R-538

# OFFICE MEMORANDUM

MICHIGAN
STATE HIGHWAY DEPARTMENT

July 26, 1965



To: E. A. Finney, Director
Research Laboratory Division

From: G. R. Cudney

Subject: Damping Bridge Vibration During Construction Widening.
Research Project 65 F-84. Research Report No. R-538.

This memorandum summarizes deflection and vibration observations made to date on two I 94 structures in Berrien County. These observations were requested in a memorandum from C. B. Laird to W. W. McLaughlin dated June 9, 1965. The purpose of the request was to evaluate the effectiveness of damping bridge vibration by placing vertical struts at different points under various stringers.

Semi-Suspended Span: Eastbound I 94 Over Eastbound US 12 (S01 of 11015)

For purposes of identification, the stringers were designated as follows:

No. 1--existing merging lane fascia beam
Nos. 2 & 3--existing merging lane interior beams
Nos. 4 & 5--existing traffic lane interior beams
Nos. 6 & 7--existing passing lane interior beams
No. 8--existing passing lane fascia beam
Nos. 9 & 10--new beams added for widening.

The span is simply supported on the north end and suspended from the anchor span at the south end. A sawcut had been made between Beams 7 and 8, and the slab and sidewalk concrete removed from this area.

On June 17, 1965, during a 3-hr afternoon period, the following range of maximum peak-to-peak deflections caused by existing traffic was recorded:

| Stringer No. | Deflection Position | Deflection Range, in. |
|---|---|---|
| 1 | South 1/4-point | 0.028 to 0.056 |
| 2 | South 1/4-point | 0.056 to 0.084 |
| 5 | Midpoint | 0.068 to 0.140 |
| 6 | Midpoint | 0.044 to 0.120 |
| 7 | North 1/4-point | 0.016 to 0.064 |
| 7 | Midpoint | 0.020 to 0.092 |
| 7 | South 1/4-point | 0.012 to 0.060 |

| Stringer No. | Deflection Position | Deflection Range, in. |
|---|---|---|
| 7 | At pin | 0.000 to 0.002 |
| 8 | North 1/4-point | 0.020 to 0.060 |
| 8 | Midpoint | 0.020 to 0.096 |
| 8 | South 1/4-point | 0.008 to 0.040 |
| 8 | At pin | 0.000 to 0.002 |

The natural frequency of vibration of the span was approximately 5.5 cps. The structure vibrated as a unit, with all stringers in phase except for one case in which a vehicle traveling near the sidewalk edge of the merging lane caused a 180° out-of-phase vibration between Stringers 1 and 8.

On June 23, 1965, vertical support timbers were placed at various stringer point locations as follows:

| Series No. | Vertical Strut Location |
|---|---|
| 1 | Under midspan of Beam 1 |
| 2 | Under midspan of Beams 1 and 6 |
| 3 | Under midspan of Beams 1, 5, and 6 |
| 4 | Under midspan of Beams 1, 5, 6, and 7 |
| 4a | Under midspan of Beams 5, 6, and 7 |
| 5 | Under midspan of Beams 5, 6, and 7, and the north 1/4-point of Beam 6 |

Maximum peak-to-peak deflections at the 1/3-points of Beams 7 through 10 for samples of existing traffic and for a two-axle Research Laboratory vehicle (7,200-lb front axle; 16,200-lb rear axle; 14-ft axle spacing; 40-mph speed) for each of the five vertical support conditions listed above are given in Table 1.

Simply Supported Center Span: I 94 Over Northbound Old US 12, South of Bridgman (S12 of 11015)

For reference purposes, the existing merging lane fascia stringer was designated as Beam 1, with the remaining nine existing stringers numbered successively across the span. A sawcut had been made between Beams 9 and 10 and all concrete had been removed from this area. In addition, the passing lane fascia stringer (Beam 10) had also been removed and was placed on the deck above Beam 9.

The following range of maximum peak-to-peak deflections caused by existing traffic, and maximum peak-to-peak deflections due to the Research Laboratory vehicle, were recorded on June 24, 1965:

| Stringer No. | Deflection Position | Deflection Range, in. (Commercial Traffic) | Average maximum Deflection, in. (MSHD Vehicle) |
|---|---|---|---|
| 6 | Midpoint | 0.100 to 0.164 | 0.092 |
| 7 | Midpoint | 0.080 to 0.140 | 0.080 |
| 8 | Midpoint | 0.052 to 0.116 | 0.061 |
| 8 | South 1/3-point | 0.052 to 0.076 | 0.048 |
| 9 | Midpoint | 0.040 to 0.100 | 0.054 |
| 9 | South 1/3-point | 0.036 to 0.056 | 0.042 |

The natural frequency of vibration of the span was approximately 5 cps. The structure vibrated as a unit except for one case with a vehicle in the merging lane. This loading caused a $180^{\circ}$ out-of-phase vibration between Beams 1 and 9. It has been requested and it is planned that further vibration observations will be made on this span during the temporary strutting operation prior to construction widening.

Discussion

In a vibrating system, damping is associated with energy dissipation and is characterized by the length of time required for the free or transient state of the vibration to die out. By placing additional supports under the span the stiffness characteristics of the structure are changed, resulting in increased frequencies depending on the number and location of supports, and decreased amplitudes of vibration. The resulting vibration of a bridge structure is dependent not only on the structural characteristics of the span, but on the vehicle load distribution, suspension, initial vibration, and speed.

The possible effects of vibration on the construction widening would include: 1) the effect on bond strength due to relative deflection amplitudes of the reinforcing steel between adjacent stringers, and 2) the effect of vibration oscillation and amplitude in general on durability of the concrete deck surface and on concrete bond and compressive strengths.

Based on the 1/3-point deflection amplitudes recorded on the semi-suspended span, the maximum relative deflection between Stringers 7 and 8, 8 and 9, and 9 and 10 due to the Research Laboratory vehicle for the various strut support conditions, were as follows:

| Series | Relative Deflection Between Indicated Beams, in. 7 & 8, in. | 8 & 9, in. | 9 & 10, in. |
|---|---|---|---|
| 1 | 0.018 | 0.016 | 0.028 |
| 2 | 0.014 | 0.008 | 0.010 |
| 3 | 0.010 | 0.004 | 0.014 |
| 4 | 0.010 | 0.006 | 0.016 |
| 4a | 0.010 | 0.006 | 0.018 |
| 5 | 0.006 | 0.004 | 0.010 |

The maximum 1/3-point relative deflection range between Stringers 7 and 8 due to existing observed traffic for the various strut support conditions was as follows:

| Series | Maximum Relative Deflection Range Between Beams 7 & 8, in. |
|---|---|
| 1 | 0.002 to 0.028 |
| 2 | 0.006 to 0.022 |
| 3 | 0.008 to 0.040 |
| 4, 4a | 0.006 to 0.039 |
| 5 | 0.006 to 0.014 |

The maximum relative deflection range between Stringers 7 and 8 at midspan due to existing traffic, prior to placing any of the temporary strut supports, was 0.004 to 0.036 in. The natural frequency of vibration of Stringer 7 was increased to about 8 cps as a result of the supporting arrangements of Series 4, 4a, and 5. The support arrangements of Series 3, 4, 4a, and 5 caused a 180° out-of-phase oscillation of Stringer 10 with respect to Stringers 7, 8, and 9.

Except for Series 5, the strut support combinations tried on the semi-suspended span structure did not appreciably alter the relative deflections between Stringers 7, 8, 9 and 10. With the exception of Series 1, the strutting arrangements were effective in reducing the absolute magnitude of deflection of the individually supported stringers and of Stringers 7 and 8. Of the six strut support groupings, there was no appreciable difference in the resulting vibrations between Series 4 and 4a. Series 5 was the most effective in reducing the absolute deflections of Stringers 7, 8, 9 and 10, and as mentioned, was the only support condition that appreciably reduced the relative stringer deflections of these beams.

OFFICE OF TESTING AND RESEARCH

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## TABLE 1

THIRD-POINT STRINGER DEFLECTIONS FOR SIX VERTICAL STRUT SUPPORT CONDITIONS
EB I 94 over EB US 12 (Project No. S01 of 11015)

| Stringer No. | Deflection, in. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Series 1 | | Series 2 | | Series 3 | | Series 4 | | Series 4a | | Series 5 | |
| | Avg. MSHD Vehicle | Max. of Comm. Vehicles | Avg. MSHD Vehicle | Max. of Comm. Vehicles | Avg. MSHD Vehicle | Max. of Comm. Vehicles | Avg. MSHD Vehicle | Max. of Comm. Vehicles | Avg. MSHD Vehicle | Max. of Comm. Vehicles | Avg. MSHD Vehicle | Max. of Comm. Vehicles |
| 7 | 0.060 | 0.078 | 0.022 | 0.046 | 0.014 | 0.022 | 0.016 | 0.024 | 0.020 | 0.024 | 0.008 | 0.014 |
| 8 | 0.056 | 0.070 | 0.020 | 0.060 | 0.016 | 0.032 | 0.026 | 0.028 | 0.030 | 0.030 | 0.016 | 0.020 |
| 9 | 0.038 | 0.047 | 0.018 | 0.052 | 0.016 | 0.031 | 0.020 | 0.022 | 0.022 | 0.024 | 0.010 | 0.023 |
| 10 | 0.034 | 0.086 | 0.028 | 0.080 | 0.020 | 0.046 | 0.016 | 0.026 | 0.020 | 0.026 | 0.012 | 0.028 |