Calibration of Load Factors for Highway Bridge Design

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Abstract

Performance based design was introduced in specifications for highway bridges for the first time in Japan in 2002. However, evaluation methods of various new techniques are not shown clearly at this time. This is one of the important problems to promote challenges toward the application of the various techniques. Recently, there is a movement towards an introduction of the load and resistance factors design shown the performance more quantitatively in Japan. The load and resistance factors design is expected as a solution of these problems.

In this paper, the current state of highway bridge design, a calibration method of load factors in Japan, and the future plan of this project are described.

1. Current State of Highway Bridge Design Code in Japan

Specifications for highway bridges notified by the Director-General of the Road Bureau and City and Regional Development Bureau of Ministry of Land, Infrastructure, Transport and Tourism (MLIT) have been revised repeatedly in response to the people's requirements or technical advancements. For example, seismic design codes were improved in 1996 after the experience of Southern Hyogo Earthquake occurred in 1995. In 2002, performance based design was introduced for the first time, in order to promote challenges towards the application of various new techniques.

Before the revision in 2002, specific rules on materials, structures, and calculation methods were shown in the specifications for highway bridges. In the 2002 revision, requirements of each specification are described, and most of the conventional rules are regarded as an example of solution of the requirements. This revision can allow us to accept any techniques as long as the techniques are considered as the adequate solution of requirements.

Recently, there are a lot of opportunities to evaluate new techniques that are not assumed in the current specifications for highway bridges. In the performance based design, evaluation methods for new techniques are very important. However, the evaluation methods for various techniques are not shown clearly at this time. In order to evaluate new techniques effectively, an introduction of the load and resistance factors design is considered as one of the important approaches. It enables us to see the degree of reliability of materials, structures, experiments or analysis more clearly. Therefore, the project toward the introduction of load and resistance factors designs is the future

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step for the next revision of specifications for highway bridges.

2. Calibration of Load factors in Japan

2-1. Flowchart of calibration in Japan

Fig.1 shows a flowchart of calibration to determine load and resistant factors. The flowchart is divided mainly into 4 steps as shown below.

a) First step selects sample bridges for the coming time-series simulation.
b) Second step draws frequency distribution of responses for loads such as vehicle, earthquake, wind, and other loads based on each statistic data.
c) Third step conducts the time-series simulation for 100 years design life time and 1000 times construction.
d) Final step conducts calibrations to determine load factors obtained from the time series simulation and resistant factors from others. Load factors and resistance factors are calibrated separately at this time.

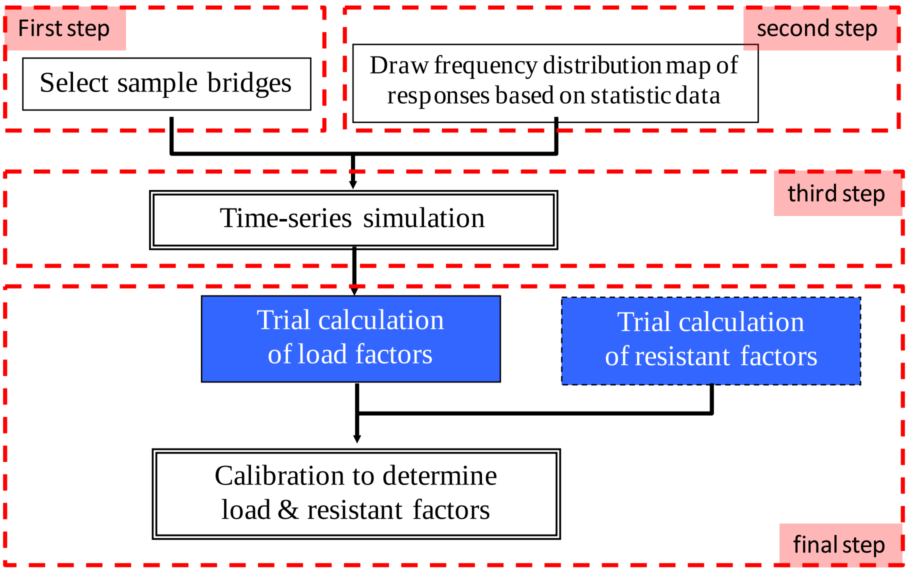

Fig.1 Flowchart of calibration to determine load & resistant factors in Japan

2-2. Setting methods of load factors in Japan

1) Selection of the sample bridges

Table 1 shows materials, structures, size of sample bridges for time-series simulation. More than 20 samples of representative types and size of bridges in Japan contain in it were selected at this time.

Table 1 Normal bridge types and the span

	Steel superstructure	PC superstructure
Simple girder	Plate girder(30-40m span) Box girder(about 60m span)	Box girder(about 40m span) T-girder(20-40m span) Slab bridge(about 30m span)
Continuous girder	Plate girder(about 40m span times 2-3 span) Box girder(about 70m span times 2-3 span)	T-girder(40m span times 4 span)

2) Distribution of responses based on statistic data

Table 2 shows the load types shown in the current specifications for highway bridges. The models of these types of loads are set by collecting the latest statistic data for them. In the time-series simulation, dead load, live load, wind load, snow load, temperature change, and effect of earthquake are set as statistic distribution model. Others were used as fixed values.

Table 2. Load types

Classification	Load considered in design	Symbol
Primary Load	1 Dead load	D
	2 Live load	L
	3 Impact	I
	4 Prestressing force	PS
	5 Effect of creep in concrete	CR
	6 Effect of drying shrinkage in concrete	SH
	7 Earth pressure	E
	8 Water pressure	HP
	9 Buoyancy or uplift	U
Secondary Load	10 Wind load	W
	11 Effect of temperature change	T
	12 Effect of earthquake	EQ
Particular Load corresponding to primary load	13 Snow load	SW
	14 Effect of ground deformation	GD
	15 Effect of support deformation	SD
	16 Wave pressure	WP
	17 Centrifugal load	CF
Particular Load corresponding to secondary load	18 Braking load	BK
	19 Load under construction	ER
	20 Impact load	CO
	21 Others	

Dead load for bridge members were modeled by using fixed self weights and statistic data of the size variation. Table 3 shows variation in size of bridge members. It was investigated from the existing reports for trends of construction records.

Table 3. Variation in size for bridge members

Factors	Classification		average(μ)	standard deviation(σ)
Variation in size	steel member		1.0098	0.0177
	concrete girder	post tension	1.0043	0.00361
		pretension	1.0051	0.00364
	RC slab		1.05	0.012
	pavement		1.03	0.05

Live load was modeled based on the frequency distributions of vehicle loads monitored on the actual bridges as shown in Fig. 2. Model of vehicle line in a traffic jam was set and loaded on bridges. As the condition of vehicle load are much different depending on characteristics of road, three models that have different mix rates of heavy traffics (10%, 30%, and 50% mix rates) were set to use the time-series simulation.

Fig. 3 shows a model of vehicle line in a traffic jam. This model reflects the monitored traffic weight data. The length of this model is 1,000,000m length. In the time-series simulation, this group of vehicles moves by 1m on the long lines.

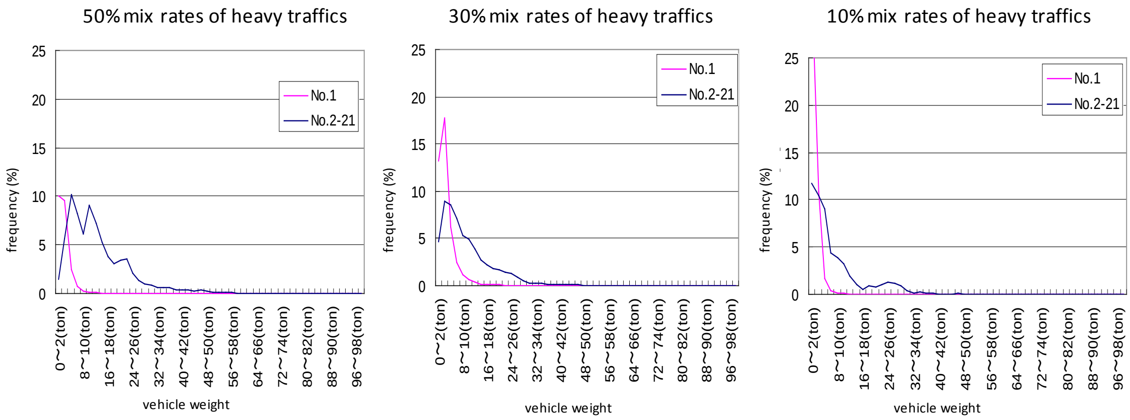

Fig.2 Frequency distribution for vehicle weight

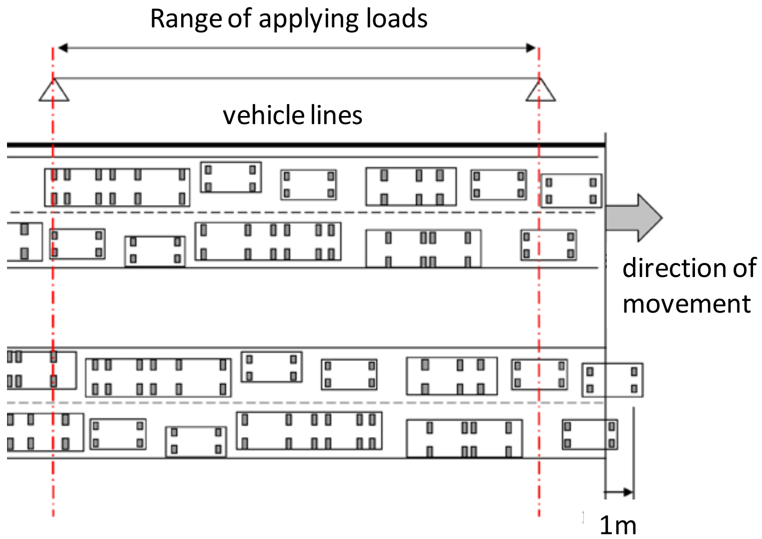

Fig.3 Schematic picture of vehicle loads

Effects of earthquake (Level 1) used by the time-series simulation were set by using the earthquake-hazardous probability density function of response acceleration for 100 years. Fig. 4 shows an example of probability density function of response accelerations for a year. This figure is one of three probability distribution maps using past earthquake records of 3 spots in Japan. The appropriate return period to be used for the time-series simulation was selected matching with the probability density function of response acceleration for 100 years.

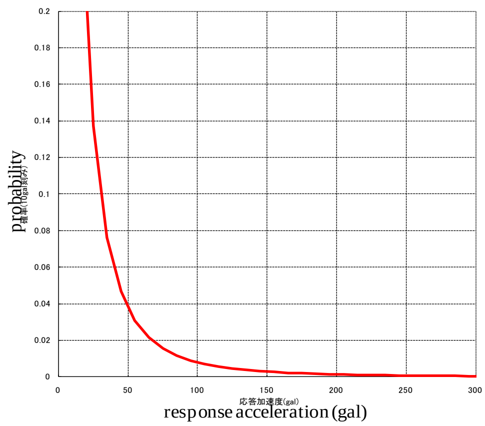

Fig.4 Example of probability density function of response accelerations for one year (Izu city in Japan)

3) Time-series simulation

100 years period of time-series simulations were conducted 1,000 times. 100 years period means the design life time. Fig. 5 shows a summary of time-series simulation. Trial calculations of load factors are conducted by the time-series simulation applying the loads randomly on the sample bridges. As the maximum values of each bridge member's responses for 100 years are extracted after the simulation, frequency distributions of the maximum data for 100 years were drawn by using 1,000 times simulation data. Fig. 6 shows the way of analysis for extraction of maximum responses for 100 years using the simulation data.

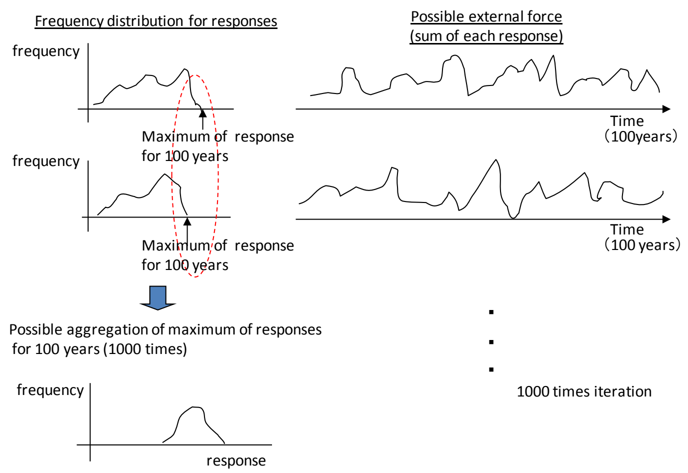

Fig.5 Summary of time-series simulation

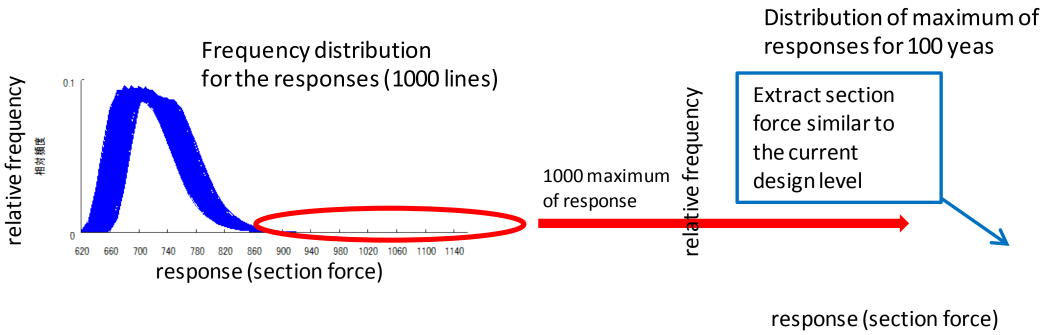

Fig.6 Way of analysis for extraction of maximum of responses for 100 years

According to Fig. 6, the load factors were set in the simulation such that the levels of the responses in the simulation and the design based on current specifications match each other. In other words, the level of reliability of the determined load factors is the same as that for current bridge design. Three main reasons why the load factors were set in this way are shown as follows:

(1) Complex structures and load conditions of bridges

(2) Relationships between the current design and the new one

(3) No significant problems on the current design level

3. Conclusions

Calibration method of load factors for the highway bridge design was introduced in these papers. The load factors were set to match the levels of the design based on current specification. However, by introducing the load and resistance factors design based on time-series simulation, the performance level of bridges can be seen more clearly. Therefore, it is expected that the project toward the introduction of load and resistance factors designs promotes the challenges for the application of new techniques and expands new research field for the more rational bridges design based on the difference of the performance level.

In the future, the settings of calibration of both load and resistance factors will be continued to match with the current design level. In order to set these factors, trial design using the calculated load factors and the resistant factors will be required to verify the adequacy of these factors in the practical design.

References

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