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STRUCTURAL EVALUATION OF IN-SERVICE BRIDGES USING W-I-M TECHNOLOGY

BRIEFING REPORT FOR ORAL PRESENTATION NO. 2

by

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This report documents the research results and contract progress from February 1985 to September 1985 in support of the second oral presentation to FHWA in Washington, D.C., and covers Tasks C, D, E and G.
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Acknowledgments

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The manuscript was typed with care by Ms. Joann Frey.
1. **Introduction**

The second (of two) oral presentations for the Contracting Officer's Technical Representative (COTR) and other Federal Highway Administration (FHWA) personnel was held at the FHWA Turner-Fairbank Highway Research Center, Washington, D.C., on October 4, 1985.

The purpose of the oral presentation is to evaluate the research results and contract progress. This report documents the second oral presentation. Many of the visual aids used during the visual presentation are contained herein as tables and figures.

The evaluation of research results and contract progress from September 1983 to January 1985 is contained in "Briefing Report for Oral Presentation No. 1", prepared for the Federal Highway Administration, February 1985 (See Ref. 1, Appendix A of this report).

An overview of the research progress from February 1985 to September 1985 is presented in Chapter 1 - Introduction of this report. The remaining chapters provide details of the research accomplished in each task.

Work on Task C - Modification of W-I-M System - was performed during the period January through May 1985. The resulting system is referred to herein as the WIM-Response System.

Work on Task D - Conduct Field Studies - was performed in two phases. The first phase was reported in February 1985 at the first Oral Briefing Meeting. The second phase began in June 1985 and was completed in August 1985. Field Studies of four bridges were conducted in this period.
Work on Task E - Evaluate Data - continued in August 1985 with the evaluation of data obtained from the four bridges investigated during the summer of 1985.

2. Task C - Modification of W-I-M System

On February 12, 1985 Lehigh University received written authorization
from the Contract Administrator to proceed with the purchase of the
items described at the first Oral Briefing Meeting (Ref. 1) and continue
with the progress on Task C through Task G.

These items were purchased and the modification of the W-I-M
System completed in May 1985. Testing of the WIM-RESPONSE system was
carried out in Fritz Engineering Laboratory in late May and early June
1985 in preparation for the Task D field studies.

A listing of the hardware and software items needed for the
modification of the W-I-M System is contained in Ref. 1. The decisions
reached and agreed to by Fritz Laboratory and FHWA which formed the
basis for the design of the WIM-RESPONSE System are as follows:

1. The FHWA MINC 11/03 will be enhanced or expanded to an
   11/23.

2. A prototype WIM-RESPONSE system will be developed, capable
   of acquisition and storage of both WIM plus RESPONSE data.

3. Deliverable software will be able to perform data reduction
   on compatible systems.

4. The WIM-RESPONSE system will be designed for a maximum of 16
   channels, 6 for WIM and 16 for RESPONSE.

5. The WIM-RESPONSE system will be designed to work on a certain
   class of bridges. The important design parameters are as
   follows:

   a) Multiple girder bridges having no more than 6 or
      8 parallel girders,

   b) Simple or continuous spans,
c) No more than 3 continuous spans, 


d) Maximum bridge length of 400 feet.

As of June 1985, the necessary hardware and software upgrades were made successfully to permit field studies to be conducted on four bridges commencing June 17, 1985.
3. Task D - Conduct Field Studies

3.1 Objectives

The primary objectives of Task D are to:

1) Demonstrate the capabilities of the modified W-I-M System by:
   
a) Conducting field studies of a minimum of four bridges
   
b) Monitoring traffic and strains on each bridge continuously for a minimum of 5 days.

2) Accumulate structural response and bridge loading data for evaluation in Task E.

Oral Briefing Report No. 1 (Ref. 1) presented the results of pilot field studies performed on two bridges prior to modification of the W-I-M System. These pilot studies were conducted primarily to gain experience in using the W-I-M System and to assist in preparing a specification for the design of the WIM-RESPONSE System.

3.2 Bridge Selection Criteria

Between March and July, 1985, about 30 candidate bridges were inspected for their suitability for study under Task D. Of these, 26 were within 50 miles and the remainder within 100 miles of Lehigh University. The following criteria were used to select four suitable bridges:

1. A variety of steel and concrete bridges are candidates as long as they met the design parameters listed in Chapter 2.

2. Right or skewed bridges are acceptable.

3. About 1 mile of reasonably level approach and sight distance is required for nearly constant traffic speed over the bridge and for traffic control safety during installation of the tape switches on the roadway.
4. Good condition of roadway at tape switch locations to avoid wheel skipping over tape switches.

5. Relatively smooth deck on instrumented spans to avoid significant impact loading which would affect WIM data (this criterion conflicted with the desirability for some impact which would enhance the RESPONSE data.

6. Bridge to be located on a highway with a reasonably high ADTT so that at least a 3,000 to 4,000 truck sample would be obtained (ADTT figures were usually not available from PennDOT, however, so an estimate had to be made).

7. Steel girders should have interesting welded or rivetted details, stiffeners and diaphragms.

8. For concrete bridges preferably prestressed concrete I girders or reinforced concrete Tee girders.

9. Accessability of the girders from below is required, within a reasonable height from the ground.

10. Suitable off-roadway location of the instruments van below the bridge is required for safety of personnel.

11. Reasonably low level of roadway traffic below the bridge for safety of personnel.

12. Good site distances below the bridge for traffic control safety during installation of transducers and strain gages to the bridge girders.

13. Availability of electric power source within 400 feet of the bridge. (Use of the portable power supply proved too noisy and costly and resulted in too many power interruptions during data collection.)

In addition, the following factors influenced the location and timing of the field studies:

1. Fritz Laboratory has performed stress history studies on approximately 75 bridges in the past 15 years. Many of these bridges are located in PennDOT District 5. A high degree of cooperation and good relations has developed with the District 5 personnel. For this reason it was preferred to locate 4 suitable bridges within District 5.
2. Of all the bridges inspected the 4 suitable bridges closest to Lehigh University were selected. Experience has shown that field studies are more efficiently organized and executed if travel time to and from the bridges is minimized.

3. All four field studies had to be completed between June 1 and August 25, 1985. The level of student help needed to provide continuous 24 hour monitoring of the data collection, instruments van, wiring and gages for a week per bridge renders it difficult to efficiently conduct these studies during the academic semesters.

4. All four field studies had to be completed when temperatures higher than 40 to 50 degrees could be expected. Lower temperatures make it difficult to mount reliable strain gages for RESPONSE data.

3.3 Description of Bridges

3.3.1 EB Route 22 Over 19th St.

Bridge: East Bound Route 22 over 19th St. in Allentown PA. (Part of I 78)

Superstructure: 5 girder, multiple, steel rivitted plate girders with a new composite concrete deck.

Span: 84'-10", simple span, right.

Truck Traffic: Estimated 2,000 to 3,000 ADTT on peak days. PennDOT estimates 40,000 to 60,000 ADT on peak days. (Due to Route 22 reconstruction 10 miles east of bridge the ADTT was somewhat lower)

WIM: 4,680 trucks in 5 days

Factors Affecting Bridge Selection:

a) Closest suitable steel girder bridge on a high ADTT route travelled by a large percentage of heavy trucks.

b) Comparison of response data with that from the adjacent west bound (Art. 3.3.2) bridge where the span length is the significant variable.
c) Superior accessibility and safety considering the traffic volume.

d) The original bridge, constructed in 1951 was non-composite. A new composite deck was placed in 1983. The AASHTO Specification for design of exterior girders was changed in 1957.

Figures 3-1 and 3-2 are aerial views of Route 22 on which the two bridges described in Arts. 3.3.1 and 3.3.2 are located. Figure 3-1 is a view looking East along a segment of Route 22. The City of Allentown is mostly under the wing of the aircraft. The City of Bethlehem is in the distance mostly to the left of the wing. The right hand lanes of the segment of Route 22 which is in line with the view in Fig. 3-1 are the approach lanes to the East Bound bridge. The East Bound bridge is immediately around the corner and to the left of the far end of this segment and cannot be seen in this view. In Fig. 3-2 the aircraft has travelled further South. The two bridges can be seen at the near end of the short segment of Route 22 which is in line with the view in the figure. The Allentown-Bethlehem-Easton (ABE) airport is in the distance further East, and just above this segment of Route 22. (The air traffic controllers at the ABE airport would not permit aerial photography closer to the bridges).

Figures 3-3 through 3-6 show various views of the East Bound bridge on Route 22 over 19th Street. The approach to the East Bound bridge is shown in Fig. 3-3. Figure 3-4 shows a view looking East over the bridge. A truck crossing the East Bound bridge is shown in Fig. 3-5.
The tape switches on the deck immediately ahead of the East Bound bridge is shown in Fig. 3-6. The bridge is to the right of the tape switches in the figure.

3.3.2 WB Route 22 Over 19th St.

Bridge: West bound Route 22 over 19th St. in Allentown, PA. (Part of I 78)

Superstructure: 5 girder, multiple, steel, rivetted plate girders with a new composite concrete deck.

Span: 125'-0", simple span, right.

Truck Traffic: (Same as East Bound bridge).

WIM Sample: 7,112 trucks in 5 days.

Factors Affecting Bridge Selection: (Same as East Bound bridge).

Figures 3-7 through 3-10 show various views of the West Bound bridge on Route 22 over 19th Street. The approach to the West Bound bridge is shown in Fig. 3-7. Figure 3-8 shows a view looking West over the bridge. The tape switches immediately ahead of the West Bound bridge can be seen in the figure. A truck crossing the West Bound bridge is shown in Fig. 3-9. The PennDOT lift truck used for instrumentation of the span is shown under the bridge. The instruments van can be seen parked under the left end of the bridge. Instrumentation of the span from the lift truck can be seen in Fig. 3-10.
3.3.3 NB Route 33 Over Van Buren Rd.

Bridge: North bound Route 33 over Van Buren Road in PA.
One Mile North of Route 248.

Superstructure: 6 girder, multiple, steel, welded plate
girder main span and 6 girder, multiple,
steel rolled beam end spans with concrete deck.

Spans: 108'-3", simple main span, 53°29'skew.
41'-6", simple end span, 53°29'skew.

Truck Traffic: Estimated 1,000 ADTT

WIM Sample: 3,626 trucks in 5 days

Factors Affecting Bridge Selection:

a) Closest suitable welded steel girder bridge
on a reasonable ADTT route travelled by
a large percentage of heavy trucks.

b) Response data obtained from both the welded
girder main span and the rolled girder end
span.

c) Interesting welded details and diaphragms.

d) Replaced selection of a concrete bridge in
original test plan in order to significantly
enhance the amount and value of the response
data.

Figures 3-11 through 3-18 show various views of the North Bound
bridge on PA Route 33 over Van Buren Road, one mile north of PA Route
248. Figure 3-11 is an aerial view of Route 33 looking SW towards
Bethlehem, PA. The North Bound bridge used in the field study is the
left most bridge of the pair of bridges in the foreground to the left
of the large buildings. The North Bound bridge is in the foreground in
Fig. 3-12. Van Buren Rd. passes under the bridge. The view in Fig.
3-12 looks roughly North. The instruments van can be seen in the figure
parked under and to the left of the North Bound bridge span. Figure 3-13
shows the approach to the North Bound bridge. Figure 3-14 shows trucks crossing the North Bound bridge. The main span and instruments van are shown in Fig. 3-15. Figure 3-16 shows the short span in the foreground and the main span with diaphragms beyond the pier. Figure 3-17 shows the tape switches on the pavement immediately ahead of the short span. The bridge skew is clearly shown in the figure. The data acquisition set-up in the van is shown in Fig. 3-18. Part of the MINC 11/23 computer is shown in the lower right hand corner of the figure. The VT-125 terminal and keyboard are next to the computer. To the left of the terminal are two signal conditioning units. The lower unit (next to the operators hand) contains 6 Vishay signal conditioners and receives signals from the 6 transducers mounted on the short span girders for obtaining either WIM or RESPONSE data. The upper unit contains 10 Vishay signal conditioners and receives signals from the 10 strain gages on the main span for obtaining RESPONSE data.

3.3.4 NB Route 33 Over State Park Rd.

Bridge: North bound Route 33 over Stat Park Road
Two Miles North of Belfast, PA.

Superstructure: 6 girder, multiple, prestressed I girder
main span and end spans with concrete deck.

Spans: 66'-3 1/2", simple main span, skewed
28'-0", simple end spans, skewed
(48° 47' skew)

Truck Traffic: Estimated 1,000 ADTT

WIM Sample: 3,984 trucks in 7 days.
Factors Affecting Bridge Selection:

a) Replaced Bartonville bridge in original test plan due to I 80 reconstruction in summer of 1985 involving the Bartonville bridge.

b) Bridge closely resembled the Bartonville bridge span but provided an additional span thus enhancing the amount and value of the response data.

c) Interesting diaphragms

d) Allows comparison with a similar steel bridge (over Van Buren Road) with expected nearly identical GVW spectra. The bridge over State Park Rd. is about 4 miles North of the bridge over Van Buren Rd.

Figures 3-19 through 3-24 show various views of the North Bound bridge on PA Route 33 over State Park Rd., 2 miles north of Belfast, PA. Figure 3-19 is an aerial view of PA Route 33 looking North. The North Bound bridge over State Park Rd. is located about midway between the two curves in Route 33. Figure 3-20 is an aerial view looking approximately East and shows State Park Rd. passing under the bridge. The North Bound bridge is the farther of the two bridges shown in the figure. Figure 3-21 shows the approach to the bridge. A truck crossing the bridge is shown in Fig. 3-22. Instrumentation of the main span from the PennDOT lift truck is shown in Fig. 3-23. Figure 3-24 shows the method of mounting the WIM transducers to the prestressed I-girders.
Fig. 3-1 Aerial View of Route 22 Looking East

Fig. 3-2 Aerial View Looking East of East Bound and West Bound Bridges on Route 22 Over 19th Street
Fig. 3-3 Approach to the East Bound Bridge

Fig. 3-4 View Looking East Over the East Bound Bridge
Fig. 3-5 Truck Crossing the East Bound Bridge

Fig. 3-6 Tape Switches on the Deck Immediately Ahead of the East Bound Bridge
Fig. 3-7 Approach to the West Bound Bridge

Fig. 3-8 View Looking West Over the West Bound Bridge
Fig. 3-9  Truck Crossing the West Bound Bridge

Fig. 3-10  Instrumentation of the West Bound Bridge from the PennDOT Lift Truck
Fig. 3-11 View of Route 33 Looking SW

Fig. 3-12 View of North Bound Bridge on Route 33 Over Van Buren Rd.
Fig. 3-13  Approach to the North Bound Bridge

Fig. 3-14  Trucks Crossing the North Bound Bridge
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Fig. 3-16 View of Short Span (Foreground) and Main Span (Beyond the Pier)
Fig. 3-17 Tape Switches on Pavement
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Fig. 3-18 Data Acquisition Set-Up in the Van
Fig. 3-19 View of Route 33 Looking North

Fig. 3-20 View of North Bound Bridge on Route 33 Over State Park Rd.
Fig. 3-21 Approach to the North Bound Bridge

Fig. 3-22 Truck Crossing the North Bound Bridge
Fig. 3-23 Instrumentation of Main Span
From PennDOT Lift Truck

Fig. 3-24 Method of Mounting WIM
Transducers to Prestressed I-Girders
4. Task E - Evaluate Data

4.1 Objectives

The primary objectives of Task E are to:

1) Process the response and loading data obtained in Task D.

2) Place particular emphasis on those items found most significant in Task A (see Ref. 1).

3) Compare actual performance with design assumptions and code specifications.

4.2 Preliminary Results

4.2.1 EB Route 22 Over 19th St.

Figure 4-1 shows a cross section of the East Bound bridge through the fascia and first interior girders. The girders are built-up from rivetted plates and angles. The superstructure was originally designed in 1951 and consisted of the girders (2 facia and 3 interior) shown in Fig. 4.1 plus a non-composite concrete deck 8 in. thick. In 1984 the deck was removed and replaced with the composite 8 1/2 in. thick deck shown in the figure. The new deck uses 4,500 psi concrete (increased from 3,500 psi for the original deck).

Figure 4-2 shows the locations of the transducers and 1/4 in. electrical resistance strain gages which were mounted on the girders and diaphragms for the field study. In the figure, the transducers are numbered 1 through 6. Strain gages are numbered 7 through 16. The transducers and strain gages shown in sections 1 and 2 were located on the bottom surface of the bottom flange and 1 1/2 in. from the edge of the plate. The locations of sections 1 and 2 were established so that
the transducers and strain gages would fall midway between the outside line of rivets which were on about 6 in. centers. The transducers and strain gages on the girders were oriented to measure strains in the longitudinal direction of the girders. The strain gages on diaphragm members were oriented in the direction of the member and were located midway between connections.

Figures 4-3 through 4-7 compares girder stresses obtained from the 1983 AASHTO Specification (solid lines) with stresses obtained from finite element analyses of the three-dimensional structure under HS-20 truck loading. Stresses are computed for the extreme bottom flange fibre at 2'-4 from midspan. The AASHTO stresses were computed for both composite and non-composite deck. For the fascia girders two stress values were calculated for each condition. The lower stresses (indicated by the dashed lines) were computed using the pre-1957 AASHTO Specifications which required only that the live load stress be computed assuming the deck to act as a simple span between the fascia and first interior girder. The 1957 and subsequent specifications required in addition the use of an S/D relationship, similar to that used for the design of interior girders. The fascia girders were not altered during the 1984 deck replacement except for the addition of shear connectors.

Figure 4-8 compares the actual girder stresses obtained in the field study with stresses obtained from a finite element analysis with composite deck for the calibration truck travelling in lane 1. The axle loads (kips) are shown at the bottom of the figure. Axle spacings,
from right to left in the figure are 12'-7, 30'-1 and 4'2. The stresses obtained from the 1957 and 1983 AASHTO Specifications (as discussed above) are also shown.

Figure 4-9 shows the girder stresses obtained from a finite element analysis with composite deck assuming two calibration trucks travelling in Lanes 1 and 2. No field results were obtained for this case.

Figure 4-10 is the gross vehicle weight (GVW) histogram representing 4,680 trucks crossing the East Bound bridge.

Figures 4-11 through 4-15 are stress range histograms produced by the 4,680 trucks crossing the East Bound bridge. These stress ranges were computed from the field data obtained from the transducers and strain gages on each girder on section 1 shown in Fig. 4-2.

4.2.2 WB Route 22 Over 19th St.

Figure 4-16 shows a cross section of the West Bound bridge through the fascia and first interior girder. The discussion in Art. 4.2.1 regarding the original design and deck replacement also applies to this bridge.

Figure 4-17 shows the locations of the transducers and 1/4 in. electrical resistance strain gages which were mounted on the girders and diaphragms for the field study. In the figure, the transducers are numbered 1 through 6. Strain gages are numbered 7 through 16. (The remaining discussion in Art. 4.2.1 regarding Fig. 4-2 also applies to Fig. 4-17).

4-3
Figures 4-18 through 4-22 compares girder stresses obtained from the 1983 AASHTO Specification with stresses obtained from finite element analyses of the three dimensional structure under HS-20 truck loading. (The remaining discussion in Art. 4.2.1 regarding Figs. 4-3 through 4-7 also applies to these figures).

Figures 4-23 compares the actual girder stresses obtained in the field study with stresses obtained from a finite element analysis with composite deck for Truck No. 64, Disc 11 travelling in Lane 1. From right to left the axle spacings are 13.5, 4.4, 32.3, 4.1 feet. Stresses obtained from the pre 1957 and 1983 AASHTO Specifications are also shown for comparison.

Figure 4-24 shows girder stresses obtained from a finite element analysis with composite deck for Truck No. 64, Disc 11 assumed travelling in Lanes 1 and 2. No field data was obtained for this condition. The AASHTO girder stresses are also shown for comparison.

Figure 4-25 is the gross vehicle weight (GVW) histogram for 7,112 trucks crossing the West Bound Bridge.

Figures 4-26 through 4-30 are the stress range histograms for all the girders on cross section 1, Fig. 4-17.
4.2.3 NB Route 33 Over Van Buren Rd.

Figure 4-31 shows the framing plan and cross section of the North Bound bridge over Van Buren Rd. Also shown are the locations of transducers and strain gages. The transducers are numbered 1 through 6. The strain gages are numbered 7 through 16.

The bridge consists of 3 simple spans with a skew of 53°29'06". The span lengths are 41'-6, 108'-3 and 41'-6. The end spans consist of W33 x 130 steel girders with non composite concrete deck. Transducers 1 through 6 are located on the bottom flanges of the steel girders at mid span. Although all six are used for RESPONSE data only 1 through 4 are used for WIM.

The main span consists of welded plate girders with composite concrete deck. Strain gage 7 is mounted below the web and 1/2 in. from the flange splice as shown in Section 2 of the figure, and measures longitudinal strains in the flange. Strain gages 8 and 11 are mounted vertically on the webs of the fascia and first interior girder as shown in the typical detail below Section 1. The gages are located just below the filet weld joining the diaphragm connection plate (transverse stiffener) to the web, which terminates at the cope. Strain gages 9, 10, 12 and 13 are mounted on the diaphragm angles and measure strains in the direction of the angles. Strain gages 14, 15 and 16 are located under the web on the bottom flange as shown in Fig. 4-31 and measure longitudinal strains in the flanges.
Figures 4-32 and 4-33 compare girder stresses obtained from the 1983 AASHTO Specification with stresses obtained from finite element analyses of the three-dimensional structure under HS-20 truck loading. Stresses are computed for the extreme bottom flange fiber at 2'-4 from midspan.

Figure 4-35 is the gross vehicle weight (GVW) histogram for 3,626 crossing the bridge.

Figures 4-36 through 4-41 are the stress range histograms for the strain gage locations shown in the figures.

4.2.4 NB Route 33 Over State Park Rd.

Evaluation of WIM-RESPONSE field study data for the North Bound Bridge on PA Route 33 over State Park Rd. is in preparation. Results of this evaluation will be included in the final report and were not available for presentation at the October 4, 1985 oral briefing meeting.
Fig. 4-1
Cross Section of East Bound Bridge Through the Fascia and First Interior Girders
Fig. 4-2 Location of Transducers and Strain Gages on the East Bound Bridge
Fig. 4-3  Comparison of AASHTO and Finite Element Analysis Stresses for HS-20 Truck Loading
Fig. 4-4 Comparison of AASHTO and Finite Element Analysis Stresses for HS-20 Truck Loading
Fig. 4-5 Comparison of AASHTO and Finite Element Analysis Stresses for HS-20 Truck Loading
Fig. 4-6 Comparison of AASHTO and Finite Element Analysis Stresses for HS-20 Truck Loading
Fig. 4-7 Comparison of AASHTO and Finite Element Analysis Stresses for HS-20 Truck Loading
Fig. 4-8  Comparison of AASHTO, Finite Element Analysis and Field Study Stresses for the Calibration Truck Travelling in Lane 1
Fig. 4-9  Comparison of AASHTO and Finite Element Analysis Stresses for the Calibration Truck Travelling in Lanes 1 and 2
Fig. 4-10 Gross Vehicle Weight (GVW) Histogram for the East Bound Bridge (4,680 Trucks)

Fig. 4-11 Stress Range Histogram - Transducer 1
Fig. 4-12 Stress Range Histogram - Transducer 2

Fig. 4-13 Stress Range Histogram - Transducer 3
Fig. 4-14 Stress Range Histogram - Strain Gage 8

Fig. 4-15 Stress Range Histogram - Strain Gage 15
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Fig. 4-20  Comparison of AASHTO and Finite Element Analysis Stresses for HS-20 Truck Loading
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Fig. 4-24  Comparison of AASHTO and Finite Element Analysis Stresses for Truck No. 64, Disc 11 Travelling in Lanes 1 and 2

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Fig. 4-35 Stress Range Histogram - Strain Gage 7
Fig. 4-36 Stress Range Histogram - Strain Gage 8

Fig. 4-37 Stress Range Histogram - Strain Gage 9
Fig. 4-38 Stress Range Histogram - Strain Gage 10

Fig. 4-39 Stress Range Histogram - Strain Gage 14

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Fig. 4-40  Stress Range Histogram - Strain Gage 15

Fig. 4-41  Stress Range Histogram - Strain Gage 16
5. Task G - Revise Documentation

Throughout this project, documentation has been viewed as central to system quality. Documentation, in general, is one of the most important aspects of the successful implementation of any computer assisted endeavor. This is especially true for a project such as the WIM-RESPONSE project where a prototype system is to be transferred for use by a wide variety of organizations and varying levels of skilled personnel. The researchers recognize that it is a formidable task to develop effective documentation to meet these diverse needs. Naturally the level of useful information content or detail will vary across the groups and will change according to the experience of the individual user.

For these reasons, the documentation in the final report for this project will be organized into multi-level or tiered segments each leading to progressive learning based on varying needs of skill or knowledge level regarding the Lehigh prototype system.

The major segments to be contained in the final report are as follows:

1. System Overview: This is written for administrative personnel both in FHWA and state Department of Transportation groups. It is intended to provide a synopsis of what the system is and what it can be used for.

The major sections within this segment of documentation will be as follows:

1. Overview of the System
2. Development of the System
3. What the System Does
4. How Results are Produced
5. How the Results can be Used
6. Resources Needed to Use the System
2. **Introductory Training Guide:** This is written for new users and field crews. It is intended to provide information to new users on how to operate the system. The major sections within this segment of documentation will be as follows:

1. General Purposes of the System
2. Phases of Operation
3. Illustrated Tasks and Operation of Equipment
4. Sample Set-Up, Data Acquisition, Field Processing, and Take-Down Procedures

3. **System User's Guide:** This is written for people who need an in-depth knowledge of the system to use it in the field and to perform data reduction. It is intended to provide a detailed understanding of how to operate the entire system.

The major sections within this segment of documentation will be as follows:

1. Overview and Introduction
2. Theoretical Justification of Procedures and Analyses
3. Logistics of Procedures and Equipment Used
4. Details of Data Acquisition Procedures
5. Details of Field Data Processing
6. Details of Data Reduction Procedures

4. **Hardware and Peripherals Reference Manual:** This is written for skilled technical people such as field personnel, system operators, or systems analysts. It is intended to provide highly detailed information on the functional characteristics of all associated hardware and peripheral devices such as the DEC equipment, strain gages, transducers, and tape switches.

The major sections within this segment of documentation will contain material on the following items:

1. MINC Computer Reference
2. Line Printer and Graphics Display Device
3. WIM Conditioner
4. Tape Switches
5. Transducers
6. Strain Gages
7. Floppy Discs
8. Cables
9. Electric Frequency Meter
10. Drawings of the Equipment Configuration for the Entire System
5. **Software Reference Manual**: This is written for technical personnel who need to know the details of the source code and algorithms used in the system. It is intended to provide highly detailed information on the software necessary to operate the system.

The major sections within this segment of documentation will be as follows:

1. MINC System Software
2. Data Acquisition Programs and their Use
3. Field Data Processing Programs and their Use
4. Data Reduction Programs and their Use

Appendices: Modifications and Updates to the System

Field Tips and Notes

**Master Program Library**: Source Code and Listing of all Software

Field Data Discs from This Project

To ensure the usefulness of the documentation, the project personnel will continue to maintain close cooperation with the COTR, Mr. Hal Bosch, during the remainder of its development.
Appendix A - References