APPENDIX 1
Request for Authorization to Experiment with Chevron Pavement Markings

Wisconsin Department of Transportation

TRANSPORTATION DISTRICT 2
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February 2, 1999

Mr. Rudy Umbs
Federal Highway Administration
Safety Design and Operations Division (HHS-10)
400 7th Street SW
Washington, D.C. 20590

Subject: Request for Authorization to Experiment with Chevron Pavement Markings

Dear Mr. Umbs:

The Wisconsin Department of Transportation requests approval to install an experimental **Converging Chevron Pavement Marking Pattern** to reduce speeds at a specific location in Milwaukee, the I-94 Westbound approach to the two-lane exit to the I-894 Westbound bypass.

The proposed pattern has been used in a number of locations in Japan. It consists of a series of white chevrons on the road surface with the spacing between chevrons decreasing as the driver travels over the pattern. Each chevron extends across only one lane of traffic. Therefore, in the proposed location, two side-by-side patterns would be installed. Traffic flow is in the direction indicated by the chevrons.

The illusion created by this pattern is intended to convince drivers that they are traveling faster than they really are and to create the impression that the road is narrowing. It is anticipated that these factors will contribute to reduced travel speeds. Although research has been conducted on other patterns of illusory pavement markings, we are unaware of any previous applications of the converging chevrons in the United States.

The relatively low cost and potential benefits of this application suggest that it could be an excellent traffic control device for speed reduction and safety. With your approval, we look forward to conducting this experiment in cooperation with the AAA Foundation for Traffic Safety and Dr. Robert Reinhardt of the Texas Transportation Institute.

If you need additional information, please call me at (414) 521-5348
or e-mail gary.knerr@dot.state.wi.us

Sincerely,

Gary P. Knerr, P.E.
Systems Operations Group Manager

cc: Peter Rusch, State Traffic Engineer
Thomas Loeffler, Bureau of Transportation Safety
William Bremer, FHWA Safety & Traffic Operations

DT1464

ATTACHMENT A

Instructions for setting out the converging chevron markings.

Figure 1 shows an installation of the chevrons in Japan (photo reversed for convenience). The proposed layout will be derived from this example. The right two lanes in the photo will be what the north bound traffic on the IH-94 approach to the westbound ramp would see. The one point about the photo to be stressed is that while the on coming traffic to the left has four chevrons per set and the out bound traffic on the right appears to have 6 or 8 chevrons per set, EACH SET IN THE PROPOSED APPLICATION WILL HAVE 10 CHEVRONS.

This determination was made based on the anti-skid characteristics of this pattern and the relatively high rate of speed at the site. The number of chevrons per set has to do with the speed within the pattern and the current application calls for 10 chevrons per set.

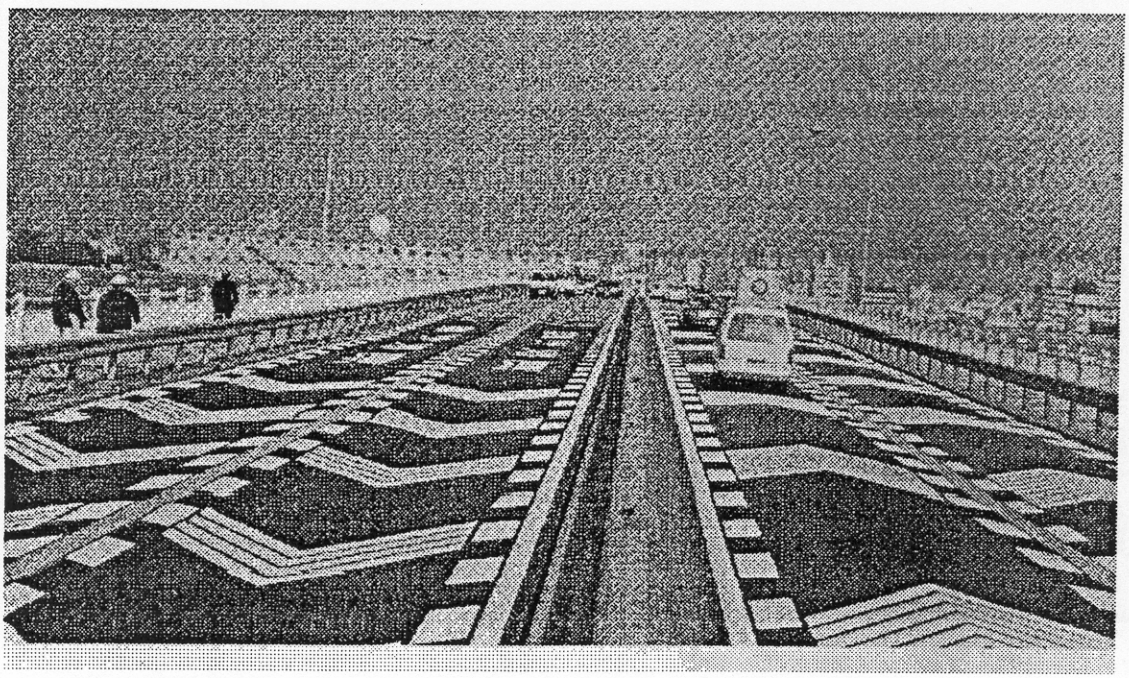

Figure 1. Converging chevrons on Yodogawa River Bridge .

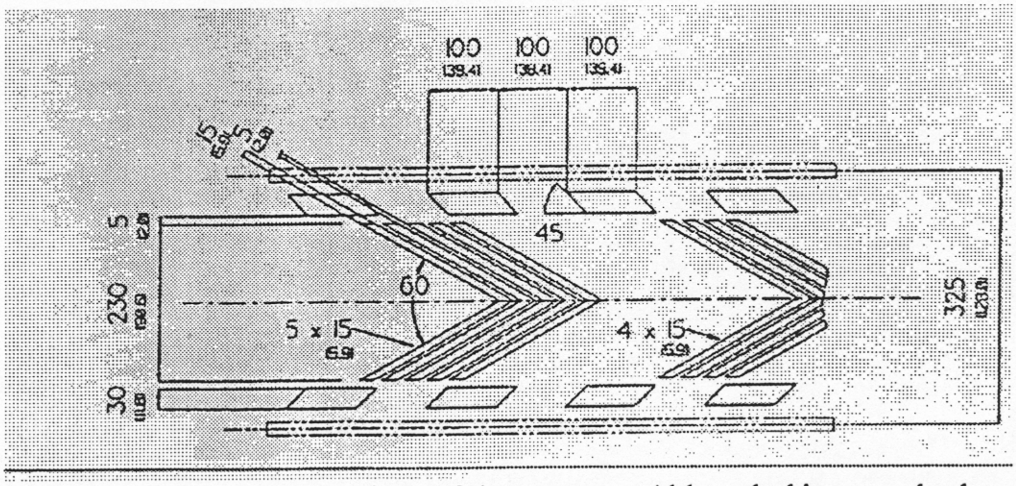

Figure 2 indicates the actual dimensions of the patterns. Although this example shows sets of 5 (left) and 4 (right) chevrons per set, as stated above, all sets will have 10 chevrons of 15cm each.

The length of an individual chevron pattern is based on certain enabling assumptions. These assumptions include the initial speed of vehicles entering the pattern (v_1), the desired speed upon leaving the pattern (v_2), reaction time (the time that elapses prior to braking), typically 0.5s (t_b), and constant deceleration once brakes are applied (a). The pattern length for the current application was calculated as follows:

Pattern Length Calculation

$$L = v_1 t_b + \frac{(v_1^2 - v_1^2)}{2a}$$

v_1 = speed entering pattern = 95.33 fps (65 MPH)

v_2 = speed exiting pattern = 73.33 fps (50 MPH)

t_b = reaction time = .5sec

a = deceleration braking = $3.3 fps^2$

$$L = (95.33) * .5 + \frac{(95.33^2 - 73.33^2)}{6.6} = 610 \text{ feet}$$

Average speed in pattern = 84.33 fps (57.5MPH)

$$\text{Time to traverse pattern} = \frac{610}{84.33} = 7.2 \text{ Sec}$$

Number of chevron sets (at 2.2 per second) = 15.8

@ 2.2/sec = 1 pattern every .4545 seconds

$$\text{Uniform deceleration} = \frac{95.33 - 73.33}{6.7^*} = 3.28\text{fps or the } 3.3\text{fps used initially}$$

Deceleration per chevron = 3.3 * .4545 = 1.49885fps, call it 1.5

* 7.2 total - .5 reaction time

Pattern Size

The spacing of the patterns is dependent on the pattern size which is itself a function of the number of individual stripes making up the pattern. Since each set of chevrons will have 10 individual stripes the size of each set of chevrons is the same.

Given: 15cm (5.9in) wide stripes and 5cm (2 in) wide spaces.
Given: 60 degree (30 degrees either side of center line)

To determine running length along highway:

$$\text{Sine } 30 = \frac{15\text{cm}}{X} \qquad .5 = \frac{15\text{cm}}{X} \qquad x = 30 \text{ cm}$$ for Stripes, 10cm for spaces.

One stripe and space = 40cm

From beginning of first stripe to end of last stripe in a 10 set pattern would be:

(9 * 40) + 30 = 390cm   or 12’ 9.5”

Pattern Spacing

While it is possible to calculate pattern spacing such that the distance between each set of chevrons is a constantly decreasing length, the practicality of installing this type pattern and the actual ability of drivers to perceive this precision make it impractical. Therefore an approximation that keeps the drivers within the marked portion of the pattern for an increasingly longer time (from .14 sec to .18sec) was chosen, which duplicates the Japanese application of these markings.

Given that the last set needs to be completed prior to the detector loop, that loop will act as the reference point. At the anticipated speeds involved, the maximum distance between the end of the pattern and the loop detector should be 40 feet. This would allow approximately ½ second to pass between the end of the pattern and the detector. Using this 40 foot mark as the ending point of the pattern, the following table gives the positions of the 16 sets of markings (negative numbers indicating up stream distances in advance of the loop detector.)

SET	DISTANCE
1	-618
2	-576
3	-534
4	-492
5	-450
6	-410
7	-370
8	-330
9	-292
10	-254
11	-216
12	-180
13	-144
14	-108
15	-74
16	-40

The actual point within the pattern (front, center, etc.) where the distance measurement is made is arbitrary as long as it is consistent.