Load Modifier for Ductility, Redundancy, and Operational Importance

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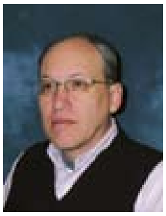

Article 1.3.2.1 of the *LRFD Bridge Design Specifications* introduces a load modifier, which is the product of factors relating to ductility, redundancy, and operational importance. The original intent of this load modifier was to encourage enhanced ductility and redundancy. Operational importance was included to provide additional reliability for more important bridges.

When the first edition of the *LRFD Specifications* was written, research into the effects of ductility and redundancy on the safety or reliability of bridges was not available. Thus, the factors were subjectively chosen as discussed in the Commentary C1.3.2.1. These subjective choices were also considered to be conservative by the specification writers. Since the writing of the first edition, research into the effects of redundancy on reliability has been completed through NCHRP Projects 12-36, *Redundancy in Highway Bridge Superstructures*, and 12-47, *Redundancy in Highway Bridge Substructures*. This research has yet to be implemented in the *LRFD Specifications*. It has been partially implemented in the forthcoming *AASHTO Manual for Bridge Evaluation* as system factors on the resistance side of the load and resistance factor rating (LRFR) equation, especially in the provisions for rating segmental concrete bridges.

A limited study of the effects of the specified load modifier on the resulting reliability of 95 girder-bridge configurations is reported in Article C1.3.2.1. The results from the study are as follows:

Reliability Index as a Function of Load Modifier

Load Modifier, η	Reliability Index, β
0.95	3.0
1.00	3.5
1.05	3.8
1.10	4.0

The placement of the load modifier, which reflects ductility and redundancy on the load side of the LRFD equation, may seem counterintuitive as ductility and redundancy are characteristics of the resistance and not the load. The modifier was placed on load side and not on the resistance side for a practical reason as they must be related to the maximum and minimum load factors of Table 3.4.1-2 used for permanent loads. This relationship is illustrated in the following equations:

For permanent loads increased by the maximum load factor:

$$\eta_i = \eta_D \eta_R \eta_I$$

For permanent loads decreased by the minimum load factor:

$$\eta_i = \frac{1}{\eta_D \eta_R \eta_I}$$

where

η_i = load modifier: a factor related to ductility, redundancy, and operational importance

η_D = a factor related to ductility as defined in Article 1.3.3

η_R = a factor related to redundancy as defined in Article 1.3.4

η_I = a factor related to operational importance as defined in Article 1.3.5

The notion of the load modifier, at least in terms of ductility and redundancy, may be counter to traditional bridge designer thought. Traditionally, bridge designers are taught that sufficient ductility and redundancy must be provided; differing degrees of ductility and redundancy are not typically considered. For example, bridges are categorized as redundant or non-redundant. Thus, the concept of load modifier has not been embraced by the practicing bridge engineering community. Typically, bridge owners specify that the load modifier be taken as 1.00 and that the basic requirements for ductility and redundancy in the *LRFD Specifications* be satisfied. Any enhancements to ductility are not considered to reduce the specified loads, and non-redundant structures are not allowed. Such owner-specified reactions to the load modifier of the *LRFD Specifications* can be found in many state bridge design manuals.