**General Literature Search for ORIL Research Idea Submission (November 2014-2015)**

**Synthesis of Research on Load Capacity of Concrete Slabs with No Plans**

Fred Pausch

County Engineer’s Association of Ohio (CEAO)

Prepared by

Zona Kahkonen Keppler, MLS

Library Administrator

[zona.kahkonen.keppler@dot.state.oh.us](mailto:zona.kahkonen.keppler@dot.state.oh.us)

Ohio Department of Transportation

Synthesis of Research on Load Capacity of Concrete Slabs with No Plans

*Prepared for*

*Ohio’s Research Initiative for Locals (ORIL)*

*November 2014*

*Prepared by*

*Zona Kahkonen Keppler*

*Transportation Literature Searches are prepared for ODOT staff to identify completed research and other authoritative information in an area of interest. The citations below are representative, rather than exhaustive of available English-language studies and other pertinent information on the topic. Primary online resources for the literature search TRID Online, TRB‘s Research in Progress (RiP), and Practice-Ready Papers databases, WorldCat, ASCE, the National Transportation Library (NTL) catalog, and other academic, engineering and scientific databases as available.*

***Keywords (singly/combinations****): Short span, concrete slab, short span concrete slab bridges, concrete bridges, bearing capacity, load factor, load rating, load factor, load tests, deflection, deterioration, field tests, strain, inspection, structural analysis*

***Citations:*** *Links to online copies of cited literature are provided when available. If you are interested in full reports/articles lacking a web link, please contact me and I will obtain the full report/article if possible.*

***Research idea:*** *Many short span concrete slab bridges exist from decades ago. The problem is that many do not have plans, so the load capacity is not easily determined. The goal would be to find a method to evaluate these slabs using common easily procured methods that the county staff could do. The goal is to allow local entities, with their small budgets to reasonably evaluate at little cost, the load capacity of concrete slab bridges for the safety of the public.*

***Summary:*** *The transportation literature yielded nineteen studies that fit the parameters of the research question. Please note that there are included in this compilation several studies with a common author, so there may be some redundancy. All studies were presented so that a comprehensive look at the body of work can be reviewed. It is suggested that the reference or bibliography section of the research reports be reviewed for additional resources of value to the research going forward.*

*A selection of the citations that matched the search parameters follows.*

**Development of a Load Test for the Evaluation and Rating of Short-Span Reinforced Concrete Slab Bridges**

[http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Reports/2002/Structures/14737-FR.pdf](https://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Reports/2002/Structures/14737-FR.pdf)

There exists in the state of Ohio a large inventory of short span reinforced concrete slab bridges, particularly on rural secondary highways, whose actual structural reliability cannot be accurately ascertained. Quite often **little or no documentation exists** to assist the responsible local jurisdictions in assessing the ability of these bridges to safely carry modern truck loading. A previously conducted feasibility study has demonstrated the potential of utilizing simplified load testing as an aid in the evaluation and load rating of such structures. In this study, an ensemble of twenty short span reinforced concrete bridges was load tested in order to develop a database, from which a suitable load-based rating methodology could be prescribed and verified, for this category of bridge structure. Two of the tested structures were loaded destructively, past the actual service limit state, in order to verify the reasonableness of the proposed nondestructive testing methodology. A nondestructive load-based test methodology, utilizing a loaded single axle dump truck as the test vehicle, was developed and verified. Simplified deflection instrumentation, consisting of mechanical dial gages, was shown to produce sufficiently accurate and precise data for reasonable and conservative capacity predictions. A wide range of span, width, depth, parapet types and skew angles were examined in order to arrive at a generally applicable methodology for this category of structure.

Eitel, A

Huckelbridge, A

Capaldi, N

State Job Number 14737(0)

Case Western Reserve University

School of Engineering  
10900 Euclid Avenue  
Cleveland, OH 44106 United States

Ohio Department of Transportation

1980 West Broad Street  
Columbus, OH 43223 United States

Federal Highway Administration

1200 New Jersey Avenue, SE  
Washington, DC 20590 United States

2002

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**Evaluation of a Short Span Concrete Arch Bridge for Rehabilitation**

A short span, open spandrel concrete arch bridge for local traffic has been found to have pieces of concrete fallen off from its components, and some reinforcing bars are exposed. **There is no available information on the bridge's details.** The safety of the bridge is of concern. Evaluation of the bridge consists of field measurement, load testing, and analysis. Load testing has been conducted and live load stresses in some components of the bridge have been measured. Results of a **live load analysis** by a finite element model compare satisfactorily with the measured values. The bridge is considered to have strength for the expected traffic loads. Minor repair to cover the exposed reinforcing bars is being recommended.

Yen, B T

Zhou, Y

Iowa State University, Ames

Department of Civil, Construction and Environmental Engineering  
Town Engineering Building  
Ames, IA 50011-3232 United States

p. 359-366

1993

Symposium on Practical Solutions for Bridge Strengthening and Rehabilitation  
Location: Des Moines, Iowa   
Date: 19930405 - 19930406  
Sponsors: National Science Foundation; and Iowa State University.

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**Evaluating the Load Carrying Capacity of Bridges without Plans Using Field Test Results**

Bridge load rating has become an integral part of bridge management in the United States. Ratings are used as a means to characterize the **load carrying capacity of bridges**, to allocate funding for the repair and rehabilitation of bridges, and to approve permit vehicles and superload crossings. Most load ratings are calculated using simple analytical models that are based on information obtained from the structural plans for the bridge; however, for some bridges, particularly for many smaller, older bridges, structural **plans may no longer** be available. Determining load rating factors for these types of structures is particularly difficult. The resulting ratings are usually based on numerous, conservative, assumptions. In many cases these structures end up with ratings much lower than they would have if plans were available for the bridge. There is a need for methods to help in determining realistic load rating factors for bridges for which plans are not available. This report summarizes the results of a study into methods for load rating bridges for which structural plans are not available, based on the results of diagnostic load tests

Chajes, M J

Shenton III, H W

Thompson, E

124p.

University of Delaware, Newark

Delaware Center for Transportation  
Newark, DE 19716 United States

Delaware Department of Transportation

800 Bay Road  
Dover, DE 19903 United States

2004

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**(Presentation of the above research at 2004 conference 2004 appearing in the 2010 literature)**

**Load Rating of Concrete Bridge without Plans**



Combining theoretical analysis and field tests can greatly enhance the understanding of the performance of the bridges for engineers, which can be applied to evaluate the **load carrying capacity of bridges without plans.** Researchers at the University of Delaware previously developed a methodology, the steel area method (SAM), to rate concrete bridges without plans, which uses strain or displacement measurements from field testing in conjunction with basic mechanics principles to estimate the unknown area of reinforcing steel in a concrete bridge. The estimated reinforcing steel area can then be used with traditional rating techniques. In this paper, the SAM procedure has been extended and improved to accommodate more realistic general load configurations used in a typical load test. A procedure for load rating bridges without plans incorporating the results of a diagnostic load test is proposed based on the improved SAM approach. A concrete slab bridge with original structural drawings is used to validate the proposed procedures. Conclusions of the proposed methodology are drawn based on the test verifications.

Huang, J

Shenton, H W

pp 298-309

American Society of Civil Engineers

1801 Alexander Bell Drive  
Reston, VA 20191-4400 United States

Structural Engineering Institute

American Society of Civil Engineers  
1801 Alexander Bell Drive  
Reston, VA 20191-4400 United States

2010

2010 Structures Congress and the 19th Analysis and Computation Specialty Conference  
Location: Orlando FL  
Date: 20100512 – 20100515

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**Guidance for Field Evaluations and Load Ratings of Bridges with Limited or Missing As-Built Data**

Research in Progress Project 36891

The Virginia Department of Transportation (VDOT) posts or restricts allowable gross vehicular weight on a bridge at a conservative level when a structure has **no as-built plans available**. Even if plans are available, deterioration - detected or not - and missing pertinent design details can make the rating process more complex. Because VDOT has a large number of such bridges, these load restrictions can affect the level of commerce across Virginia. This project will develop a "state of the current practice" for VDOT regarding analytical **rating practices**, augmented by rapid and reliable in-service field evaluation of structures - including nondestructive methods or in-service monitoring - for load-rating purposes. This synthesis should allow VDOT to use the results to develop a plan to perform these load ratings in-house, create a collaborative partnership with universities or contract these services, with the goal of increasing or eliminating the posting of bridges in a safe manner.

University of Virginia, Charlottesville

P. O. Box 400195  
Charlottesville, VA 22904 United States

Virginia Center for Transportation Innovation and Research

530 Edgemont Road  
Charlottesville, VA 22903 United States

Harris, Devin

Ozbulut, Osman

Chase, Steven B.

Kassner, Bernard

Start date: 2014-07-01

End date: 2016-04-30

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**Approach for Establishing Approximate Load Carrying Capacity for Bridges with Unknown Material and Unknown Design Properties**

<http://ntl.bts.gov/lib/42000/42300/42309/MPC11-236.pdf>

There are 16 small to medium simple span bridges in Larimer County that are currently load rated solely based on visual inspections. Most of these bridges are pre-stressed concrete bridges. The objective of this project is to load rate these bridges using structural analysis with **very little to no information available** related to their design. Larimer County provided everything available, which essentially was very limited plans and inspection reports for the bridges. The plans lacked details concerning pre-stress, cross-section dimensions, and material properties. The bridge (pre-stress concrete) manufacturer does not have records of the bridges built in the 1960’s or earlier. Due to these limitations, a **basic structural analysis was performed** using a program developed for the Colorado Department of Transportation (CDOT) in 2007 with rating-conservative assumptions in order to determine the capacities of the bridges. The influence of these assumptions on the conclusions is also discussed.

Colorado State University, Fort Collins

Fort Collins, CO 80523 USA

Mountain-Plains Consortium

North Dakota State University  
P.O. Box 5074, 430 IACC Building  
Fargo, ND 58105 USA

Authors:

Taylor, Zach

Amini, Omar

van de Lindt, John W.

86p.

2011

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**Load Testing for Bridge Rating: Dean's Mill Over Hannacrois Creek**

[https://www.dot.ny.gov/di...and-d-repository/sr147.pdf](https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/sr147.pdf)

The report discusses testing and load rating of the bridge carrying Dean’s Mill Road over the Hannacrois Creek in Greene County, New York (County Bridge BIN 3201350). The bridge was built in 1961, and consists of five 70-ft long post-tensioned bulb-T beams connected by 8-in. wide closure pours. No documents or plans for the structure are available. The bridge deck is topped with an asphalt overlay for a riding surface. It is a single span structure, has two traffic lanes, and an AADT of approximately 650 vehicles. In 1970, the structure was load posted for 12 tons. **Absence of the bridge plans** discouraged the County Engineers’ evaluation of the structure to increase the 12 ton posting. Pressed by the public’s demand to accommodate school bus traffic on the bridge, the County approached the New York State Department of Transportation (NYSDOT) on how to respond to the pressing demand. The County agreed to a load testing plan proposed by the Transportation Research and Development Bureau of the NYSDOT. The plan was based on investigating actual behavior of the structure under controlled **truck loading**. The bridge was instrumented and load tested using trucks of known weights and configurations positioned at specified locations on the deck, to gradually increase their load effect on the structure. The load testing results gave actual stiffness of the bridge beams and revealed the level of fixity at the bridge abutments. Prior to the load testing, the beam geometry was determined and the bridge structure was analyzed using the 1961 American Association of State Highway and Transportation Officials (AASHTO) specifications. The analysis was based on the assumption that the structure was designed to meet the specifications’ requirements regarding satisfying initial and final stresses. This analysis provided estimates for the initial and final post-tensioning forces, and the eccentricity and cross sectional area of the post-tensioning steel. Using this information, the beams’ ultimate and cracking moments, and a safe/threshold moment to be applied during the testing were determined. Utilizing the test results, the bridge load rating at the inventory and operating levels was performed using the **AASHTO load factor method**, for both H-20 and HS-20 trucks.

New York State Department of Transportation

Transportation Research and Development Bureau, 50 Wolf Road  
Albany, NY 12232 USA

Federal Highway Administration

1200 New Jersey Avenue, SE  
Washington, DC 20590 USA

Hag-Elsafi, Osman

Kunin, Jonathan

71p.

2006

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**Concrete Bridge Assessment: an Alternative Approach**

Since the Department of Transport launched the bridge rehabilitation program in 1987, many thousands of bridges have been assessed to determine their safe **load carrying capacities**. Although the majority of structures have been found to be satisfactory, large number of bridges have 'failed' their assessments. In this paper progress on the assessment and strengthening part of this program is reviewed. The conventional approach to bridge assessment is examined, and the definition and consequences of 'failure' are discussed. Alternative methods of assessment are considered, and the potential for using plastic collapse or **yield line analysis** for the assessment of **short-span reinforced concrete slab bridges** is evaluated. A new technique for performing yield line analysis has been developed recently at Cambridge University and implemented in a computer program called COBRAS. This approach provides a simple, rapid and practical means of performing yield line analysis and overcomes many of the difficulties that have previously limited the application of this method in practice. Over 20 concrete bridges, 'failed' using conventional assessment methods, have now been reassessed using this program. All were found to have higher flexural capacities when plastic, rather than elastic, analysis was used for assessment. It is concluded that there is considerable potential for using yield line analysis for evaluating the ultimate load capacity of short-span concrete slab bridges.

Middleton, C. R.

Institution of Structural Engineers

11 Upper Belgrave Street  
London SW1X 8BH United Kingdom

1997

*Structural Engineer*  
Volume: 75  
Issue Number: 23/24  
Publisher: Institution of Structural Engineers

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**Nondestructive and Destructive Testing of Decommissioned Reinforced Concrete Slab Highway Bridge and Association Analytical Studies**

Recently there have been many examples of undesirable bridge performance under service loads and scour and after floods and earthquakes. There is also evidence that, according to present inspection and rating procedures, a large number of bridges may be deemed structurally deficient without justification. Many reinforced concrete (RC) **slab bridges** are now being replaced without taking full advantage of their inherent capacities because of a lack of understanding and knowledge of the effects of deterioration and aging on these bridges. To establish procedures to allow for the full utilization of RC slab bridge capacity, **a 38-year-old sample was loaded to failure**. The bridge, which was decommissioned because of its age and deteriorated state, endured the equivalent loading of 22 rating trucks before failure.

This paper appears in Transportation Research Record No. 1371, Bridge, Culvert, and Tunnel Research.

Aktan, A. E.

Zwick, M.

Miller, R.

Shahrooz, B.

p. 142-153

1992

Transportation Research Record  
Issue Number: 1371  
Publisher: Transportation Research Board

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**Performance of Concrete Slab Bridges. Final Report.**

Highway bridge rating practice in the United States currently follows the procedures outlined in the "AASHTO Manual for Maintenance Inspection of Bridges". However, field testing results indicate that there is significant reserve strength in most bridges that is not accounted for by the AASHTO rating procedures. Consequently, bridges that possess sufficient strength to remain in service may be rated structurally deficient. This finding is especially significant for many **older bridges** that were designed for smaller loads, but that may possess sufficient capacity to allow the passage of modern vehicular loads. Because this reserve strength is not predicted by any contemporary analytical techniques, field testing is critical for developing rating procedures. This project focused on **concrete slab bridges**. In Nebraska there are many multiple-span slab bridges which were designed for H15 truck loading. Many of these bridges, when rated using current analytical tools, have insufficient capacity to carry modern traffic loads, resulting in their replacement, strengthening, or load posting. The **overall objectives of this project were to assess more accurately the load carrying capacity of reinforced concrete slab bridges** and develop simple analytical tools for predicting their behavior under service and ultimate load conditions. A five span bridge over the Niobrara River in northwestern Nebraska was selected for testing. Two spans of the bridge, which was built in 1938 and decommissioned in 1972, were subjected to numerous tests including loading to collapse. Using the BARS program the bridge was rated for approximately 67% of HS20 truck load. However, experimental results indicated that this bridge could carry 4 times the HS20 truck load in each lane while behaving in a perfectly elastic manner and, furthermore, it would require the equivalent of 7 HS20 truck loads in each lane to reach ultimate capacity. A detailed analytical study using finite element analyses and yield line analyses incorporating a moment curvature approach together with actual material properties were conducted to assess the differences between observed capacity and that predicted by conventional analysis approaches. Based on the experimental and analytical investigations conducted, it can be concluded that concrete slab bridges possess significant reserve capacity and that yield line analysis can effectively be utilized to accurately predict the strength of these bridges.

Shekar, Y.

**Azizinamini,** Atorod

Barnhill, G.

Boothby, T. E.

609p.

University of Nebraska, Lincoln

College of Engineering and Technology  
Lincoln, NE 68503 United States

Nebraska Department of Roads

1500 Highway 2, P.O. Box 94759  
Lincoln, NE 68509 United States

1993

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**Advanced Methodology for Rating Concrete Slab Bridges**



Azizinamini, A.

Elremaily, A.

Choobineh, F.

**Field testing** of **old concrete slab bridges** designed for smaller truck loads shows that these bridges possess much higher strength than that indicated by current rating procedures. Extensive experimental and analytical investigations were carried out to evaluate the behavior of concrete slab bridges. Information gained from conducting the experimental and numerical analysis is used in this paper to develop a state of the art method to rate concrete slab bridges using a **probabilistic approach.** Monte Carlo simulation technique is used to develop probability density functions (PDF) for both load effect and resistance. The PDFs are then used to develop the probability of failure of the bridge. Results of this investigation indicate that concrete slab bridges, including those originally designed for H15 loads, have large reserve capacities and most of these bridges could carry modern traffic loads.  
  
2000

*Advanced Technology in Structural Engineering*: pp. 1-8

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**Reliability Based Rating Procedure for Concrete Slab Bridges Using Field Testing**

**Concrete slab bridges** are **short span bridges** that are found in the thousands in both state and county inventories. A majority of these bridges are three-span continuous and were constructed during the years when H15 AASHTO truck loads were used as the designed vehicle load. The problem occurs when these bridges are required to carry higher traffic loads, such as AASHTO HS20 design truck loads, which are 72,000 lb. (32,659 kg). An extensive investigation to comprehend the behavior of concrete slab bridges and **develop a state of the art method of rating them** was conducted at the University of Nebraska-Lincoln between 1991 and 1997. This report summarizes the entire investigation, which was carried out in two phases. The experimental work included testing 12 concrete slab bridges in the field and constructing and testing of a 1/4 scale three span bridge in the laboratory. One slab bridge was tested to collapse in the field. Experimental data were used to develop a reliable procedure to carry out three dimensional analysis of concrete slab bridges. Information gained from conducting experimental and numerical analysis was used to develop a state of the art method to rate concrete slab bridges using **probabilistic approach**. Results of this investigation indicate that concrete slab bridges have large reserve capacities, including those originally designed for H15 loads, and most of these bridges could carry modern traffic loads.

Azizinamin**i**, A.

Keeler, B.

Choobineh, F.

Mans, P.

Luedke, J.

University of Nebraska, Omaha

Department of Civil Engineering, 6001 Dodge Street  
Omaha, NE 68182-0178 United States

Nebraska Department of Roads

1500 Highway 2, P.O. Box 94759  
Lincoln, NE 68509 United States

Federal Highway Administration

1200 New Jersey Avenue, SE  
Washington, DC 20590 United States

276p.

1998

FHWA NE-98-P480  
Final Report

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**Feasibility Study for Simplified Load Testing of Slab Bridges. Final Report.**

The objective of this investigation was to demonstrate the feasibility of obtaining meaningful quantitative structural response data, suitable for rating purposes, from **short span reinforced slab bridges by simplified load testing**. Such simplified load testing could be carried out by regular inspection personnel, utilizing **pre-weighed vehicles** for loading the structures and collecting the resulting deflection data with readily available instrumentation, such as mechanical dial gages, etc. Quantitative in-situ load performance data, combined with conventional visual inspection, would provide a much sounder basis for load rating than visual inspection alone. Before such a rating procedure can be developed, however, it must be verified that useful data can be collected by the "low-tech" instrumentation alluded to. The investigation revealed that measurable deflections, providing data with more than adequate accuracy and resolution, were indeed possible. The "low-tech" dial gages agreed very well with more sophisticated electronic instrumentation, and simple portable fixturing was demonstrated. Load ratings were estimated for the test structures which would appear to be quite reasonable for the test loads utilized. Reasonably heavy loads (axle weights in excess of 30 kips) still did not load the bridges in question beyond the service limit state, defined as steel stresses in the reinforcement estimated at 50% of yield.

Huckelbridge Jr, A. A.

Case Western Reserve University

School of Engineering  
10900 Euclid Avenue  
Cleveland, OH 44106 United States

Ohio Department of Transportation

25 South Front Street  
Columbus, OH 43215 United States

Federal Highway Administration

1200 New Jersey Avenue, SE  
Washington, DC 20590 United States

State Job No. 14593(0)

45p.

1995

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**Concrete Slab Bridges: How Strong are they?**

An investigation is being conducted to evaluate more accurately the performance of old reinforced **concrete slab bridges**. Several tests, including **ultimate load tests**, were carried out on two spans of an existing reinforced concrete slab bridge built in **1938** and decommissioned in 1972. This paper summarizes the results of some of the experimental and analytical investigations conducted on one of the simply supported spans.

Iowa State University, Ames

Department of Civil, Construction and Environmental Engineering  
Town Engineering Building  
Ames, IA 50011-3232 United States

Shekar, Y.

Azizinamini**,** A.

Barnhill, G.

Boothby, T. E.

p. 379-387

1993

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**Testing of Old Reinforced Concrete Bridges**

<http://publications.iowa.gov/16919/1/IADOT_hr390_Test_Old_Reinf_Conc_Brid_1997.pdf>

The objective of this research project was to **service load test** a representative sample of old reinforced concrete bridges (some of them historic and some of them scheduled for demolition) with the results being used to create a database so the performance of similar bridges could be predicted. The types of bridges tested included two reinforced concrete open spandrel arches, two reinforced concrete filled spandrel arches, one reinforced **concrete slab** bridge, and one two span reinforced concrete stringer bridge. The testing of each bridge consisted of applying a static load at various locations on the bridges and monitoring strains and deflections in critical members. The load was applied by means of a **tandem axle dump truck with varying magnitudes of load**. At each load increment, the truck was stopped at predetermined transverse and longitudinal locations and strain and deflection data were obtained. The strain data obtained were then evaluated in relation to the strain values predicted by traditional analytical procedures and a carrying capacity of the bridges was determined based on the experimental data. The response of a majority of the bridges tested was considerably lower than that predicted by analysis. Thus, the safe load carrying capacities of the bridges were greater than those predicted by the analytical models, and in a few cases, the load carrying capacities were found to be three or four times greater than calculated values. However, the test results of one bridge were lower than those predicted by analysis and thus resulted in the analytical rating being reduced. The results of the testing verified that traditional analytical methods, in most instances, are conservative and that the safe load carrying capacities of a majority of the reinforced concrete bridges are considerably greater than what one would determine on the basis of analytical analysis alone. In extrapolating the results obtained from diagnostic load tests to levels greater than those placed on the bridge during the load test, care must be taken to ensure safe bridge performance at the higher load levels. To extrapolate the load test results from the bridges tested in this investigation, the method developed by Lichtenstein in NCHRP Project 12-28(13) A was used.

Klaiber, F. W.

Wipf, T. J.

Streeter, C. M.

Iowa State University, Ames

Department of Civil, Construction and Environmental Engineering  
Town Engineering Building  
Ames, IA 50011-3232 United States

Iowa Department of Transportation

800 Lincoln Way  
Ames, IA 50010 United States

308p.

1997

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**Finite-Element Analysis and Load Rating of Flat Slab Concrete Bridges**



Davids, W.

Poulin, T.

Goslin, K.

*Journal of Bridge Engineering*, 18(10), 946–956.

A significant portion of the nation’s aging bridge inventory consists of **flat slab concrete bridges**. Many of these bridges were **constructed in the middle third of the 20th century**, and although they are in generally good condition, they were not designed to carry modern highway loads. This research builds on prior studies that indicate that the equivalent strip width method—prescribed by AASHTO and widely used for the analysis of flat slab bridges—may be overly conservative and lead to under prediction of bridge structural capacity. The development of **finite-element (FE) analysis software** designed specifically for the load rating of flat slab bridges is presented. The FE software formulation and convergence were verified by comparison with predictions from commercial FE software under realistic loading scenarios. Results of live load tests of an instrumented, in-service flat slab bridge are reported. The FE model-predicted slab moments were shown to be conservative relative to the moments inferred from the load test data for a range of truck positions. Fourteen in-service flat slab bridges were load rated with both FE analysis and the equivalent strip method to assess the degree of conservatism inherent in the AASHTO approximate analysis. The results show an average increase in rating factor of approximately 26% when using FE analysis and that 58% of the bridges predicted to be under capacity using AASTHO approximate methods are sufficient based on FE analysis.

2013

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**Old Concrete Slab Bridges. I: Experimental Investigation**

Azizinamini, A.

Boothby, T.

Shekar, Y.

Barnhill, G.

*Journal of Structural Engineering*, 120(11), 3284–3304.

Old reinforced concrete slab bridges designed for smaller truck loads are called on to carry the modern, heavier, loads. These bridges, when rated according to the current American Association of State Highway and Transportation Officials procedures, are found to be structurally deficient. The present paper reports the experimental part of the investigation carried out to understand the behavior of this category of bridges, both at service and ultimate load levels in order to rate them more realistically. A **five‐span reinforced concrete slab bridge, built in 1938** and decommissioned since 1972, was tested destructively. The destructive test was performed by applying loads that simulated the presence of two trucks side‐by‐side on the bridge. Also, six three‐span reinforced concrete slab bridges were subjected to service load tests. Two dump trucks, each weighing approximately 222.5 kN, were used to carry out the service load tests. Experimental results indicate that reinforced concrete slab bridges possess much higher strength than that indicated by current rating procedures.

1994

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**Old Concrete Slab Bridges. II. Analysis**



Azizinamini, A.

Shekar, Y.

Boothby, T.

Barnhill, G.

1994

*Journal of Structural Engineering*, 120(11), 3305–3319.

**Old reinforced concrete slab bridges** designed for smaller truck loads are called on to carry modern, heavier loads. These bridges, when rated according to current American Association of State Highway and Transportation Officials procedures are found to be structurally deficient. Therefore, it is important to rate these bridges more realistically. The experimental part of the investigation to understand the behavior of slab bridges is given in a companion paper. The present paper provides the **analysis of the experimental data.** The reasons for the conservatism of the current rating procedures observed during the experimental investigation stemmed from the facts that the actual material properties were much higher than the assumed design values, and the curbs participated to a considerable extent in carrying the applied loads. Also, a simple three‐dimensional finite‐element model to analyze these bridges under service loads is presented.

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**Dynamic Testing of a Short span Rural Bridge**



An on-going research project examines the feasibility of using ambient vibration measurements as a supplement to routine bridge inspection. The goal of this research is to develop a **cost-effective testing** methodology, which can be **easily implemented on** **county highway bridges** in Shelby County, Alabama. This paper summarizes a preliminary study on a two-lane concrete deck/steel stringer bridge. Vibrations due to impact excitation and ambient traffic were used to extract the first bending mode. These data were used to determine the dynamic load impact factors of the bridge. Due to the relatively lightweight of the bridge, the weight of the automobile significantly influences the resonant frequencies. Based on the study, recommendations on field measurements as a standard inspection procedure have been made and discussed.

Shen-En Chen

Dept. of Civil & Environmental Engineering, University of Alabama at Birmingham, Birmingham, AL 35294-4440

Thomas Grimes

County Engineer’s Office, Shelby County Highway Department, Columbiana, AL 35051

Sreenivas Alampalli

Transportation Research & Development Bureau, New York Department of Transportation, Albany, NY 12232-0869

Mostafiz Chowdhury

Transportation Research & Development Bureau, New York Department of Transportation, Albany, NY 12232-0869

Gregory Myers

Weapons and Materials Research Directorate, U.S. Army Research Laboratory, Adelphi, MD 20783-1145