Verification of capacity by proof loading

Verification of Capacity by Proof Loading

Andrzej S. NOWAK
Professor
University of Michigan
Ann Arbor, MI, USA

Andrzej S. Nowak received his PhD from Warsaw University of Technology, Poland, and has been at University of Michigan since 1979. He has been involved in reliability-based development of the LRFD bridge design codes in the United States and Canada. He also has an extensive experience in field testing of bridges.

Vijay K. SARAF
Doctoral Student
University of Michigan
Ann Arbor, MI, USA

Vijay K. Saraf is a doctoral student at the University of Michigan. The topic of his dissertation is the development of reliability-based criteria for proof load testing of bridges.

Summary

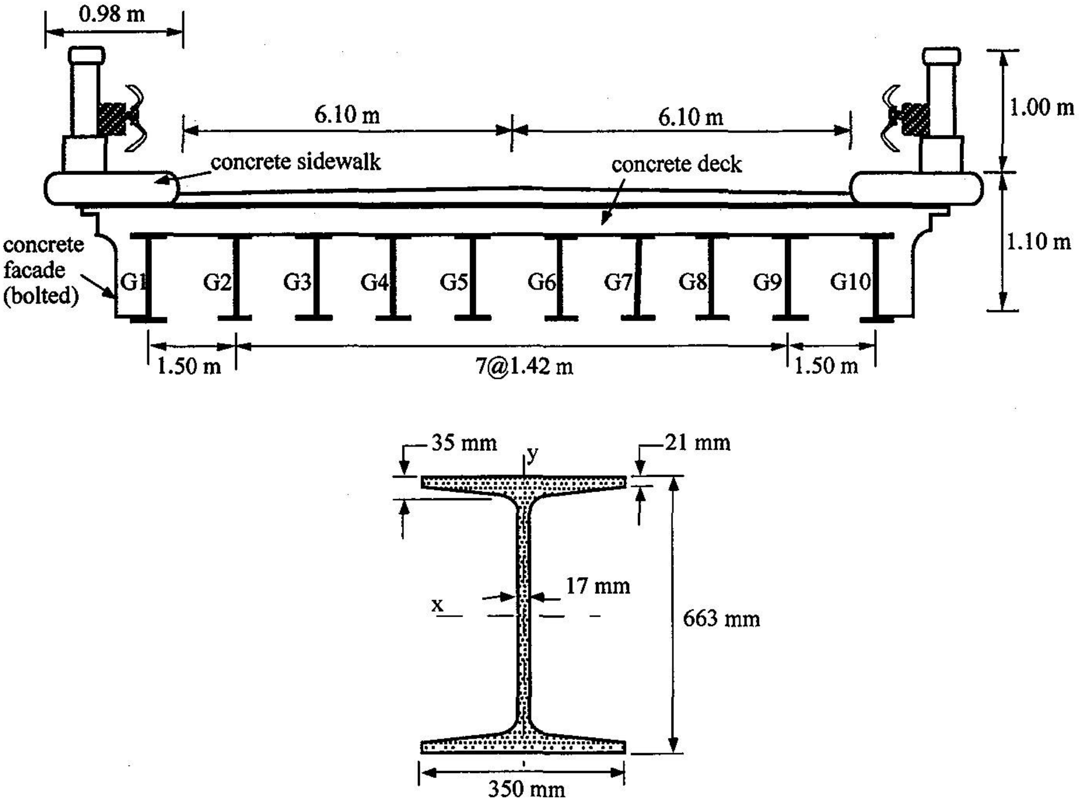
The objective of the paper is to demonstrate an efficient proof load testing procedure for existing bridges. Proof load level required for meaningful tests is approximately twice the legal load. In the State of Michigan, the legal 11-axle truck can weigh over 70 tons. In this study, military tanks were used. Each M-60 tank weighs about 55 tons over the length of about 4.5 m (15 ft). The structural performance was measured in terms of stress/strain level and deflection. Any nonlinearity of response was considered as an indication of inadequate strength. The measured stress levels were unexpectedly low. This can be justified by unintended composite action, effect of non-structural components such as parapets, and more uniform distribution of load.

1. Introduction

The objective of the study was to verify the load carrying capacity of an existing steel girder bridge. The load capacity of the bridge was in question due to extensive corrosion of steel girders. Initial rating showed that the bridge had marginal operating rating factor for the 11-axle two-unit truck (77 tons), which is the heaviest vehicle allowed in Michigan. To avoid the load limit posting, it was decided to verify if the bridge is safe to carry the normal truck traffic by using a proof load test. The bridge was instrumented and proof load was applied in form of two military M-60 tanks. The paper describes the test methodology and the results.

2. Selected bridge

The bridge is a simply supported steel girder bridge carrying state route M-50 over Grand River in Jackson County, Michigan. The total span length is 14.6 m. The total width is 13.8 m. It carries one lane in each direction with total ADT of 11,900. As shown in Fig. 1, there are ten steel girders, a 165 mm thick reinforced concrete slab, and a 170 mm thick bituminous overlay. It was designed to behave as non-composite section. Based on the initial inspection, lower flanges of steel girders were found heavily corroded. At some locations close to mid-span, the flange thickness was reduced by as much as 60 percent. This reduces the moment capacity of steel girder by about 25 percent. There was not much corrosion in steel girders near the supports, and reinforced concrete slab was in moderate condition.



Exterior and Interior Girders

Fig. 1 *Cross-section of the tested bridge*

3. Analysis of the bridge

Based on the specifications in the Michigan Bridge Analysis Guide, the remaining capacity to carry live load and impact corresponding to the operating rating was determined to be 1,550 kNm per lane. In preliminary calculations, the inventory rating factors were 0.98 and 0.53 for H15 and HS20 trucks, respectively [1]. The operating rating factor for the 11-axle two-unit truck was 0.95. A rating factor less than 1.0 indicates that the bridge is deficient. The critical limit state for this bridge was the moment capacity at mid-span. The shear capacity was found to be adequate at all sections. These rating factors were reduced after the site inspection to include better estimates of the steel section loss. The revised inventory rating factor was 0.60 for H15 truck and operating rating factor was 0.45 for the 11-axle truck.

Since proof load testing requires careful comparison of analytical and experimental results during the testing in order to avoid accidental overload, two different types of analytical models were prepared by using the semi-continuum method developed by Jaeger and Bakht [3]. In the first model, the structural properties were taken as specified in design drawings, i.e., the slab-girder-interaction was considered to be non-composite and the effect of non-structural components was not included. For second model, the possibility of unintended composite action and contribution of non-structural members, such as parapets and railings, etc., were incorporated. For both models the supports were idealized as pin supports.

For the proof load test, a heavy load is used to test the bridge. The load is increased in several steps until the yield capacity of the bridge, or a pre-specified load limit is reached. Usually, the yield capacity of a bridge is very high. Therefore, this bridge was loaded only up to a predetermined load limit. Since, the objective of the test is to check if the bridge can carry the maximum allowable load, the applied proof load should exceed the legal load by a comfortable margin of safety. If the target proof load is successfully reached without any distress, then the resulting operating factor would be 1.0.

4. Selection of proof load

The target proof load was calculated using the draft report on NCHRP project no. 12-28(13) A, by multiplying the maximum legal load by a factor of safety of 1.4. It was further multiplied by an impact factor. According to the AASHTO Specifications [1], the impact factor would be 1.29. However, for this bridge, it was taken to be 1.10, because the dynamic experiments conducted by Nassif and Nowak [7] showed that the multi-axle vehicles with heavy loads exhibit much smaller impact. Also, it was decided to load one lane at a time. Therefore, the target load was increased by 15 percent to account for unloaded adjacent lanes.

The required proof load was calculated to be an 11-axle two-unit truck with gross vehicle weight of 1,210 kN. In previous studies by other researchers [4], concrete barrier blocks were placed on a flat bed truck to load the bridge. Each block weighs about 22 kN. Therefore, for this study the required number of blocks would be so large that it would not be possible to safely fit all of them on one truck. Therefore, a different scheme had to be prepared. Since the moment capacity at mid-span was found to be critical in preliminary calculations, it was decided to apply a load that would cause the equivalent proof load moment.

The innovative idea was to use M-60 military tanks on flat-bed trailers to achieve a very high target proof load level. The side view of the M-60 tank is shown in Fig. 2. Each tank weighs over 490 kN. This load is distributed over a small track of 4.5 m. Two such tanks were required to test this bridge. These tanks were provided by the Michigan National Guard. Only the four rear axles of each trailer were used to load the bridge. Each tank was placed on a flat bed trailer, such that the load on rear tandem axles was maximum. Both tanks had the same total weight. However, the configuration of the trailers was different. Therefore, the resulting axle loads were different.

For first load step, the tank on military trailer was placed close to support, to start with small mid-span moment. Then, the mid-span moment was increased gradually in several steps by moving the trailer towards mid-span. For third load case, the trailer was placed so that it caused maximum mid-span moment. For the fourth load case, the second trailer was positioned on the bridge, to further increase the moment. Load was also moved to three different transverse load positions. They were called upstream, center and downstream, depending on their location with respect to the flow of the river underneath, i.e. in upstream load position the trailers were placed close to the upstream railing.

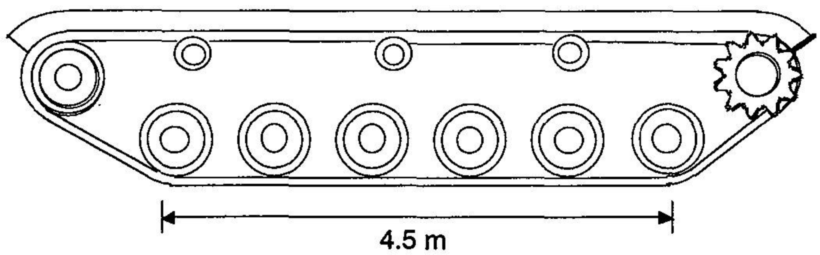


Fig. 2 Side view of M-60 tank

5. Instrumentation

Results of the test were closely monitored for any sign of distress. Several strain transducers were placed on steel girders close to mid-span and quarter-points. These transducers are reusable and clamped to the lower flanges of girders. Deflections at mid-point of all interior girders were measured using LVDT's. Deflections at quarter-points of selected girders were also measured. After placing the trailers in each load position, the data from each instrument was collected using a portable data acquisition system. The real time response of selected transducers was also monitored at all stages of testing. The data from LVDT's and strain transducers was collected by a portable SCXI-1200 data acquisition system. The system consists of a four slot SCXI-1000 chassis, one SCXI-1200 data acquisition card and two SCXI-1100 multiplexers. Each multiplexer can handle up to 32 channels of input data. The current system is capable of handling 64 channels of strain or deflection inputs. Up to 32 additional channels can be added if required. A portable field computer is used to store, process and display the data on site. A typical data acquisition setup is shown in Figure 3.

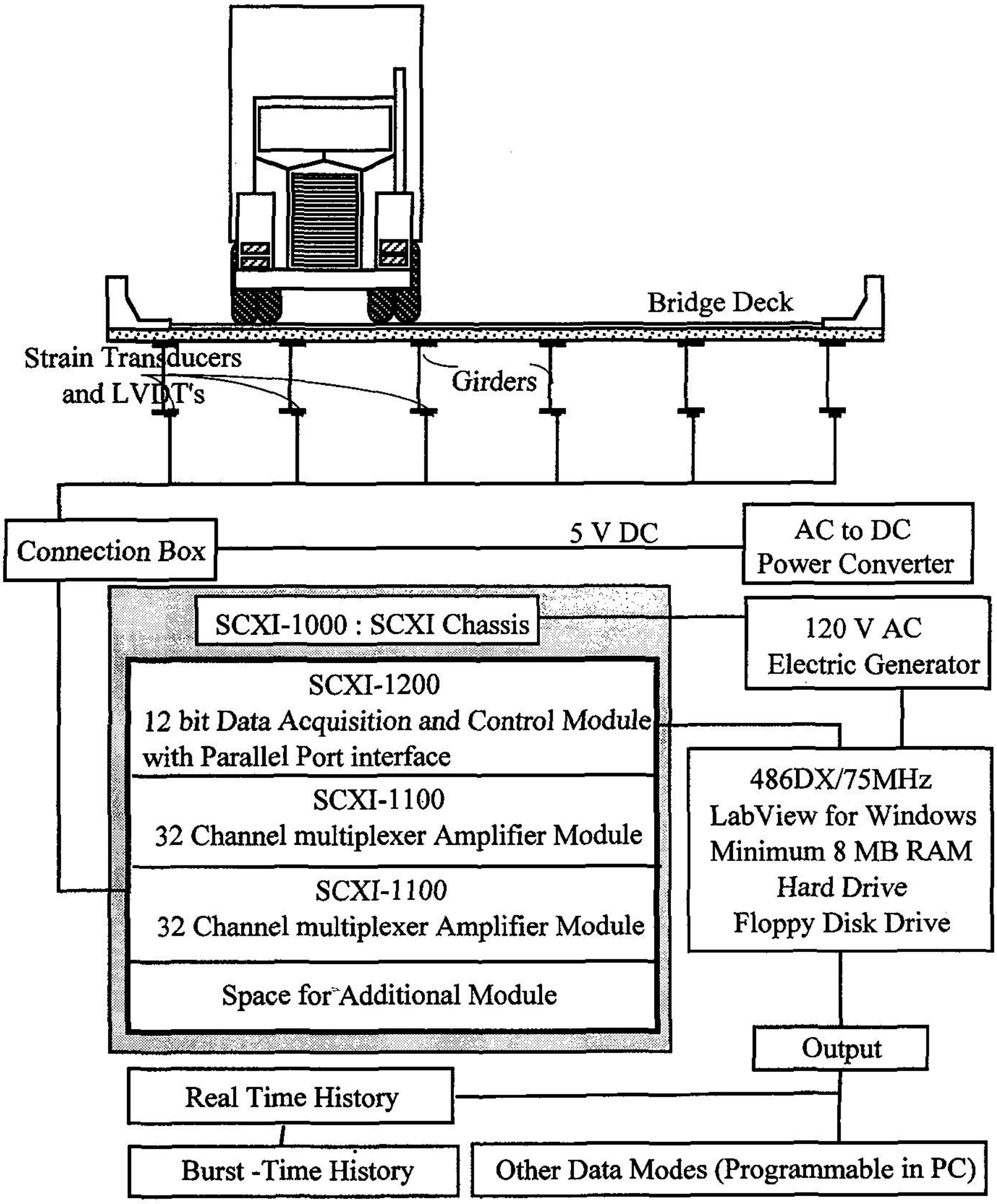


Fig. 3 SCXI Data Acquisition System Setup.

6. Proof load test results

During the test a maximum mid-span moment of 2,120 kNm was applied, which is over 2.6 times the moment caused by the HS20 design truck. The target proof load level was successfully reached without any noticeable distress. Therefore, the operating rating factor for an 11-axle two-unit truck is 1.0, after the test. Figs. 4 to 6 show the stresses at mid-span of girders for downstream, center and upstream loading, respectively. The four points in these figures relate to the four test load cases described in Section 4.

The maximum stress of 19.4 MPa was observed during experiments, for girder no. 3. It is less than 0.1 of the yield strength of steel. Also, for all girders, the stress increased linearly with increasing lane moment, and similar behavior was observed for center and upstream load cases. This indicates the extra safety reserve in the structure. The predicted maximum analytical stresses were 29 Mpa and 48 MPa for composite and non-composite models, respectively. It shows that the composite action between concrete slab and steel girders is present even at loads several times larger than the design load. The non-structural members also contributed to the overall flexural strength of the structure. Lateral distributions of girder deflections at mid-span are shown in Figs. 7 to 9. Although several diaphragms were severely deteriorated, the actual load sharing between girders is more uniform than analytically predicted. Following the test, the bridge was opened for normal traffic without any load posting.

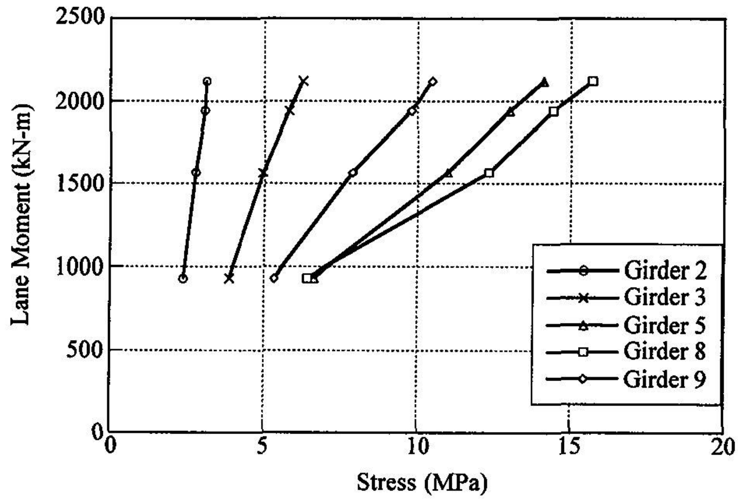


Fig. 4 Stresses at mid-span of girders for downstream loading

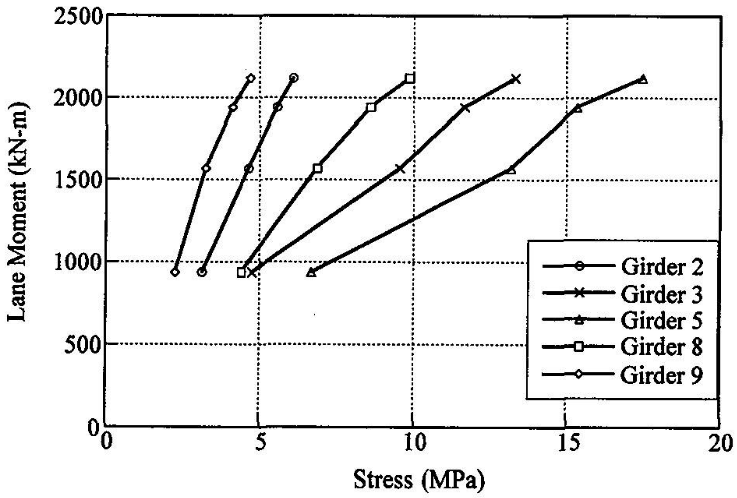


Fig. 5 Stresses at mid-span of girders for center loading

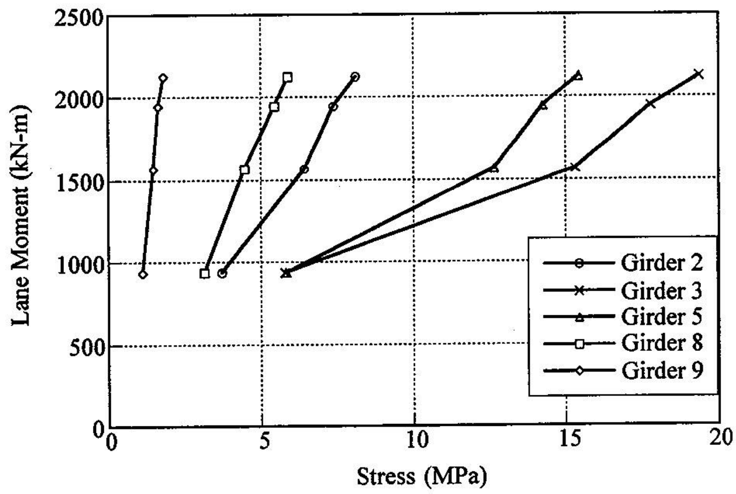


Fig. 6 Stresses at mid-span of girders for upstream loading

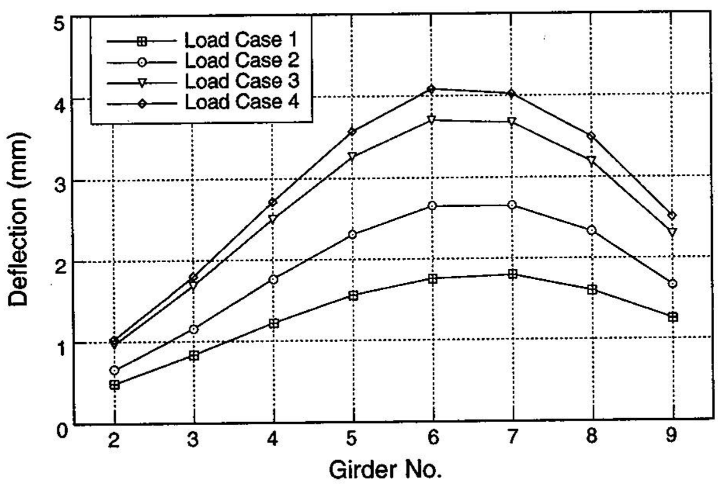


Fig. 7 Lateral distribution of deflections at mid-span for downstream loading

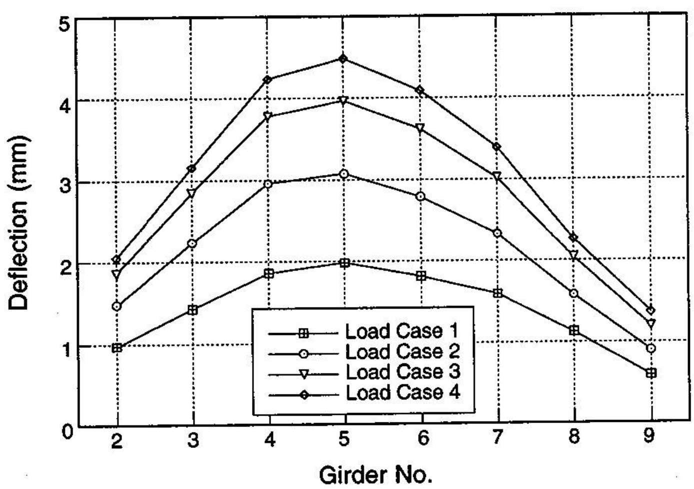


Fig. 8 Lateral distribution of deflections at mid-span for center loading

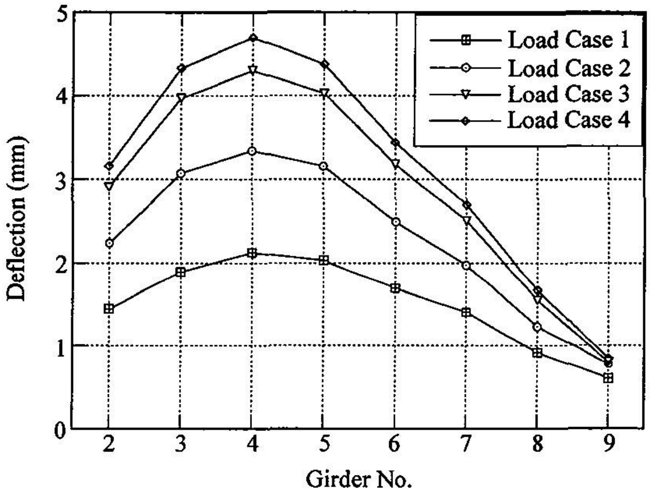


Fig. 9 Lateral distribution of deflections at mid-span for upstream loading

7. Conclusions

The proof load tests can be used as an efficient method to verify the minimum load carrying capacity of the structure. It may require a relatively greater effort, but it provides immediate answers about the load carrying capacity. The proof load must be considerably larger than legal load.

As a result of proof load test described in this paper, the bridge was found to be safe to operate under normal traffic.

Acknowledgments

The research presented in this paper has been partially sponsored by the Michigan Department of Transportation, the Great Lakes Center for Truck Transit Research, National Science Foundation, IDEA Transportation Research Board, NATO Collaborative Research Grants, and the University of Michigan, which is gratefully acknowledged.

References

1. AASHTO Standard Specifications for Bridge Design, American Association of State Highway and Transportation Officials, Washington, DC, 1992.
2. Hwang, E-S. and Nowak, A.S., "Simulation of Dynamic Load for Bridges," ASCE Journal of Structural Engineering, Vol. 117, No. 5, May 1991, pp. 1413-1434.
3. Jaeger, L.G., and B. Bakht, *Bridge Analysis by Microcomputer*. McGraw-Hill Book Company, New York, 1989.
4. Juntunen, D.A., and M.C. Isola, *Proof Load Test of R01 of 61131 M-37 over CSX Railroad*, South of Bailey. Michigan. Michigan Department of Transportation. Lansing, MI, April 1995.
5. Lichtenstein, A. G. *Bridge Rating Through Nondestructive Load Testing*. NCHRP report no. 12-28(13) A, June 1993.
6. *Michigan Bridge Analysis Guide*. Michigan Department of Transportation, Lansing, MI, December 1983.
7. Nassif, H. and Nowak, A.S., 1995, "Dynamic Load Spectra for Girder Bridges", Transportation Research Record, No. 1476, pp. 69-83.

Leere Seite
Blank page
Page vide