論文

SELF-PROPELLED IMPACT VIBRATION EQUIPMENT FOR THE UTILIZATION OF INSPECTION OF BRIDGE DECK

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A lot of fatigue damage of reinforced concrete slabs of bridges have been seen in Japan. Therefore, the maintenance of bridges is an important issue.　In this study, SIVE (Self-propelled Impact Vibration Equipment) was developed to evaluate the deterioration degree of slab simply and rationally. SIVE can make small turns by a simple operation using hands. The equipment also can change the mass of a falling weight, height and rubber condition used as cushion system. Several investigation concerning those parameters were done and concretely shown

Key Words : *Bridge deck, Impact vibration, Degradation diagnosis*

1. INTRODUCTION

It is well known that almost all highway bridges in Japan were built in period 1965-1980 when the Japanese economy grew up rapidly. Currently, there are a significant number of bridges nearly 50 years of age, it is recognized that those bridges have to be maintained[(1,2,3)]. The fatigue damage of reinforced concrete slabs have been seen not only in Japan but also in developing countries, such as Vietnam, which might be serious problems in future . In this study, SIVE (Self -propelled impact vibration equipment) was developed to evaluate the deterioration of slab simply and rationally. This equipment can change the mass of falling weight, a height and a rubber condition used as cushion system. When SIVE is used at the site, generally, proper impact force, momentum and duration of impact force are required depending on the scale of objective structure. In this study, impact tests for series of rubber buffer were perfomed, characteristics of impact force were shown and summarized.

2. DEVERLOPMENT OF SIVE

Generally a certain equipment which has a feature of mobility and enough power to carry out a field test on an entire bridge or a part of bridge, such as a slab deck, is required. Therefore, an equipment(SIVE) was developed to fulfill such requirements.

The overview of SIVE is shown in Figure 1. It is easier to set SIVE at any point by a simple operation compared with FWD car systems. This equipment consists of two large parts which are a forklift truck and an impact occurrence equipment. Electric truck works by the battery DC 24 volt and supplies necessary power to the impact occurrence equipment, the measuring equipment and personal computer. The occurrence equipment consists of the hoist lifting a weight, steel weight, rubber buffer, load cell and loading plate. The equipment can change the mass of a falling weight, a falling height and a rubber cushion used in cushion system. The maximum falling height is 0.3 m and the maximum mass of weight is 220 kg. The capacities of energy and momentum are 0.65 kJ, 0.44 kNs respectively.

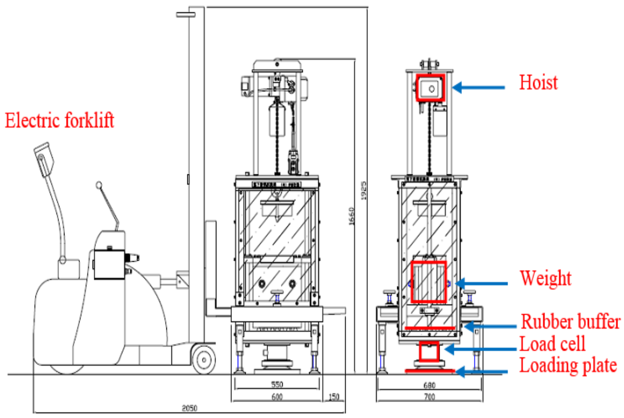


Fig.1: Overview of SIVE (Self -propelled Impact Vibration Equipment)

3. METHOD OF EXPERIMENT

The series of impact experiment using SIVE were done. Table 1 shows the list of experiments. In this series of experiment, the 220 kg mass of weight is used three times for each case. The figure 2 shows the arrangement of 5 types of rubber cushion for choosing the suitable rubber to control the maximum forces and duration of impact

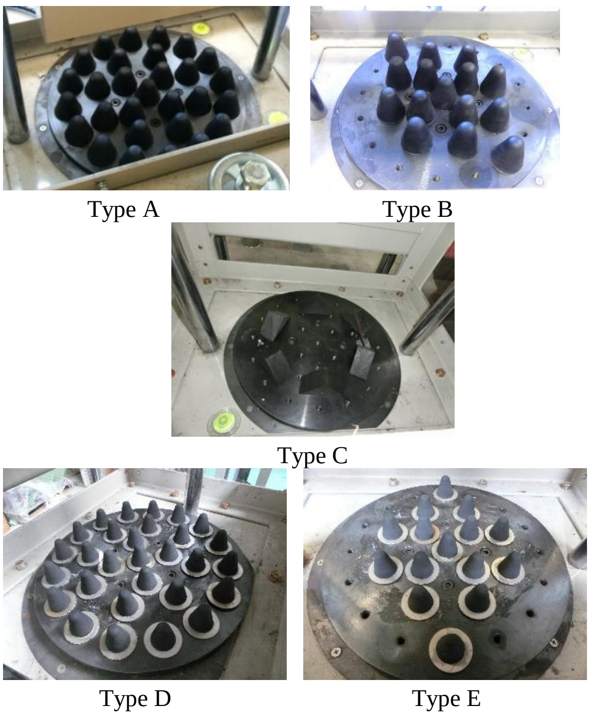


Fig.2: Rubber buffer

Type A and B There were 29 and 15 of rubber cones were arranged in Type A and B respectively. This type of rubber cone (rubber buffer KFDF-51, Tokyo sokki kenkyujo co. ltd) is normal rubber, 48 mm of height, 40 mm of diameter . Type D and E are low rebound rubber (Hanenaite, Naigai rubber industry co. ltd.) with the height is 32 mm and the diameter is 26.09 mm. In addition, type C arranged by 6 low rebound triangle rubbers.

Experiments were conducted with a plate that has detail of dimensions (Figure 3). The plate was setup in two support, loading plate was set in the center of plate. Displacement of the center point of the plate was measured by a displacement meter (CDP5, Tokyo sokki kenkyujo co. ltd.).

In the same conditions and five types of rubber, data were collected from equipment built-in load cell. Velocities and displacements were got by using numerical integrations.

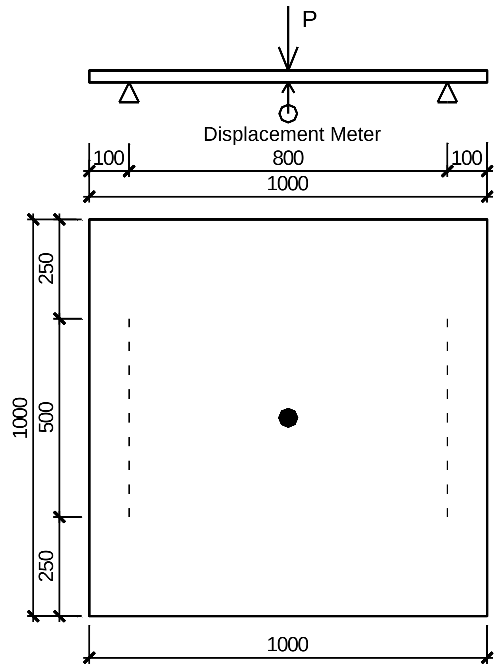
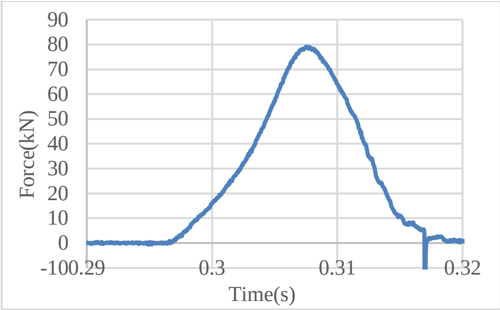


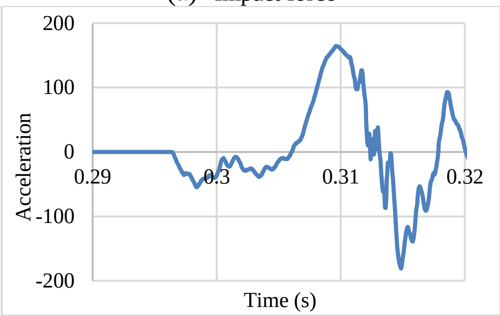
Fig.3: Test specimen

Table 1: List of experiments

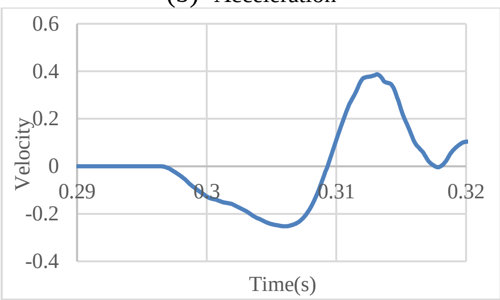
Cushion Type	Mass of weight M_w (kg)	Falling height H_f (m)	Collision energy E_{ini} (kJ)	Momentum M_{ini} (kNs)
A	220	0.05 to 0.30	0.11 to 0.66	0.22 to 0.53
B	220	0.05 to 0.30	0.11 to 0.66	0.22 to 0.53
C	220	0.05 to 0.30	0.11 to 0.66	0.22 to 0.53
D	220	0.05 to 0.30	0.11 to 0.66	0.22 to 0.53
E	220	0.05 to 0.30	0.11 to 0.66	0.22 to 0.53



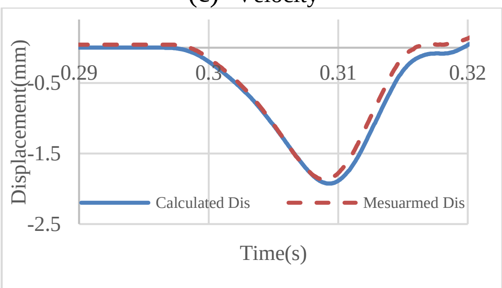
(a) Impact force



(b) Acceleration



(c) Velocity

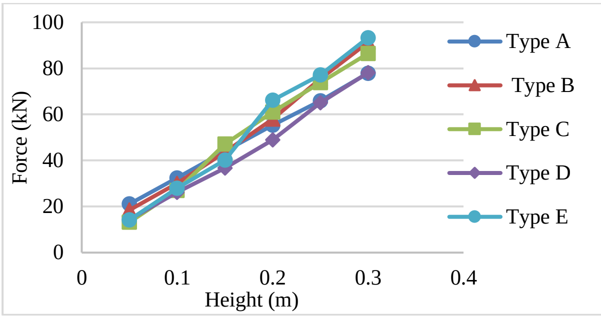


(d) Displacement

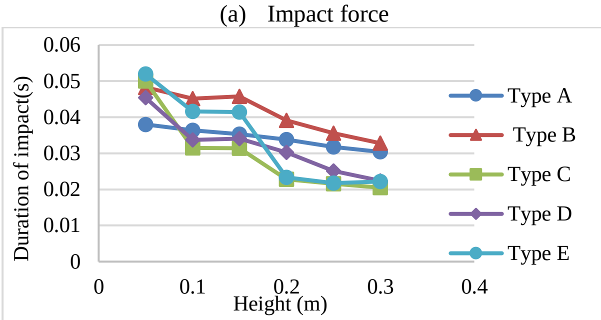
Fig.4: Example of impact force, acceleration, velocity and displacements (M_w=220 kg, H_f=0.3 m, Cushion Type D)

4. RESULTS OF EXPERIMENTS

Figure 4a and 4b show the time course impact force from 0.3 m height in case of type D rubber and the acceleration data. The first impact is the most important for the dynamic behavior of structure. Thus the first impact should be forcused. In this type of cushion, the impact force reached the peak at about 80 kN in only 0.02 s. With rebound rubber, the rebound of falling weight seems to be reduced. In addition, the velocity was calculated from the acceleration in figure 4c. The displacements measured by the displacement meters and calculated based on acceleration were shown in figure 4d. It became clear that the displacement calculated from acceleration at the center point is in good agreement with the value by displacement meter. The ratio between them was approximately 1.0.



(a) Impact force



(b) Duration of impact

Fig.5: First impact force and duration of impact

Figure 5 shows the maximum force and duration of impact of different falling heights on all type of cushions. It shows that the maximum force has monotonously increased with the rise of falling heights in all type of cushions. Cushion Type B,C,D and E had experienced some dramatic changes in duration of impact while cushion Type A had slight one. Different cushions differs in duration of impact and forces. The largest impact force was found in type E cushion. Duration of impact, on the other hand, has decreased along the falling heights.

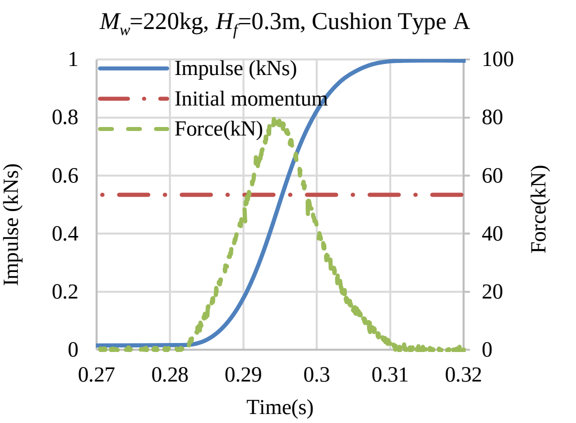
Figure 6 indicates the sample of impulse by the first impact of two typical type of cushion A and D. The maximum force and the duration of force are approximately 90 kN and 0.03 s in both types. It can be seen that rebound is large in Type A (normal rubber) and small in Type D (low rebound rubber).

Table 2 provides the overall view of displacement. The difference between the calculated displacements and the true value is small in all case except the one with a low falling height 0.05 m. Displacements experienced the same trend of increase in all case with the rise of falling heights

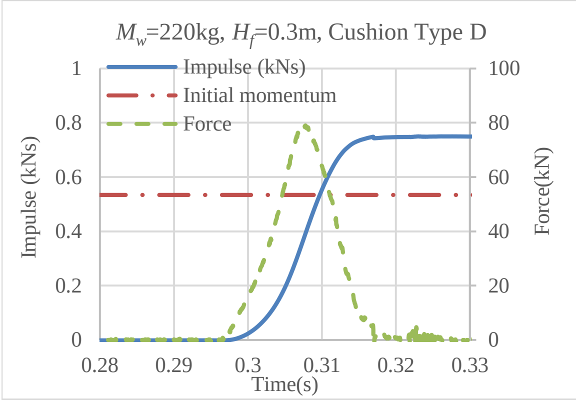
It is generally suggest that it was so important to control the maximum force, duration of force and less rebound of falling weight for better pursuit of experiment at site.

Table 2: Relationship between calculated displacements and measuarmed displacements

Height (m)		Type A	Type B	Type C	Type D	Type E
0.05	D^C_{max} (mm)	-0.579	-0.483	-0.399	-0.396	-0.285
	D^m_{max} (mm)	-0.552	-0.425	-0.345	-0.358	-0.305
	D^C_{max}/D^m_{max}	**1.049**	**1.136**	**1.158**	**-1.106**	**0.934**
0.1	D^C_{max} (mm)	-0.815	-0.812	-0.926	-0.648	-0.068
	D^m_{max} (mm)	-0.888	-0.743	-0.771	-0.620	-0.068
	D^C_{max}/D^m_{max}	**0.918**	**1.093**	**1.201**	**1.045**	**1.004**
0.15	D^C_{max} (mm)	-1.092	-1.115	-1.252	-0.868	-1.033
	D^m_{max} (mm)	-1.115	-1.068	-1.154	-0.803	-1.035
	D^C_{max}/D^m_{max}	**0.980**	**1.044**	**1.084**	**1.081**	**0.998**
0.2	D^C_{max} (mm)	-1.311	-1.487	-1.616	-1.160	-1.705
	D^m_{max} (mm)	-1.305	-1.460	-1.553	-1.147	-1.721
	D^C_{max}/D^m_{max}	**1.005**	**1.019**	**1.041**	**1.012**	**0.990**
0.25	D^C_{max} (mm)	-1.620	-1.870	-2.001	-1.576	-1.985
	D^m_{max} (mm)	-1.603	-1.869	-1.856	-1.567	-1.986
	D^C_{max}/D^m_{max}	**1.011**	**1.000**	**1.078**	**1.006**	**1.000**
0.3	D^C_{max} (mm)	-1.947	-2.241	-2.358	-1.927	-2.569
	D^m_{max} (mm)	-1.840	-2.268	-2.276	-1.869	-2.462
	D^C_{max}/D^m_{max}	**1.058**	**0.988**	**1.036**	**1.031**	**1.044**



(a) Type A



(a) Type D

Fig.6: Sample of impulse and force

5. CONCLUSION

In this study, SIVE (Self-propelled Impact Vibration Equipment) was developed for the bridge deck damage inspection. The conclusion are summarized as follows.

1) The maximum forces and durations of impact by SIVE were concretely shown for 5 types rubber cushions.
2) Generation of ideal single impact is possible, when low rebound rubber cushion (Type C, D or E) is used.
3) The maximum force can be controlled bellow 100 kN and duration of impact are approximately 0.2 s to 0.5 s.
4) It is possible to calculate the accurate displacement by the acceleration measured in SIVE.

With the accuracy we will us SIVE for the measurement of displacements at actual site in the future.

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