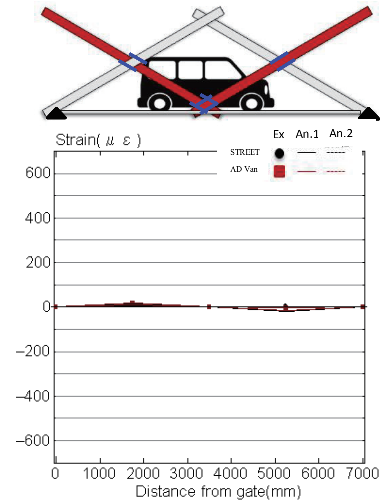


(b) The simplified model

Figure 2: Outline of the 2D model as a simple support



(a) Structural members of ends-support



(b) Structural members with free ends

Figure 3: Distributions of the strain values caused the vehicle loading

Results of the experiment

Fig.3(a) and (b) show distribution of the strain values when the bridge was loaded with a vehicle in the center. **Fig.**3(a) depicts the structural members in 'Λ'-shaped form, which contact the supports and **Fig.**3(b) presents 'V'-shaped members with ends in free boundary condition. The presented members are colored in red. The blue marks in the figure show the positions of the strain gages. It can be seen that the experimental and analytical values obtained for loading vehicle with actual weight of 13.6kN are less than the maximum admissible strain. The maximum strain of about $500\mu\epsilon$ occurred in the member intersection part, providing a safety ratio nearly twice more than the yield strain. From **Fig.**3(a), we can see that the maximum measured strain was $500\mu\epsilon$ at the edge part of the member crossing of the first unit, and the minimum strain was measured at the edge part of the member crossing of the second unit. Because the distribution of the strain is almost equal in the compression and tension region, the influence of the bending moment is high. Maximum accuracy variations in comparison with analytical results is distributed within 10%. **Fig.**3(b) shows that measured strain in the structural members with end-free conditions hardly exceeded $\pm 10\mu\epsilon$. The analytical results follow the same tendency, and it shows that the strain is caused mainly by axial tension and not by bending moment.

Remarks

The points which became clear from this research are following:

- With a maximum loading weight of 13.6 kN, the main frame and deck were within allowable stress, and it turned out that the vehicles of about 10 kN could pass safely.
- In the vehicle passing test, we found that the strain change which arose in MB1.0 at the time of vehicles loading was consistent with an analytical value with error less than 10%.
- When we compared results of two kinds of analytical models, there were few differences of the strain values at the vehicle loading on MB1.0. So, if analysis or desing of Mobile Bridge is simplified, it is sufficient to consider loading applied the pins and neglect the stiffness of the deck.

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