IOWA STATE HIGHWAY COMMISSION

Review of

GEOMETRIC DESIGN CRITERIA
LIGHTING DESIGN CRITERIA

MAY 1968

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May 1, 1968

Mr. J. R. Coupal, Jr.
Director of Highways
Iowa State Highway Commission
Ames, Iowa

Dear Mr. Coupal:

We present in the attached report the results of our review of current Iowa Highway Commission roadway geometric design criteria and lighting design standards and criteria, for conformance with national policies and standards.

The report compares the policies and standards currently being used by the State of Iowa with those of 15 other states and with the criteria prescribed by the American Association of State Highway Officials. In those areas of design where there appeared to be a lack of agreement as to preferred practice, we have expressed our opinion to provide the Commission with the maximum information for their evaluation.

Grateful acknowledgement is made to the engineering staff of the Commission for their time, cooperation and assistance in the assembling of data relating to the practices and policies of the Commission.

Respectfully submitted,

HOWARD, NEEDLES, TAMMEN & BERGENDOFF

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I hereby certify that this plan, specification or report was prepared by me or under my direct personal supervision and that I am a duly registered Professional Engineer under the laws of the State of Iowa.

Signed R. N. Bergendoff Date May 1, 1968
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REVIEW OF GEOMETRIC DESIGN CRITERIA
AND
LIGHTING DESIGN CRITERIA

I. SCOPE AND PROCEDURE

SCOPE

The investigations for this report were initiated in October, 1967, to perform the following:

1. Review the current Iowa State Highway Commission roadway geometric design standards and criteria for conformance with national policies and recent research findings with special attention to highway safety.

2. Review the current Iowa State Highway Commission roadway lighting design standards and criteria for conformance with national policies and recent research findings with special attention to highway safety.

PROCEDURE

The following procedure was used in the development of this report:

1. A meeting was held with the Iowa State Highway Commission to effect a clear understanding as to the exact scope of this report and to secure the latest information on the Iowa geometric design standards and criteria.

2. The following material was requested and received from the Highway Commission.

   A. Current book of Design Standards and Road Design Memorandums.

   B. Copies of current typical sections.

   C. Sketches showing dates various sections of interstate roadway were opened to traffic.

   D. Four sets of paving plans for interstate roadways which had been let at approximate three-year intervals since the beginning of the interstate system. One set of paving plans for a roadway on the primary system. These plans were reviewed to determine what revisions and modifications had been made to the Iowa design standards since the beginning of the interstate highway system.

   E. Copy of the current manual on Uniform Traffic Control Devices.

   F. Various maps and publications showing traffic volumes and highway classifications.

   G. Copy of the current lighting design criteria.

3. Other State highway departments and commissions were contacted to secure information concerning their current design standards and to determine what action was being taken to conform to the AASHO Safety Program.

4. Available information concerning highway safety and geometric design standards were thoroughly researched.

5. All material received from the Iowa State Highway Commission was reviewed.

6. A field trip of selected interstate and primary roads in the state of Iowa was conducted.

This report is intended to record the results of these studies and in so doing enable the Iowa State Highway Commission to evaluate their current design standards in comparison with standards used by other states and criteria prescribed by the American Association of State Highway Officials.

II. GEOMETRIC DESIGN CRITERIA

DESIGN DEPARTMENT MANUAL

Part II - Road Design

The design procedures and technical information used as a basis of roadway design in the state of Iowa is contained in Part II, Road Design, of the Design Department Manual. This section of the manual is divided into the following chapters:

01	Road Design Memorandums
10	Plan Flow
20	Procedures and Technical Information
30	Drainage
40	At Grade Intersections
50	Interchanges
60	Lighting
70	Estimating
80	Plan Preparation
90	Computer Programs

Sections 30 through 60 are currently being revised and, therefore, were not available for reference in making this study. These sections are not considered pertinent to this study since Section 01, Road Design Memorandums, and Section 20, Procedures and Technical Information, are utilized for the Commission's geometric design policies.

Section 20 was reviewed and found to be compatible with the current AASHO manual, A POLICY OF GEOMETRIC DESIGN OF RURAL HIGHWAYS, dated 1965.

Section 20-04.1, Superelevation contains one item worthy of note. Paragraph 3 refers the reader to Tables 20-04.11 and 20-04.12 for superelevation rates. These tables were not in the copy of the manual being reviewed. It is believed that these tables may have been superseded by Standard Drawings RJ-7 to RJ-10 and RP-1 to RP-3. If this is the case, it is recommended that the reference to the tables be changed to refer to the Standard Drawings.

Part IV - Standard Road Plans

The Standard Road Plans used by the Highway Commission are contained in Part IV of the Design Department Manual.

This part of the manual was reviewed to determine if standard drawings are consistent with present safety standards.

The review revealed that the Commission has done an excellent job in updating their standard drawings to conform to present safety standards. It was found that all standard drawings have been revised.

General Comments

General comments resulting from the review of Parts II and IV of the Design Department Manual are as follows:

1. The manual was well organized, easy to follow and contained the essential information necessary for roadway design and plan preparation.

2. The Commission staff should be commended for publishing an outstanding Design Manual and for the manner in which they have kept the manual up to date. There are few, if any, states that can match this achievement. This is best expressed by excerpts from letters received in collecting material for this report.

   A. "We have long recognized the need for such a manual, but due to personnel shortages have never been able to develop one on our own."

B. "We are now working on a design manual but do not have this work far enough along to furnish copies at this time."

C. "This acknowledges your request for a copy of our Geometric Design Manual. Unfortunately, we have not prepared such a document."

D. "In reviewing______________State Standards I was appalled to find how ambiguous and incomplete they are."

E. "Our design manual is presently being revised; the current edition would be of little use since it has not been revised since 1955."

IOWA STANDARDS COMPARED WITH THOSE OF OTHER STATES

Introduction

The quality of the Iowa Geometric Design Standards is best shown by comparing its standards with those of the fifteen other states shown in Table 1. A study of this table reveals that Iowa is conforming with national policies and is using design criteria that equals or surpasses that being used by the other states.

The fifteen states chosen for this comparison are considered to be among the more progressive in their policies concerning the geometric design of roadways. This group is also considered a representative geographic sampling since it includes states located on the east coast, west coast, midwest, southern, and northern sections of the United States.

Summary of Table 1

The following is a general summary of the data shown on Table 1.

1. Design Speed:

The values shown for the different states are in general agreement.

2. Lane Widths:

All states use a 12′ lane width on the main line. The ramp widths vary from 14′ to 22′, with 10 states, including Iowa, in the 14′ to 16′ range. Two of the three states using widths of 20′ or greater utilize curbed pavements without paved shoulders.

There was no definite trend in the lane widths used for rural frontage roads. Six states, including Iowa use 10′, two use 11′, five use 12′, one varies from 12′ to 9′ and one state's standards depend on the local government standards. There was general agreement on the width of urban roads and streets with 12 states using 12′ lanes and, where necessary, providing 8′ for parking. One state uses a standard 16′ lane, which provides a 12′ lane and 4′ widening in the initial stage and would accommodate a future section, if warranted, of two 12′ lanes and one 8′ parking lane. It seems to be the general consensus that if curbs are used, a one foot or two foot widening should be provided for driver reaction. With a 12′ lane and a two foot driver reaction, a 28′ roadway measured from face of curb to face of curb would be provided. This tends to lend credibility to the state that is using the equivalent of a four-foot driver reaction and at the same time providing room in the initial design to allow for a future parking lane. A number of states have indicated that local standards had a great influence on the roadway widths used. An example of local standards prevailing is the instance where the city used a three foot gutter to control drainage along the curb. The width used in this case was 24′-6″ or 30′ face to face of curb for those feeder streets that had to be reconstructed to accommodate the freeway

Following this review of the standards and general practices of the various states relating to urban frontage roads and feeder streets, it is believed that most states do not have a set standard roadway width. General practice is to consider the local street standards, traffic requirements, parking considerations and then design the roadway to best serve these needs. It is believed that the Bureau of Public Roads, in most instances, will approve such a design.

3. Shoulder Widths:

A ten foot shoulder on the right side of the main line is used by Iowa and twelve other states, while three use a 12′ shoulder.

On the left side of a four-lane divided freeway, six including Iowa use a six-foot shoulder, six use four-foot, two use three-foot, one uses a five-foot and another an eight-foot shoulder.

On the left side of a freeway having six lanes or more, Iowa and five other states use a six foot shoulder, eight use a ten-foot shoulder, two use four foot and one uses an eight foot width. It is notable that eight states carry a ten foot shoulder on both the right and the left sides when the freeway is six lanes or greater.

The total width of paved shoulders on both right and left sides of ramps range from 0′ to 18′. Four states use 12′, Iowa and two others use ten feet, three use none and one uses each of the following widths: six, eight, fourteen, sixteen and eighteen.

4. Median Widths:

The design standards for freeway medians is presently in a state of flux. The 30′ recovery area concept indicates that wide medians should be at least 64′ wide. The increased use of the General Motors or New Jersey type concrete median barrier would indicate that narrow medians could be made even narrower if this type of barrier is used.

An increasing number of states are either using or testing the G.M. or N.J. type of concrete median barrier. However, the metal beam barrier is used to some extent by all states, except one, which uses a cable or box beam barrier.

5. Sight Distance:

All states follow the 1965 AASHO standards.

6. Vertical Alignment:

All states have generally the same standards for the maximum allowable grade, which agree with the 1965 AASHO standards.

There is a wide variation in the minimum length of vertical curves in use by the various states. Long vertical curves are of a greater need on high speed roadways because they provide better operating characteristics, comfort and appearance. There is only one state that requires a longer minumum length of vertical curve than Iowa.

7. Horizontal Alignment:

The horizontal alignment standards are basically the same for all states. The major difference would seem to be in the allowable curves on the main roadway without spirals. These figures ranged from 0°29′ to 5°. Half of the states use spirals and half do not.

8. Clearance:

The vertical alignment standards being used are very similar with the exception of the normal clearance over main roadways. On this item, nine states including Iowa use either 16′-4″ or 16′-6″, three use values between 15′-0″ and 15′-6″ and four use 14′-6″. It is believed that the present trend is toward the use of the higher clearance values. All of the states surveyed, use a vertical clearance of 16′-3″ to 16′-6″ for roadways in the Defense Highway System.

The standards for horizontal clearance are rather unstable at the present time as evidenced by the wide variations shown on Table 1. The AASHO Safety Report made quite an impact in this area.

Some states are still studying this matter, but the trend seems to be toward providing 30′ clearance and providing adequate protection to the obstruction in those instances where the 30′ clearance is not feasible.

9. Ramp Terminals

The acceleration lane design being used by the 16 states is very similar. The normal length varies from 917′ to 1330′ with most using a long tapered design (50:1) rather than the parallel lane design. A standard length for all design speeds is used by nine states, including Iowa.

The deceleration lanes used were also similar. The normal length varies from 450′ to 800′ with all except one between 450′ and 650′. Again the tapered design is preferred to the parallel lane type.

The acceleration and deceleration lanes of twelve states were studied to determine the usage of curbs at ramp noses. The findings are as follows:

A. Five do not use curb on either the accelaration or the deceleration lane. One of these states uses a "white concrete traffic separator, singing type," in front of the nose and another uses traffic bars at 10′ centers to channel the traffic. One of these five just recently eliminated curbs from both the entrance and exit noses.

B. Four use curbs on both the entrance and the exit noses.

C. One uses curb to a point 60′± back of the entrance nose but does not use curb on the exit nose.

D. One uses curb to a point 40′ ± back of the exit nose but does not use curb on the entrance nose.

E. One state uses curb on both types of noses if the approach is curbed and does not use curb on either nose if the approach is not curbed.

If a conclusion is to be drawn from this study, it would be that a lack of uniformity exists in current practice regarding the use of curb at ramp noses. The apparent trend seems to favor the elimination of curbs, which Iowa has recently done.

10. Superelevation:

The rate of superelevation being used varies according to the climate. The cold weather states use superelevation rates from 6 per cent to 8 per cent and the warm weather states use rates varying from 8 per cent to 12 per cent.

The location of superelevation transitions varies from 30 per cent to 100 per cent of the transition being placed on the tangent. Twelve of the sixteen states place from 60 per cent to 80 per cent of the transition on tangent.

11. Normal Cross Slopes:

The cross slopes being used are in general agreement.

12. Side Slope Treatment:

Each state uses basically the same criteria to determine the rate of slope. Six including Iowa, use 6:1 minimum fore slopes, four use 4:1, two use 3:1, and one state uses 2:1 on all cut slopes.

The fill slope rates being used are also similar. All states use 6:1 slopes for low fills, with the maximum height for this slope ranging from 4′ to 10′. Ten of the sixteen use a 6:1 or 8:1 slope for a distance of 30′-35′ from the normal edge of pavement and for large fill heights break to a steeper slope. Another uses an 8:1 slope for 19′, one uses a 6:1 for 22′ and Iowa uses a flat slope for 16′± before breaking to the steeper side slope as dictated by the height of fill. The practice of one state is not known, another is making a study to set a standard practice and only one goes directly to the required side slope at the shoulder P.I. The most complex section now in use is shown in Column 4. With a fill height greater than 30′ three different slopes would be used, a 6:1, 4:1, and 3:1. In summary, for those states with known practices, ten out of fourteen (70%) use a flat slope for a minimum of 30′.

13. Guard Rail Warrants

In regard to the policy of using guard rail to protect fill slopes, it was found that only two states, under normal conditions, use guard rail on high fills with 4:1 side slopes. Ten use guard rail on high fills with 3:1 slopes with another using it if the Guard Rail Need Index indicates the need. Guard rail is used on side slopes steeper than 3:1 by thirteen states and on side slopes of 2:1 by fourteen. Two do not use guard rail to protect the motorist on high fills regardless of the side slope, as long as there are no obstructions present. These states feel that since they are providing an optimum recovery area, one that has 6:1 side slopes for 30′ and no obstructions, that some 80 per cent of the vehicles leaving the road will be brought under control in the recovery area. With this in mind, it is believed that the cost of providing guard rail to protect the remaining 20 per cent is not warranted. This theory appears to be gaining in popularity, and would seem especially applicable to the warm weather states. In those regions where there are frequent snows it is believed that the presence of guard rail on high fills gives the driver a sense of security and is probably more of a psychological factor than a safety factor.

The use of concrete barrier rail of the General Motors or New Jersey type seems to be gaining in popularity. Seven states are now using it to some degree and another is studying its use. Its greatest use seems to be on narrow medians on both roadway and bridges. Its use on bridges is rapidly increasing with a number of states using it as the outside rail as well as on the median.

The recommendation of the AASHO report that the median be made continuous on bridges having a median width of 20 to 30′ is probably the greatest single factor in increasing the use of the concrete barrier median on bridges.

Box beam guard rail is used by three states and cable guard rail is used to some extent by six. In January of 1968, the Bureau of Public Roads ruled that cable guard rail would not be allowed on routes where Federal funds have been expended unless they were of the weak post design as developed by the state of New York. An article on this design is available in Highway Research Record Number 174.

Metal beam guard rail is the most popular type of guard rail as it is used by all sixteen states. All except three use 6′-3″ post spacing. Two of the remaining three use 10′-6″; the third state uses 12′-6″ for speeds less than 50 mph and 6′-3″ for speed greater than 50 mph. There is a large variation in the type of posts used. Five states including Iowa use wood, one uses concrete, three use steel with one using a light breakaway type, three use wood or steel, two use wood or concrete and one uses steel or concrete. Thirteen states, including Iowa, use a blocked out beam. Eleven set the top of rail 27″ above the ground, one uses 26″, another 25 1/2″, another 25″ and Iowa uses 24″.

14. Ditches:

There was considerable variation in ditch standards but no trends were evident.

15. Median Drainage:

The main item of note here is the discontinued use of the raised, umbrella-type inlet. The states are using an inlet with the grate flush with the ground line.

16. Safety Features:

It was found that two of the sixteen states have not as yet established a definite policy on the safety features outlined in the AASHO Safety Report.

The term recovery area used in this report denotes the area that has a side slope of 6:1 or flatter and is clear of obstructions. A full recovery area is one 30′ in width. The 6:1 side slope restriction in the definition is considered debatable by some authorities. There are those who feel that the 4:1 slope provides the driver some chance to retain control of his automobile. Mr. Don Loutzenheiser, Chief, Highway Standards and Design Division, Office of Engineering and Operations, Bureau of Public Roads in Washington, presented a paper at the 1967 AASHO meeting in Salt Lake City where he said, "You doubtless have driven at moderate speeds down 4:1 slopes 3 to 5 feet high, and where they are rounded at the bottom you would rate them as having a tolerable recovery condition. A 4.5:1 slope would be even better and a 5.3:1 slope even better yet if the bottom rounding were there." The 6:1 slope used in this report is the recommended slope resulting from field tests run at the General Motors Proving Grounds.

Using this definition, it was found that ten states provided the full recovery area, two do not have a set policy, one meets all requirements except setting the bridge piers back 30′, three including Iowa meet all requirements for a full recovery area except the 6:1 slope is not provided for the full 30′, one state does not provide any 6:1 slope on fills greater than 10′.

All states except one are using breakaway sign posts.

Eleven of those surveyed, including Iowa, have implemented a program to update their completed interstate routes, with guard rail, signing and lighting being the items receiving the greatest attention.

Conclusions

A review of the summary of Table 1 would indicate that there are two areas of design in which Iowa is more conservative than the other states. One item is the width of 6:1 slope provided in fills greater than five feet and the other item is guard rail.

As stated in the summary of Item 16, eleven of the fourteen states that have updated their standards provide a 6:1 maximum foreslope from the shoulder line to a point 30' from the normal edge of pavement, where feasible. In areas of cut and in fills up to five feet high Iowa also provides this amount of flat slope. In those areas where the fill height exceeds five feet Iowa provides a 6:1 or flatter foreslope to a point some 16'± from the normal edge of pavement and then breaks to a steeper slope. It is in these areas that Iowa is more conservative than the other states.

It should be pointed out that many engineers, including officials of the Bureau of Public Roads, believe that the 6:1 foreslope to the 30' point and then a break to a sharper slope is not the answer in all cases. The increased safety with this design cannot be argued; the cost, however, can be. In comparison with the present Iowa policy of carrying a flat slope for 16' and then break to the required slope, it would cost additional $1.90 per linear foot ($1.80 embankment and $0.10 right of way) or $10,000 per mile to provide the 6:1 slope to the 30' point and then break to the required slope for a fill 10' high with 4:1 foreslopes. For a 20' fill height and 2:1 foreslopes the increased cost would be $9.15 per foot ($8.70 embankment and $0.45 right of way) which is equivalent to $48,000 per mile. The cost of guard rail in areas with high fills would be $11 per linear foot or $58,000 per mile. This indicates that with the policy of not using guard rail when the full 30' recovery area is provided, as now being used by two states, it would be more economical to provide the additional embankment for the recovery area rather than the guard rail. These costs are based on an embankment cost of $0.60 per cu. yd., right of way at $1,000 per acre and guard rail at $5.50 per linear foot.

It is readily recognized that it is going to cost more money to provide the "full" recovery area. The feasibility of providing this additional 14' of

6:1 slope is considered to be beyond the scope of this report. This decision requires a knowledge of the overall highway program for the state of Iowa and can best be rendered by the engineering staff of the Commission.

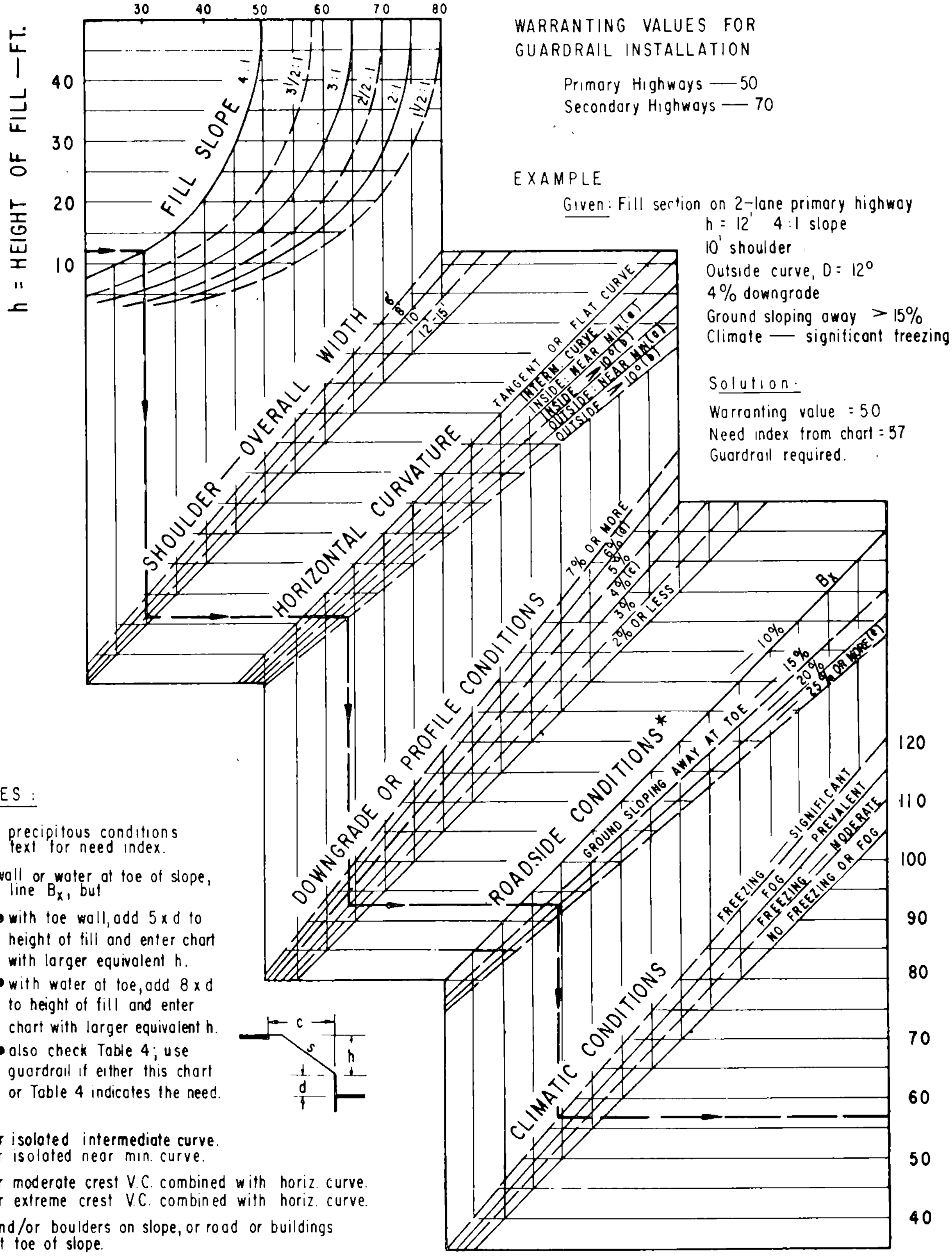
Guard rail design is the second area in which the Commission may wish to consider adopting revisions to its standards. A review of Item 13A reveals that states use guard rail to protect the motorist on high and/or steep side slopes. It is believed that the Commission should consider adopting a standard for this condition. The use of a Guard Rail Need Index Nomograph, Figure 1, would be one solution. A reference for use in this consideration would be a report on Guard Rail Need in HIGHWAY RESEARCH BOARD SPECIAL REPORT 81. Other references would be NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 36, "Highway Guard Rails - A Review of Current Practice" and HIGHWAY RESEARCH RECORD NUMBER 174.

It was noted in the review of Item 13, G(3) that all states are using a higher mounting height for guard rail than is Iowa. The predominate height used is 2'-3" whereas Iowa is using 2'-0". One, and possibly the most valid, justification for the 2'-3" dimension is expressed in an atricle on "Dyanamic Tests of Corrugated Metal Guard Rail" wirtten by engineers of the California Division of Highways and published in HIGHWAY RESEARCH RECORD NUMBER 174. The first three conclusions of this report read as follows:

"1. A 12-gage (0.105-in.) corrugated steel guard rail beam mounted 27 in. high, blocked out at least 8 in., on standard timber posts spaced 6 ft. 3 in. on centers, will perform satisfactorily. A 27-in. beam height is optimum for blocked-out corrugated steel beam guard rail without a rubbing rail."

"2. A guard rail (or median barrier) installation with the corrugated steel beam mounted more than 27 in. high, even though blocked out, requires a rubbing rail to prevent whell entrapment."

"3. A blocked-out corrugated steel guard rail beam mounted 24 in. high, on standard timber posts spaced 6 ft. 3 in. on centers, will



WARRANTING VALUES FOR GUARDRAIL INSTALLATION

Primary Highways — 50
Secondary Highways — 70

EXAMPLE

Given: Fill section on 2-lane primary highway
h = 12' 4:1 slope
10' shoulder
Outside curve, D = 12°
4% downgrade
Ground sloping away > 15%
Climate — significant freezing

Solution:

Warranting value = 50
Need index from chart = 57
Guardrail required.

NOTES:

* For precipitous conditions see text for need index.

If wall or water at toe of slope, use line B_x, but

- with toe wall, add 5 x d to height of fill and enter chart with larger equivalent h.
- with water at toe, add 8 x d to height of fill and enter chart with larger equivalent h.
- also check Table 4; use guardrail if either this chart or Table 4 indicates the need.

(a) or isolated intermediate curve.
(b) or isolated near min. curve.

(c) or moderate crest V.C. combined with horiz. curve.
(d) or extreme crest V.C. combined with horiz. curve.

(e) and/or boulders on slope, or road or buildings at toe of slope.

GUARD RAIL NEED INDEX NOMOGRAPH

Figure 1

generally perform satisfactorily. However, since this beam height is only slightly higher than the center of gravity of the average passenger car there are possibilities of vehicle roll-over and penetration under extreme conditions of impact."

An excellent article on guard rail written by Malcolm Graham, William Burnett, John Gibson and Robert H. Freer of the New York State Department of Public Works is published in HIGHWAY RESEARCH RECORD 174.

The article concerns a six-year research program which resulted in the complete revision of the guard rail standards used by the New York Highway Department.

This research program led to the development of a new design, termed the box beam barrier. In this approach, a commercially available hollow structural rail section of considerable beam strength is supported by relatively weak posts; such a barrier deflects and absorbs impact forces while decelerating and redirecting the vehicle. By using box beams of different strengths and by varying the spacing of posts, barrier deflection can be controlled, thus making this type of barrier suitable for a guide rail, median barrier, or bridge railing.

Also resulting from this research was a method of guide rail and median barrier selection based on the amount of deflection which can be tolerated in any given situation. This criterion, used in conjunction with the improved barrier designs developed in the program, should insure that the minimum practical decelerations will be imposed on a colliding vehicle.

It is understood that twelve states have now adopted certain features or are running further tests on the guard rail designs set forth in H.R.R. 174.

BRIDGE WIDTHS

The U.S. Department of Commerce, Bureau of Public Roads Instructional Memorandum 40-2-66 dated November 3, 1966, approved the practice of making the bridge width equal to the full roadway width on the approaches, including the usable width of shoulders. This memorandum covered only those bridges on the National System of Interstate and Defense Highways. The coverage was extended to include all projects on the Federal Aid Primary and Secondary Systems where the design speed is 50 mph or more and where the current ADT is 750 or more by Bureau of Public Roads Instructional Memorandums 21-11-67 dated May 19, 1967 and 21-11-67(1) dated June 29, 1967.

Memorandum 40-2-66 stated that the width of bridge is measured between inside face of parapets or rails and indicated that there would be the following two classes of bridges:

Case 1 - All Interstate overcrossing structures, urban and rural, except major long span bridges.

Case 2 - Major long span bridges (exceptional case) wherein the site conditions and type of structure result in a high cost per square foot of roadway.

The interpretation of widths for Case 1 bridges is explained quite adequately in Memorandum 40-2-66. The point of concern among engineers has been what constitutes a major long span bridge.

A study was conducted with the purpose of clarifying the difference between Case 1 and Case 2 bridges. The following are the major findings of this study, which resulted from conversations with officials of the Bureau of Public Roads, Highway officials from other states and the general experience of Howard, Needles, Tammen & Bergendoff engineers.

1. The length of the bridge has no direct influence on its Case Number.

2. There is no set standard to be used in classifying a bridge as either Case 1 or Case 2.

3. Each bridge should be considered as Case 1 unless it is a special type bridge having a high unit cost in which case it must be con-

sidered individually to determine whether it is to be a narrow or a wide bridge.

4. As a general rule of thumb, $40 a square foot is considered by some as the dividing point between a Case 1 bridge and a Case 2 bridge.

URBAN PAVEMENT WIDTHS

The widths of pavement to be used in urban areas is a subject of concern to the highway engineer. A definite criteria is not available which can be applied to this problem and produce an ideal solution in all cases.

A review of the standards used by other states reveals that they have varying criteria. General practice is to use local city standards, where available.

It is generally agreed that on curbed sections, a widening for driver reaction is desirable. A two-foot widening is considered acceptable practice and could be provided by using the Iowa standard "Two and One-Half Foot Portland Cement Concrete Curb and Gutter Unit."

In those locations where suitable city standards are not available, it is suggested that the following widths of pavement be considered as standard practice.

1. Two Through Lanes - No Parking
   2-1/2' + 24' + 2-1/2' = 29 feet back to back of curb

2. Two Through Lanes - Parking One Side
   2-1/2' + 24' + 8-1/2' = 35 feet back to back of curb

3. Two Through Lanes - Parking Both Sides
   8-1/2' + 24' + 8-1/2' = 41 feet back to back of curb

4. Two Through Lanes - Provision For Parking in Future
   2-1/2' + 28' + 2-1/2' Initial
   1/2' + 24' + 8-1/2' Future
   33 feet back to back of curb

5. Three Through Lanes - No Parking
2-1/2' + 36' + 2-1/2' = 41 feet back to back of curb

6. Three Through Lanes - With Parking
36' plus widening shown in 2., 3., or 4., depending on parking requirements.

7. Four Through Lanes - No Parking
2-1/2' + 48' + 2-1/2' = 53 feet back to back of curb

8. Four Through Lanes - With Parking
48' plus widening shown in paragraph 2., 3., or 4., depending on parking requirements.

9. Primary Highway Through a Small Town
At these locations it is believed advisable to locate the curbs a minimum distance from the normal edge of pavement equal to the shoulder width of the roadway approaching the town.

Twelve-foot is recommended as the desirable lane width. However, in low speed urban areas an eleven or ten-foot lane will carry the same amount of traffic as a twelve-foot lane, although sacrificing some driver comfort.

The lane width is a design feature that must be determined for each location. If the right of way is available or can be obtained at a reasonable cost, the twelve-foot lane with widening for driver reaction is believed to be a sound investment.

III. CHANNELIZED INTERSECTIONS

It is no wonder that the at-grade intersection has long been, and will continue to be, a formidable problem to both the design engineer and the traffic engineer who is responsible for its operation. The accident potential created by the exposure of vehicles within conflicting streams of traffic that intersect on a common plane is ever present. The degree of this exposure can be controlled and the accident potential reduced, but neither can be eliminated without physically separating the intersecting roadways. In the design of at-grade intersections, it is this element of control on which the engineer must focus and direct his attention.

There seems to be a great deal of controversy and disagreement between engineers concerning intersection design. Perhaps the reason this controversy exists is the lack of sufficient data concerning the contributory and causative factors of accidents. If all of these factors were to be tabulated, the list would be virtually endless. The mere acknowledgment of these factors, however, is not enough. To be meaningful and to provide definite answers as to what constitutes safe design, each factor must be evaluated separately and then studied in regard to how it interrelates with all other factors. The process is quite complex and there is just now beginning to be signs of increased research activity in an effort to provide much needed enlightenment. Fortunately, however, there has recently been a number of studies conducted that are quite conclusive and will greatly assist the engineer in his design decisions.

Very generally these factors might be grouped into four principal categories; (1) Traffic magnitude and composition (2) physical characteristics of the intersecting roadways (3) environmental conditions (4) driver behavior. The engineer has direct control over roadway characteristics, and he has limited control over the magnitude and composition of the traffic stream and to some extent he can control the environment, but he does not exercise any degree of control over the vehicle. He can only attempt to communicate with the driver through the provision of high standards of design in an effort to afford the driver maximum safety.

Some might argue that economy should occupy the same level of importance as safety and design, while some insist that economics should not influence the provision of whatever design is required to optimize safety. Undoubtedly, it is this variance in opinion regarding the relative significance of the many factors that influence intersection design that is contributing to most of today's disagreement among highway and traffic engineers. At a recent Highway Safety Conference, a Bureau of Public Roads official's opening remark was that if each engineer present was given an intersection to design it would be highly unlikely that any two designs would be the same. He further stated that there are as many opinions on the subject as there are engineers who express them. The accumulation of data and the studies performed in conjunction with the preparation of this report confirms this statement.

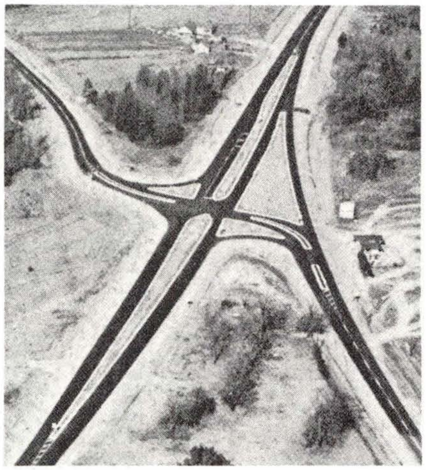
These studies were initiated by conducting an extensive search for available reference materials. The Linda Hall Library, a science and technology library in Kansas City, was contacted. Certain offices of Howard, Needles, Tammen & Bergendoff were also contacted. Inquiries and requests for available information were directed to the Bureau of Public Roads and the National Research Board in Washington, D. C. The Highway Research Board was asked to conduct a manual retrieval of document records relating to channelization, on file with the Highway Research Information Service. In all, some forty papers were accumulated. A complete list of this information is listed in the bibliography at the end of this chapter.

The following sections of this chapter summarize the more pertinent points found by a detailed review of the available information on channelized intersections regarding geometric design, method of channelization, the utilization of interior islands for sign placement, and the warrants for providing left turn storage lanes.

GEOMETRIC DESIGN OF CHANNELIZED INTERSECTIONS

Rather than presenting a generalized review of the many elements of channelized intersection design, it is felt that it would be far more meaningful and beneficial to confine the discussion to those specific design elements of the plans submitted by the Iowa State Highway Commission. In this way, direct comments reflective of the review of the material collected expecially for this purpose, can be made regarding the current design practice that is being followed by the State.

There are, however, certain principles of intersection design that are considered to warrant special mention. The 1965 edition of "A Policy on Geometric Design of Rural Highways" by the American Association of State Highway Officials, an excellent summary of design elements, discusses two of these principles that have, through long experience, come to demand greater attention and consideration by the designer. One of the first investigations that should be made in the improvement of an existing intersection is the angle formed by the intersecting roadways. An acute crossing is often maintained when it would have been possible to provide a right angled - and a much safer crossing. Figure 2 illustrates how this can be accomplished. It is recognized that alignment modification can be achieved with greater ease in rural areas, but urban locations should at least be investigated to see if better alignment is feasible.



SOURCE: AASHO

INTERSECTION WITH RIGHT ANGLE CROSSING

Figure 2

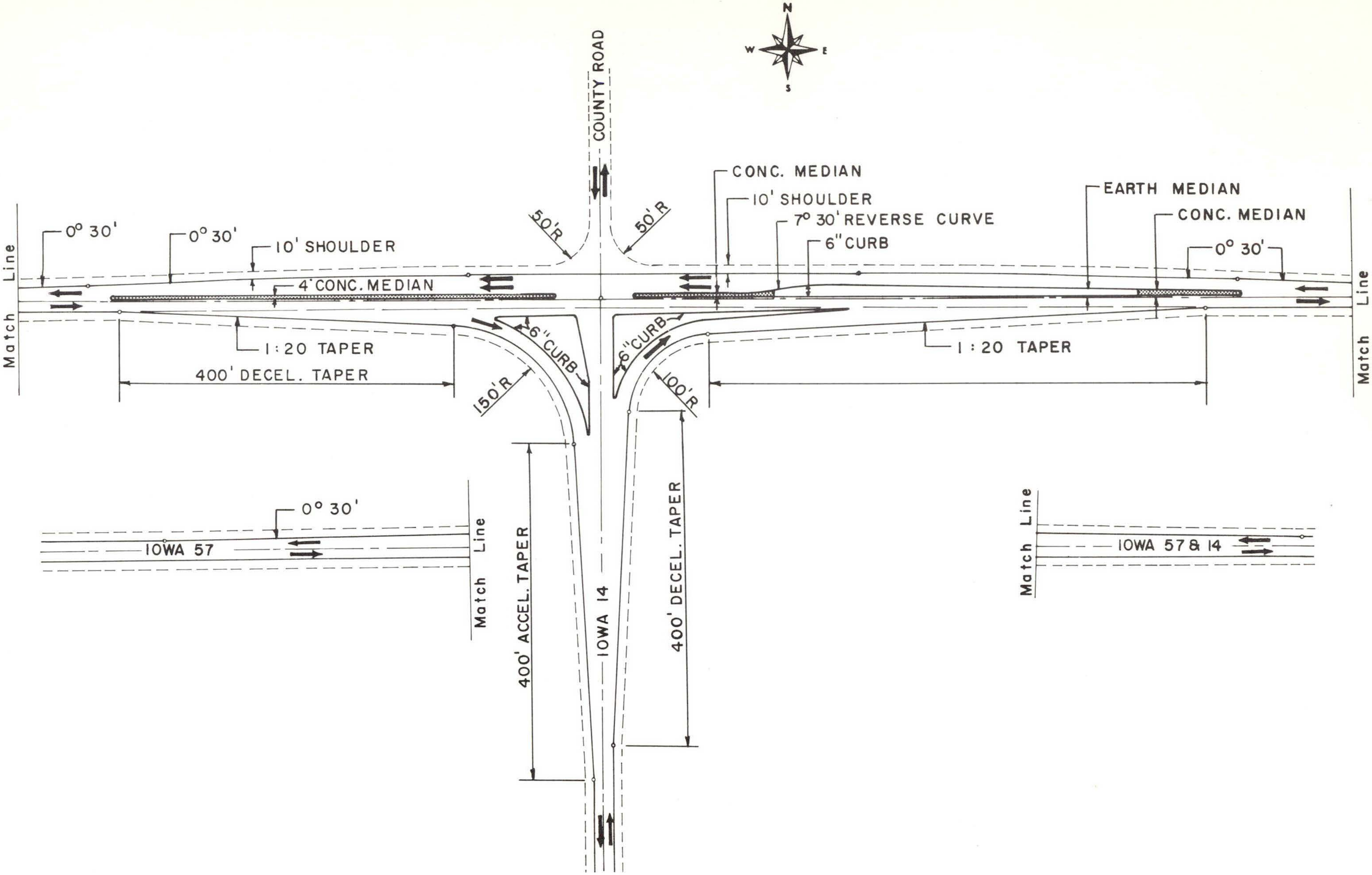
Vertical alignment is particularly critical in intersection design and often constitutes a definite hazard. Severe vertical alignment is often encountered during the upgrading of older highways that were designed on less stringent standards than those currently in use. Every effort should be made to maintain flat grades on each approach to the intersection in order to increase sight distance and to better accommodate braking vehicles.

Any intersection design, whether it is a new design or an improvement to an existing facility, should be initiated by reviewing and analyzing the traffic that it will be required to accommodate. Quite often, especially in urban and suburban areas, the magnitude of the existing or anticipated traffic volumes dictates the geometric configuration of the intersection and the degree of channelization that is necessary. Preference must often be given to certain movements and refuge areas are sometimes required. It might be found that a large turning radius is required to provide a freeflow separate turning lane, or that the successful operation of the intersection is dependent on the provision of a double left turn lane. Once these basic requirements are defined, the design process can proceed in a more direct manner.

A review of the intersections of Iowa Highways 14 and 57 and of U. S. Route 63 and Iowa Highway 96 follows. It is understood that the geometric design shown by Figure 3 represents the curbed channelization concept used prior to June, 1967. Figure 4 represents the uncurbed channelization concept currently in use by the Iowa State Highway Commission. All comments pertaining to the use of curbs will be covered in the section on "Methods of Channelization."

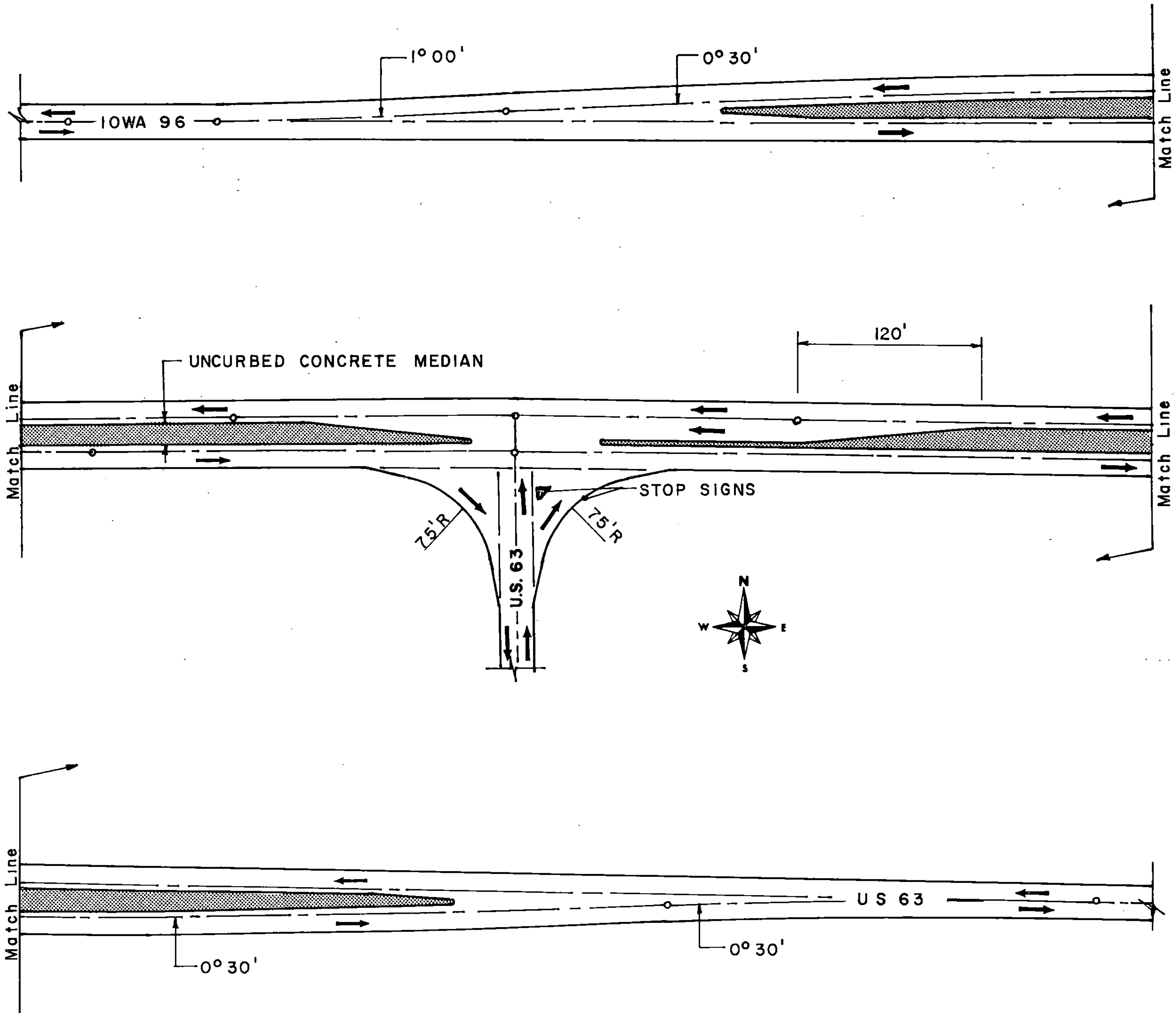
Intersection of Iowa 14 and Iowa 57

1. The angle of intersection, as shown by Figure 3, approximates 90 degrees and both intersecting roadways are virtually on tangent which provides optimum sight distance. It is presumed that the grades on both facilities are relatively flat and do not exceed 3 per cent, which would require special corrections in order to produce conditions equivalent to those on a level roadway.



INTERSECTION - IOWA 14 AND IOWA 57

Figure 3



INTERSECTION - U.S. 63 AND IOWA 96

Figure 4

2. The 100 foot and the 150 foot turning radii are both considered to be quite adequate for the type of movements involved. It is presumed, from the manner in which these radii are used with the acceleration and deceleration lanes, that the movement from the west to the south and from the south to the east are freeflow. In recognition of the fact that the longer of the two turning radii is more desirable, it is further presumed that the 150 foot turning radius could not, for some reason, be provided in the southeast quadrant of the intersection.

3. Considering the speed at which the vehicles within the intersection will be operating, both the 400 foot acceleration and deceleration lengths on Iowa 14 are considered quite adequate.

4. The method used to widen into a channelized section is recognized to be no longer employed by the state. Comment, therefore, will be reserved for the following discussion of U.S. 63 and Iowa 96.

Intersection of U.S. 63 and Iowa 96

1. In regard to the angle of intersection, sight distance and grades, the same comments apply that were made in Item 1 of "Intersection of Iowa 14 and Iowa 57".

2. The 75 foot turning radii, as shown by Figure 4, while certainly acceptable for accommodating vehicles from a stopped condition, are not considered sufficient for the provision of a freeflow movement. It is assumed that when freeflow movements are required or when, in the judgment of the designer, such a provision should be made, they will be provided as shown by Figure 3.

3. The provision of tangent roadway sections on the approaches to the intersection is in accordance with current theory and is considered to be excellent design and superior to that shown by Figure 3. Special notice was taken of the horizontal curvature used in achieving the widened section and was found to be acceptable.

It is recognized that each and every intersection will differ in alignment and will require various combinations of horizontal curves to achieve the widened section.

4. The taper for the left turn lane in the median is appropriate and is similar to that presently in use in other states. There is a trend toward shortening the transition in these cases in order to provide a more positive indication of the left turn movement. It has been observed that long, smooth tapers tend to invite through vehicles into the turning lane. The provision of a 24 foot separation between through roadways, while it provides sufficient refuge for turning vehicles, allows only 4 feet of separation from oncoming traffic. Additional comment will be made in regard to this in the discussion on channelization. The 120 foot tapered section opposite the left turn lane is especially desirable. Another state also provides a 24 foot median for T-intersections and uses a 36 foot median with conventional intersections in which opposing left turning movements are involved.

In both Figures 3 and 4, it was noted that the edge of the islands are offset from the normal pavement edge extended which is considered to be a desirable and necessary element of design.

While this review of Figures 3 and 4 is limited to "T" intersections, it is assumed that the same design criteria would also be followed on each approach of a 4-legged intersection requiring left turn channelization.

METHODS OF CHANNELIZATION

Throughout the review of the available material on methods of channelization, it became increasingly evident that any one method of channelization cannot be established as being superior. In the provision of channelization, the desired result is simply the separation and regulation of conflicting movements into definite paths of travel and the manner in which this is accomplished depends upon a great number of factors. The continuous controversy on whether channelization is best achieved through the use of barrier curbs, mountable curbs or no curbs at all eludes the issue. The point should not be which of these methods to use, but rather when and under what circumstances one is more desirable than the other. The following excerpts from the various reports, papers, articles and state design manuals serve to indicate the multiformity of opinion.

1. "The value of curbed medians, combined with intersection channelization, in reducing the number of certain types of accidents has long been acknowledged."

2. "The Oregon State Highway Department, in recent years, has discarded the general use of concrete islands and other raised medians for channelization in rural and suburban areas. This was because through vehicles occasionally hit the islands and were thrown out of control."

3. "For highways with high approach speeds channelization should normally be accomplished entirely with painted markings, supplemented with plastic lane markers or traffic buttons. Under urban conditions curbed channelization may be necessary for traffic control."

4. "Since most traffic islands are provided only to define and regulate traffic movements, these islands should be traversable in case of an emergency. Islands bordering high-speed through lanes should generally be kept clear of the shoulder areas. Barrier curbs generally can be justified only where protection of pedestrians is a primary consideration."

5. "The extent and type of channelization utilized in urban and suburban areas is normally dependent upon obtaining design capacity and satisfactory operating conditions and, since conditions vary greatly, no general guide values can be employed."

6. "The question as to whether medians should be raised or flush and the manner in which drainage is handled appear to have

no clearcut answers. Practice seems to vary greatly among states, some installing depressed medians. There seems to be no particular basis for recommending any one practice. However, these details should be resolved in a manner that does not increase the hazards of occupants of vehicles leaving the road. In all cases there should be a clear visual demarcation between pavement and median area."

7. "It is apparent that most agencies are in agreement concerning the desirability of separating opposing lanes of traffic. It is also apparent that there is no significant amount of agreement on how or when this protection should be installed."

Perhaps some of the controversy can be dispelled, or at least subdued, by reviewing the findings of a recent study conducted in California[1]. The number and type of accidents in 40 unsignalized, unchannelized, at grade intersections was compared to the number and type of accidents after the provision of left turn channelization in each and every intersection. The method of channelization used consisted of raised bars, curbing and paint only.

Of the 40 intersections, 13 were channelized by the use of either curbing or raised bars. Of these 13 intersections, 9 were located in urban areas while only 4 were located in rural areas. The results of the study indicated that after the provision of curbed or raised bar channelization in these 13 intersections the number of accidents was reduced by 64 percent. Since detailed study data was unavailable, it is not known whether there was a greater reduction in urban accidents than rural accidents.*

More conclusive results are provided by a study of the remaining 27 intersections for which detailed data <u>is</u> available. Twelve of these intersections were located in urban areas and 15 were located in rural areas. Left turn channelization was provided in these 27 intersections by the use of paint only, and the "before" and "after" accident histories were compared. It was found that there was a 50 percent reduction in total accidents in the rural sections, while there was only a 15 percent reduction in accidents in the urban

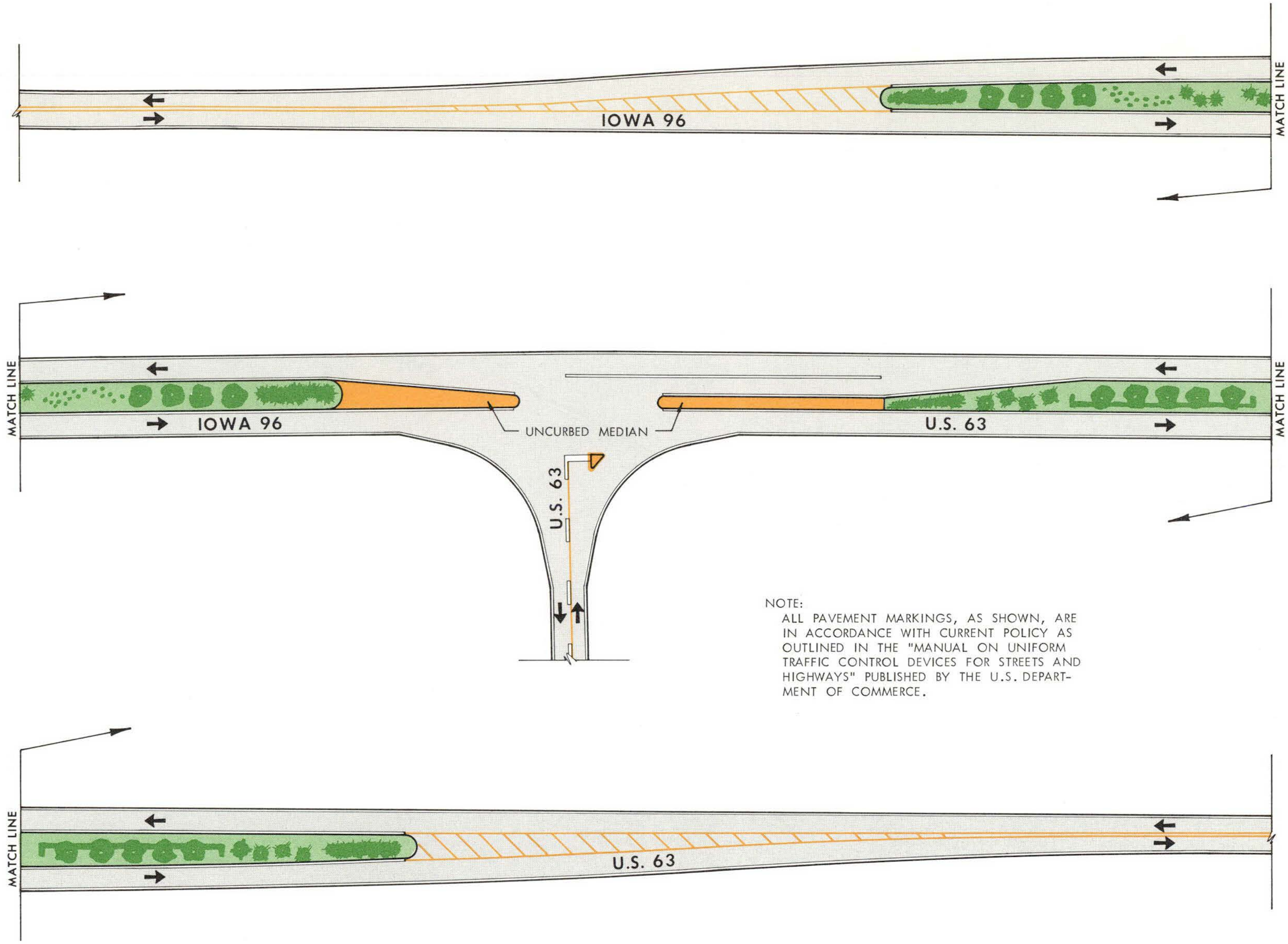
* *Refer to Addendum*

intersections. Additional study in California[1] revealed that painted channelization reduced accidents as much if not more than curbed and/or raised bar channelization on traffic facilities where the zoned speed is 55 mph or greater.

These results are quite revealing and, while they do not represent sufficient study to allow the establishment of a universally acceptable criteria, they do permit positive guidance which has, in the past, been conspicuously absent. On the basis of these studies and from the review of available data on the general subject of channelization, the following comments are considered to be appropriate and should be regarded as our considered opinion.

1. In rural areas where operating speeds are likely to be 50 mph or greater and where the motorist is accustomed to the provision of shoulders adjacent to the roadway, the sudden introduction of a barrier or mountable curb creates an undesirable and potentially hazardous situation. Because of this, and on the support of the California data, the provision of uncurbed channelization in rural areas is considered to be the safer and more favorable design.

2. If the median separating the waiting left turn vehicle from the opposing oncoming traffic is to be uncurbed, the 4 foot median currently being provided by the state is adequate but is considered to be minimal. Figure 5 indicates a painted median and also shows a portion of the median to be landscaped and sodded. The purpose of the landscaping, which consists of small bushes not more than 3 feet in height, is to provide better delineation of the channelized area so that greater visability can be afforded to the driver - particularly under adverse weather conditions. The use of landscaping for delineating the roadway is gaining recognition. A study conducted by the University of Illinois in 1966[2] concluded that more emphasis should be placed on providing landscape plantings for this purpose. It is realized that the main disadvantage to any landscaped area is the maintenance that is required. In the utilization of landscaping for a definite purpose such as delineation, however,



NOTE:
ALL PAVEMENT MARKINGS, AS SHOWN, ARE IN ACCORDANCE WITH CURRENT POLICY AS OUTLINED IN THE "MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES FOR STREETS AND HIGHWAYS" PUBLISHED BY THE U.S. DEPARTMENT OF COMMERCE.

INTERSECTION - U.S. 63 AND IOWA 96
(LANDSCAPED MEDIAN)

Figure 5

it would appear that this disadvantage is outweighed by the fact that it is performing a definite and beneficial function. While a painted median is virtually maintenance free and provides adequate delineation the majority of the time, it becomes totally invisible during periods of heavy snowfall.

3. In urban areas where operating and posted speeds are lower, the use of curbed channelization is considered to be acceptable. Often the provision of barrier curbs is necessitated by the need to control access to abutting property along a traffic facility. In fact, there are many cases on record in which overall traffic service and safety were greatly improved by controlling the number of median crossings through the use of curbed medians and left turn lanes at selected locations. Again, the documented results of the study in California[1] is sited in support of the use of curbed channelization in urban settings. This is not meant to infer that painted channelization is not applicable to an urban area. Under certain circumstances, it might be found to provide a better solution than curbs and should be left to the judgment of the designer.

4. In suburban areas where curbs may or may not be required, the manner in which channelization is provided should be based primarily on the need to control crossing movements. If the operating speed exceeds 50 MPH and there is no specific reason for curbs, painted or sodded channelization will probably prove favorable.

INTERIOR ISLANDS FOR SIGN PLACEMENT

Nearly every agency responsible for the provision and maintenance of highway facilities has had unfortunate experiences with the placement of signs in traffic islands. Until the recent development of breakaway posts, these signs constituted a dangerous and sometimes fatal hazard. There has undoubtedly been cases where curbs have been installed solely for the protection of the sign just as there have been islands created expressly for sign placement. Not only do these practices represent poor design, but they also lead to false conclusions regarding the causes of accidents and cast doubt on those installations that are designed properly.

The placement of signs within the median and interior islands or anywhere adjacent to the roadway should be avoided whenever possible. There are certain signs, however, that must be provided when an intersection is channelized in a particular manner. The channelization shown in Figures 3 and 4, for example, should include a "Keep Right" sign on each end of the medial area. If a separate right turn lane is to be provided as shown in Figure 3, a stop sign might be required for left turning traffic, and the only logical location is within the island. As mentioned before, the breakaway features that are now available permit the safe installation of these signs adjacent to the roadway. If the intersection is signalized the signal heads can be suspended over the roadway in most cases, thereby reducing the number of control devices that are ground mounted.

In summary, it is believed that the placement of regulatory and warning signs can and should be located in the median or on interior islands, provided they are considered necessary by the designer and are of the breakaway type. This would hold true regardless of whether or not the median or the island is curbed.

LEFT TURN STORAGE WARRANTS

Recently, there seems to be an increased awareness of the value of a left turn lane in increasing safety and improving overall operation on both urban and rural traffic facilities. Not only does a left turn lane offer refuge to the stopped vehicle, but it also allows the following through traffic to continue without delay. One has only to study the results of "before" and "after" accident studies of locations where left turn lanes have been provided to become convinced of their value. Thus, it can be argued that a left turn lane is "warranted" wherever such a provision will result in a reduction of accidents. Some states presently provide left turn lanes at all intersections regardless of traffic. Other states have established definite warrants based on traffic speed and volume such as the one exemplified below:

"A. Policy on Multi-lane Divided Highways

1. When the design speed of a multi-lane divided highway is 40 mph or higher, left-and right-turning lanes shall be standard features at all public access points....."

"B. Policy on Two-lane Highways

1. Left- and right-turning lanes shall not normally be provided on two-lane roads having a 20-year projected ADT volume 1500 VPD (DHV-Under 400 VPH). Physical features may require left- or right-turning lanes with volumes under 1500 VPH but special justification will be required....."

"D. This policy applies primarily to rural areas. In urban areas left- and right-turning lanes shall be provided wherever feasible."

Following are excerpts from several different states:

1. "Median lanes are authorized for any channelization where left turns are permitted from the through lanes regardless of whether traffic signals are to be installed."

2. "A 250' taper (0' to 12' wide) is a required part of a median crossing at all public highway intersections. It is adequate for storage of left-turn vehicle volumes of 30 DDHV or less and no length of uniform 12' width left-turn lane is required. For volumes greater than 30 DDHV, a length of 12' lane shall be provided at the end of the taper as shown below.

Left Turn Vol. DDHV	31-60	61-90	91-120	121-150
12' Wide Lane Length	50'	75'	100'	125' "

3. "Under normal conditions the length of storage lane is required to be as follows:

DHV of Turning Vehicles	25-180	180-210	210-240	240-270	270-300
Length of Storage Lane	150'	175'	200'	225'	250' "

In many cases, especially in urban areas where traffic volumes are heavy, the provision of a left turn lane at an intersection is necessitated by the need to provide adequate capacity.

A study conducted at Purdue University[3] provided some interesting results. Through an analysis of the operation of 11 intersections, this study developed a warrant for the construction of a median lane which relates the annual cost for construction and maintenance of a median lane to the total estimated benefits derived from reductions in delays and in accidents for suburban and rural areas. The paper written summarizing the study closed as follows: "The benefits were found to be such that when compared with the cost of a median lane, almost every intersection on a divided highway with a median of 16 feet or more and many intersections on other 4-lane and 2-lane highways possess the warrants for construction of median lanes."

On the basis of this evidence, it appears there are actually few locations where left-turn lanes <u>cannot</u> be warranted. The real issue then centers directly on what it will cost or what must be accomplished to make such a provision. In an urban area, for example, a separate left-turn lane might require the removal of parking from both sides of the street in a highly commercialized area. While the elimination of parking might have an adverse effect on sales in such an area, it is the price to be paid by the merchants and general public for greater safety and a better level of traffic service. These are the kinds of situations the engineer will encounter in urban areas and the decisions he will have to make. For these reasons, no attempt has been made to establish left-turn warrants for such an attempt would be virtually meaningless.

Rural areas, while vastly different from the urban setting, sometimes require much the same type of approach. However, it is possible in the case of two intersecting rural highways to establish a rather firm policy, as has been done in Iowa, in regard to the T intersections shown in Figures 3 and 4. The decision to provide left-turn channelization at other, less important, rural locations rests entirely on the engineer's evaluation of the particular conditions. Locations having a high accident potential should be detected and then studied in order to determine if left turn channelization is required. The left-turn demand and total traffic volume should also be considered but should not be decisive in the final determination.

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IV. ROADWAY LIGHTING CRITERIA

INTRODUCTION

The current roadway lighting design standards and practices of the Iowa State Highway Commission have been reviewed with the objective of comparing them with national policies, general practices of other states and recent research findings.

It should be recognized that highway lighting practice is presently in a transition period with emphasis on highway safety and national safety design standards. For the past several years this practice has been in a remarkably rapid change because of constantly changing research, development and application, with emphasis on efficiency and competition.

Iowa Standards and practices have been found to compare most faborably with those of other states and normal practice. The comparison is in respect to engineering, economy, completeness, safety, adequacy, clearness, moderness of practice, attention to details, recognition of attractive features, facilitated bidding, and AASHO and Bureau of Public Roads' recommendations.

REVIEW OF IOWA PRACTICE

Luminaires

The luminaire overhang of two feet over the roadway for luminaires used in Iowa seems to represent the average practice.

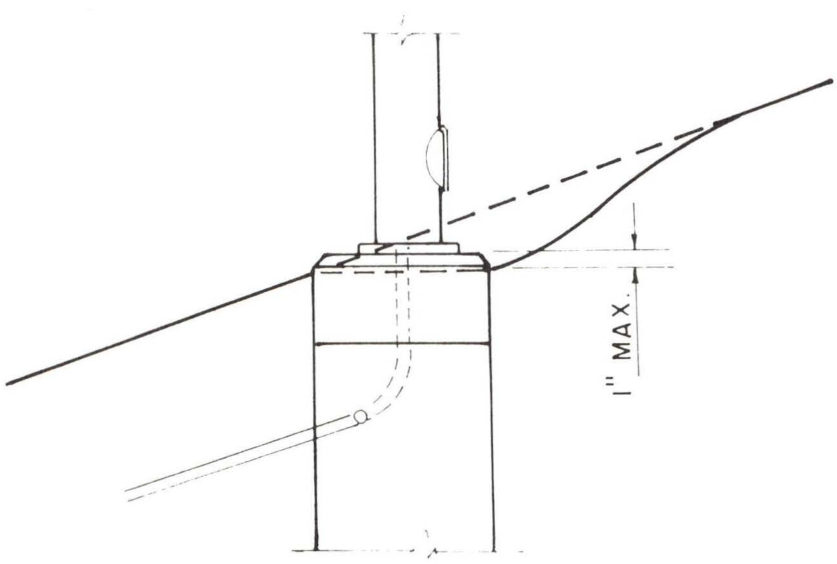
There appears to be consideration for color-improved and white mercury, as well as the clear lamps. It is believed that the generally accepted practice today for freeway lighting work favors the clear lamps for efficiency and lumen maintenance. Color improved and white mercury lamps generally require about 25 per cent more lighting units. Fluorescent luminaires for ramp and roadway lighting are waning in popularity, and perhaps removing them from the specifications should be considered.

Standard road plan RM-14 indicates mercury for low mounting heights. This practice has been adopted by about 47 states as standard lighting for underpasses, presumably because of the longer lamp life, lower initial cost, and lower maintenance and operating costs.

However, fluorescent or shielded mercury units seem to be preferred for the higher intensity tunnel lighting, based on glare and comfort calculations.

Pole Footings

A small, but possibly important item is the method of shaping the finished ground line around pole footings. The present practice of Iowa, which meets Bureau of Public Roads recommended practice, and offers the most protection against pole corrosion, is to build up the slopes on the high sides of footings so that the concrete will project only about one inch above a raised finished ground line. It appears to be a more general practice to either set the pole in a shaped out recess in the ground, or to provide an area-wall retainer around half the base to dam the earth. It is believed the former arrangement as indicated in Figure 6 should be considered for safety reasons. The mound presently in use could possibly be the cause of an unnecessary accident.



FINAL GROUND LINES AT LAMP POLE BASES

Figure 6

There is no question as to the adequacy of the pole concrete footings for average conditions. The depth for bases is more than is generally used, and the reinforcing is in the best practice. The depth for most pole bases is 5'-6" to 6 feet for mounting heights to 40 feet, and 8 feet for poles with a mounting height greater than 40 feet.

In reference to the practice of tapering light pole foundation by enlarging the top, as shown on Road Standard RM-11, it is thought that perhaps revising the standard pole base to 30 inches in diameter, could be considered as a means to simplify the excavation, anchor bolts and reinforcing. Tapered forms have been abandoned by many states in the interest of economy.

Underground Cables

The practice of Iowa seems to favor direct burial cables for most sections. This is satisfactory recognized practice, and there may not be sufficient reasons for changing this procedure. However the more widely used and general practice today is to use preassembled cable-duct with relatively low cost insulated conductors in polyethylene ducts. The polyethylene ducts provide appreciable mechanical and electrical protection by their resilience and moisture resistance. Many engineers experienced with both systems, prefer the cable-duct due to its increased reliability, and for maintenance reasons.

The main benefit and advantage of cable-duct appears to be a greater reliability from the air space around the cables which gives more mechanical protection and causes the earth stresses to be placed on the duct rather than the cable. Available bid records indicate a 25 per cent premium is paid for cable-duct in the smaller sizes, to 36 per cent premium in the larger sizes. The Bureau of Public Roads recognizes the cable-duct as worth the increased cost. Records are not available, but it is believed most states are now using cable-ducts, and that most cities are now installing most of their lighting and underground distribution circuits in cable-ducts or rigid or non-metallic ducts.

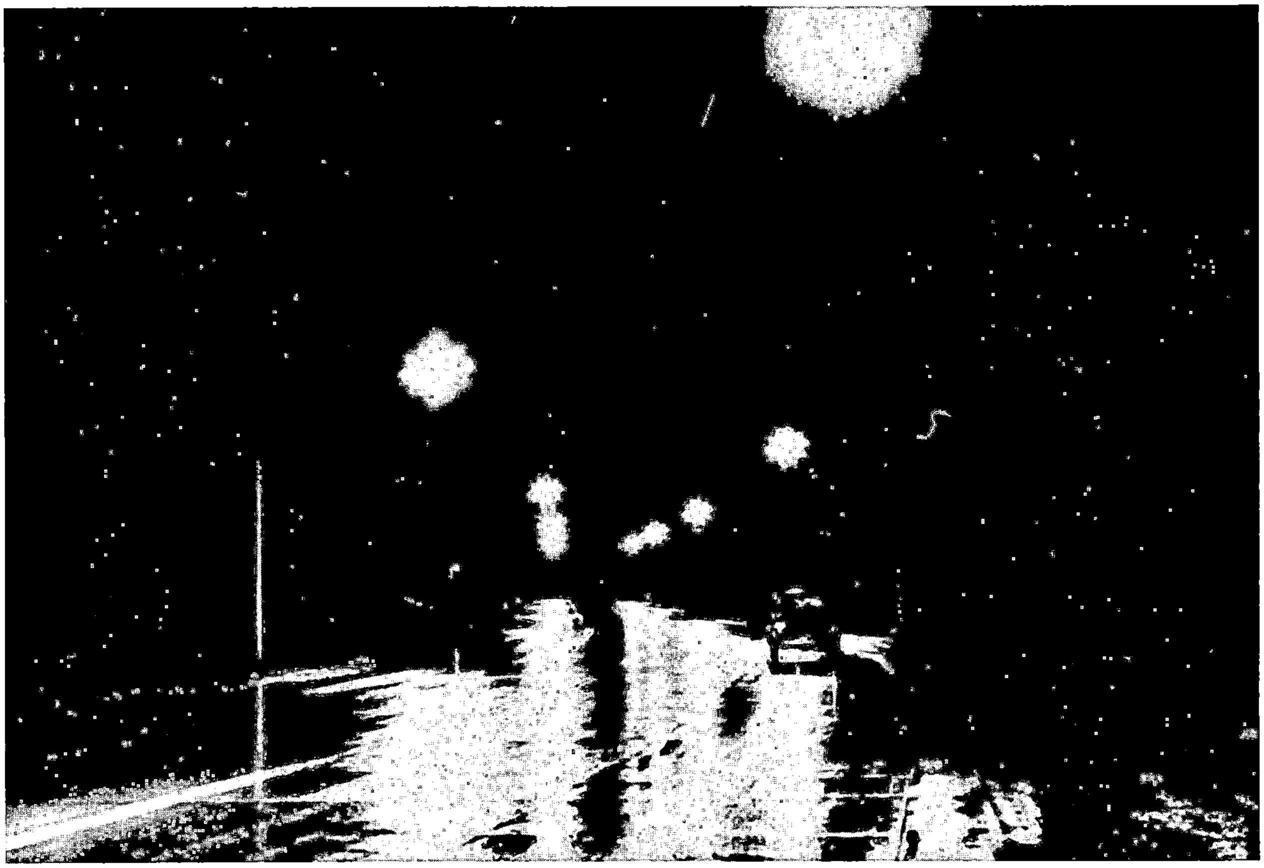
Light Poles

It is understood that the Commission intends to delete concrete poles from the new specifications and to provide an alternate between galvanized poles and aluminum poles. This is considered the proper course of action since the concrete poles must be considered a safety hazard. Galvanized and aluminum poles require less maintenance and posses better aesthetic qualities.

It is noted that Iowa has adopted the breakaway type light pole for use within 30' of the normal edge of pavement. It is recommended that this type of pole also be used adjacent to ramps in order to afford the motorist the maximum protection at all times.

There is a decided tendency toward higher mounting heights based on the Bureau of Public Roads' recommendation that 35 to 50-foot mounting heights be considered for economy. Since steel poles are now available with up to 50-foot mounting heights using brackets out to 35 feet, there is a preference for 40 and 50-foot mounting heights for rural and urban uses, respectively. Cost estimates substantiate that some economy is to be gained from higher mounting heights. Figure 7 would suggests that some advantages are apparent from more frequent smaller light sources to spread the light sheen more widely and uniformly, as compared with fewer larger sources farther apart which provide fewer paths of light for the driver.

In reference to the median mounting from high poles for economy, there is no doubt that some economy would be realized. However, there is not complete acceptance of this benefit in all cases. Some of the median mounted installations in service should perhaps be evaluated for acceptability. It is believed this lighting might generally be acceptable on dry nights, and that the answer on wet nights would be somewhat dependent upon the intensity of light provided. It is the opinion of some who have used median mounted poles that complete satisfaction is not generally provided especially in areas confronted with an appreciable number of wet nights. If a sufficiently high intensity of light were placed on the roadway surface, satisfactory conditions would exist, but generally, approval of the required minimum intensity of three foot candles would be difficult to obtain.



LIGHT REFLECTIONS ON A WET NIGHT
Figure 7

Figure 7 indicates the predominant method of seeing at night. Light should be delivered from both sides of the roadway so that specular reflections will be toward the driver, and will distribute a sheen of brightness over the surface viewed by him. Roadway brightness of the entire width or roadway for silhouette discernment is a function of the light reflected toward the driver's eyes, and is the predominant method of discernment at night.

Appreciable intensities are required to achieve good visibility where candlepower distribution is out at about right angles to the driver. Anticipated ratios of object to background brightness appear somewhat inefficient. Seeing by reverse silhouette and surface detail requires candlepower away from the driver and high intensity direct illumination on objects.

To attain a 30-foot pole setback, there are some plans to use a short bracket that will mount 1000-watt luminaires 50′ high, 10′ back from the edge of the pavement. This practice should perhaps be tested because of the difficulty in distributing a sheen of brightness across a roadway immediately ahead of a driver, particularly on a wet night.

Intensities

It is believed that an average initial intensity of 1.2 foot-candles with maximum brightness contrast ratios of 6:1, is considered the recommended practice for freeways. However, intensities as high as two foot-candles are being installed with Federal-aid highway funds where justification for matching existing intensities, overcoming high surrounding brightness, or other reasons can be obtained.

Controllers

Iowa standards permit time controllers. Nearly all lighting controllers in freeway application are now photo-electric. Astronomic time switches could conceivably offer advantages in certain types of applications. However, since these applications are so few, consideration should be given to deleting this type of switch from the specifications.

Ground Rods

Possibly the specifications should be revised to permit the substitution of solid, pointed 1-inch by 10-foot wrought iron ground rods as an acceptable alternate to Copperweld to facilitate competitive prices and to conserve copper.

Handholes

Perhaps the use of prefabricated helical corrugated steel, fiber, asbestos-cement, or plastic handholes should be considered. Several states have adopted them for economy. Even though it is generally conceded that a concrete box is better, the additional cost might not be justified for some applications.

Splice, Duct And Cable Markers

The possible application of concrete markers should be mentioned. They are used by many states to mark splices and changes in directions of underground cable runs or ducts. Their use is often advantageous, and should be considered to facilitate future maintenance.

Voltage Drop

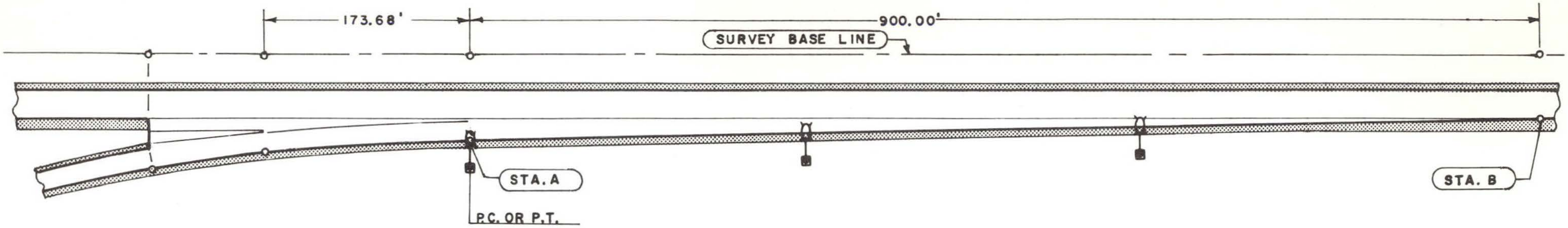
A requirement for maximum permissible voltage drop allowable on branch circuits was not found. Some states still permit as high as 10 per cent loss, with the average permissible loss about 5 per cent. It seems the requirement of a maximum allowable of five should be indicated because some of the newer light sources will not perform satisfactorily when the drop exceeds five, and ultimately it may be found desirable to use the newer sources.

Lighting of Speed Change Lanes

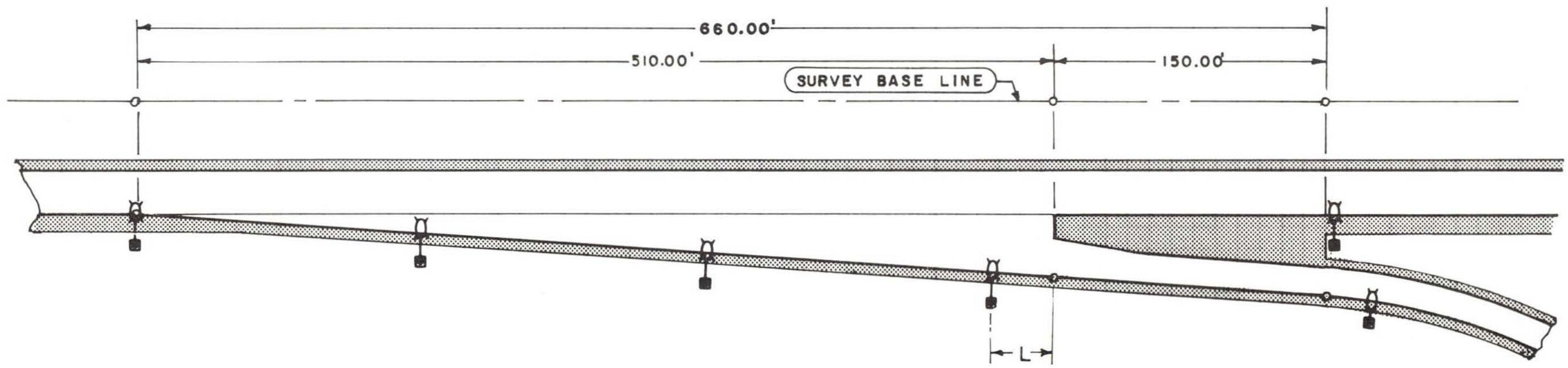
It should be noted that many states have a typical location plan for lights on speed change lanes to insure proper placement of lighting units for maximum visibility in these critical areas.

It would appear advantageous to have a standard plan for a deceleration lane indicating that the lighting unit should be installed at the beginning of the taper and at a distance "L" ahead of the nose. (See Figure 4). The distance "L" varies according to the mounting height with the following considered to be the general practice: L = 30′ for 30-foot mountings, L = 40′ for 40-foot mountings and L = 50′ for 50-foot mounting. The number of additional lights on the deceleration lane would vary according to the intensity, luminaire size and mounting height.

Also shown on Figure 8 is a standard layout for lighting on an acceleration lane. The critical light in this case is at Station A. The intensity luminaire size and mounting height would control the positioning of the lights between Station A and Station B.



ENTRANCE RAMP



EXIT RAMP

LIGHTING OF SPEED CHANGE LANES

Figure 8

Warrants For Lighting

Warrants for roadway lighting are listed in the Policies and Procedure Manual, and generally parallel the Bureau of Public Roads' participation. Consideration should be given to adopting a policy similar to that followed by the Bureau in assisting local governments where they are willing to pay for the installation, maintenance and operation for safety, policing, or other purposes should be considered. The Bureau of Public Roads will participate in lighting underpasses over 150 feet long.

The warrants for lighting in some states is directed toward lighting intersections in the order of accident incidence. Warrants are included for streets in municipalities to light in accordance with ASAIES practice; lighting rural intersections where there are more than 2.4 accidents per million vehicles in each of three consecutive years; where there are 2.0 or more accidents per million vehicles per year, and four or more accidents per year in each of three consecutive years; where there are 3 or more accidents per year in each of two consecutive years; and where there have been five or more night-time accidents on a signalized intersection is the past year, and the night accident rate exceeds half of the daytime rate.

General Comments

Other items reviewed generally conform to the latest and best practices of other states. Some additional items could be suggested for inclusion and improvement, but these would be more applicable to special installations. Examples of such items would be provisions for future traffic surveillance systems, police call boxes, and circuit and light pole identifications.

V. HIGHWAY SAFETY

THE AASHO HIGHWAY SAFETY REPORT

The February, 1967, Report of the Special AASHO Traffic Safety Committee, HIGHWAY DESIGN AND OPERATIONAL PRACTICES RELATED TO HIGHWAY SAFETY, was approved by the Bureau of Public Roads for use on federal-aid highways in their Instructional memorandum 21-11-67 dated May 19, 1967. This AASHO Report is used herein as the guide line for highway safety.

The AASHO Report listed the following principal conclusions and recommendations in two major subject areas: Roadside Design and Appurtenances, and Traffic Operations. The following paragraphs, 1 to 19 of Roadside Design and Appurtenances and 1 to 15 of Traffic Operations, were copied from pages 1 to 5 of the AASHO Report. The underlined sentences were a part of the AASHO Report but were not underlined. They have been underscored in this report since they are thought to be items of special note. The sentence in parenthesis was not in the AASHO Report but has been added in this report because it is thought to represent a design feature of equal importance.

"Roadside Design and Appurtenances

"1. In the development of plans for highway improvements, all elements of design should be reviewed to insure that any feature likely to be associated with injury or accident to the highway user is eliminated or minimized in its effect. Special attention must be directed to the safety characteristics of the roadside so that they too are the result of deliberate design and not an unpredictable by-product of grading, drainage or other construction activity.

"2. An intensive crash program to remove roadside hazards on existing streets and highways and to engineer the roadsides of new facilities with safety as a major criterion should have a paramount place in the highway program of each state. Only in this way will the motorist who inadvertently leaves the traveled way have adequate protection against death or injury.

"3. Design standards more liberal than the minimums prescribed will often increase safety. Constant field checks of the operating conditions with existing and new designs are recommended for evaluation of their effectiveness and cost efficiency.

"4. Embankment and cut slopes 6:1 or flatter can often be negotiated by a vehicle with some chance for recovery and these should therefore be provided where possible.

"5. A full shoulder width should be carried across all structures. Shoulders should be flush with the adjoining through lane. Contrast in color or texture or both, and the use of a conspicuous edge-line marking are recommended for the guidance of drivers and to discourage use of shoulders by through traffic.

"6. To increase safety when vehicles leave the pavement, a clear recovery area, free of physical obstruction, should be provided along the roadway 30 feet or more from the edge of the traveled way in rural areas. Corrective programs should be undertaken at once to eliminate from the roadside or to relocate to protected positions such hazardous fixed objects as trees, drainage structures, massive sign supports, utility poles, and other ground-mounted obstructions that are now exposed to traffic. Where this is impracticable, an adequate guardrail or other type of protection should be provided.

"7. The gore area at the divergence of two roadways, as at the exit from a freeway, must be kept clear of heavy structures, unyielding sign supports and similar installations that would not readily give way if struck by a vehicle out of control. The standard EXIT sign is a permissible installation in the gore but should always be mounted on a breakaway type support.

"8. The use of appurtenances along the roadside must be reviewed continually to minimize the number of such objects that can be struck by vehicles. Each jurisdiction should periodically review its signing and retain only the essential signs. The continuing demands for additional nonessential highway signs must be firmly resisted.

"9. Many ground-mounted highway signs can be placed farther from the pavement, laterally, and still retain their effectiveness. Under favorable viewing conditions, a minimum distance of 30 feet from the edge of pavement to the edge of sign is recommended. The detailed location of all individual signs and sign supports should be subjected to a field review of existing highway conditions prior to installation whenever possible to assure maximum effectiveness and safety.

"10. On multilane facilities with heavy traffic volumes, additional use of overhead sign locations is recommended to provide information equally visible to all traffic and for specific lane assignment.

"11. Much greater use of overhead crossing structures for support of overhead signs is recommended.

"12. The adoption and use of a suitable breakaway or yielding design for lighting and sign supports by all jurisdictions is recommended. Concrete bases for these supports should be flush with the ground level.

"13. A consistent nationwide policy for the application of guardrail should be established at the earliest possible date. Designers must keep in mind that the objective of guardrail installation is to lessen the hazard to highway users, and not to protect any part of the roadway. <u>Guardrail should only be used where the result of striking an object or leaving the roadway would be more severe than striking the rail.</u>

All guardrails on the approaches to structures must be securely attached to the structure. All approach ends of guardrail must be flared away from the road, anchored to the ground, or otherwise blended into the approach environment. A dike or curb should not be used in front of guardrail. When guardrail is used as a median barrier or as a marginal barrier at high exposure locations, the spacing of mounting posts should not exceed 6'-3" to provide adequate strength and resistance against penetration. The bolt attaching the rail to the post should include a suitable washer to prevent the bolt pulling through the rail.

"14. On new construction a median width of about 60-80 feet is highly desirable. Median barriers of a suitable design should be considered where the median is 30 feet or less in width.

Openings in a median lead to operating hazards and should be avoided. Proper signing should be installed to prohibit the general use of crossovers constructed for essential maintenance, patrolling or emergency purposes. Movable barriers for the necessary crossovers should also be considered.

Narrow grassed medians are undesirable. To eliminate maintenance operation hazards, narrow medians of this type should always be paved.

"15. The adoption and use of two-span bridges for overpasses crossing divided highways is recommended to eliminate the bridge piers normally placed adjacent to the outside shoulders.

"16. Where twin bridges are used on divided highways, adequate median barrier protection for motorists should be provided. For separations up to 20 or 30 feet, the median should normally be made continuous by bridging the undercrossing.

"17. On long, sustained grades where slow moving trucks cause disruptions in normal traffic flow, separate truck-climbing lanes should be provided. In some cases, escape areas to contain heavy vehicles out of control on long downgrades will also be warranted.

"18. The safety of selected critical locations, such as weaving areas, exit and entrance ramps, and junctions, as well as intersections where traffic movements are in conflict with one another, often can and should be improved by modern highway lighting. However, better accident data will be needed if continuous lighting of rural freeways is to be justified as a safety measure. More attention should be given to higher mounting heights for lighting installations, which will reduce the number of lighting standards required, permit their safer placement away from the traveled way, and reduce the adverse effects of glare.

"19. Regular nighttime inspections by trained personnel to detect operational deficiencies must become a routine practice to assure round-the-clock safety.

"Traffic Operations

"1. Continual evaluation of present signing and marking practices is urgently needed, with a view to providing only the most relevant information at the right place and in a uniform manner. <u>Route numbers should be used to a greater extent and usually in preference to freeway names on guide signs. The standardization of sign messages should receive much greater attention.</u> (The use of trail blazer signs is vital).

"2. A large scale, comprehensive program of minor physical improvements and the concentration of maintenance activity on the alleviation of hazards must be undertaken immediately and in every jurisdiction if traffic accidents are to be successfully reduced in numbers and severity.

"3. All traffic control devices used during maintenance and construction operations should be equal to and preferably larger than those on completed comparable facilities. More emphasis should be given to the proper use and maintenance of these devices on maintenance and construction projects.

"4. Much greater attention must be given to improvements in the planning, design, and control of transition areas between facilities of different design to minimize accident potential. This problem is particularly acute where freeway traffic leaves the through lanes and reaches typical city streets, channelized or open intersections, frontage roads and intersecting routes. More effective signs should be developed for some of these situations. In other cases, standard devices, more intelligently applied, would help to solve the transition problem.

"5. 'ONE WAY' signs, 'TURN PROHIBITION' signs, and assemblies consisting of a 'DO NOT ENTER' sign above a white-on-red 'WRONG WAY' sign should be used at all ramps and crossroads where needed to prevent or redirect wrong-way travel on divided highways.

"6. Because drivers tend to follow longitudinal construction joints in the pavement when pavement markings become worn and inconspicuous, extreme care should always be used in determining their location so as to avoid any possibility of guiding the driver into a hazardous traffic situation.

"7. Edgeline markings are recommended for use throughout the Interstate System and on all major highways. Their general design, use, and color should be uniform throughout the country. Current efforts should be expedited to establish distinctive lane markings for unidirectional and bidirectional flow of traffic.

"8. It is recommended that standardized mileposts be installed on all sections of the Interstate System, and on all other highways under jurisdiction of the State, except for urban extensions of the State highway system, with numbers increasing in a northerly or easterly direction.

"9. With the large existing investment in highway signing and the need for standardization, the green background should be universally adopted for freeway and expressway direction signs, but the black-on-white combination should be retained as a standard for direction signs on other highways.

"10. Interchange sequence signs that identify the next three available exits at points roughly midway between interchanges are valuable aids to driving and should be employed more frequently where interchanges are tightly spaced.

"11. The 'THRU TRAFFIC' legend on overhead signs at multi-exit interchanges is generally less effective than destination names and/or the appropriate Interstate route number, and more widespread use of specific messages is therefore recommended.

"12. Lane drops should normally be avoided altogether by original design or later rebuilding, but where this is not practicable, fully adequate advance warning of lane-drop situations must always be provided to give drivers sufficient time to maneuver safely into the proper lanes.

"13. To serve the public and attain maximum usage of Interstate routes open to traffic, trail blazers should be installed over the best available highway to connect completed sections of Interstate routes. Gaps up to 50 miles or more in length should be signed in this way to provide continuity in route marking for users of the Interstate System.

"14. For orderly and efficient traffic operations there should be one police agency responsible for patrolling the Interstate System and other controlled access highways under State jurisdiction.

"15. As an aid to reducing accidents on heavily-traveled, high-speed multilane facilities, <u>the exclusion of trucks and buses from the left lane has proved to be helpful, and this practice should be extended wherever conditions warrant."</u>

IMPLEMENTATION OF AASHO SAFETY PROGRAMS BY IOWA HIGHWAY COMMISSION

A review of the Commission's standards indicates that all of the recommendations listed under Roadside Design and Appurtenances pertaining to design features have been incorporated into the new design standards. Those recommendations that concern the removal of hazards from existing roadways have been complied with to a lesser degree.

It is not believed within the scope of this report to recommend that the Commission should or should not step up their present program to eliminate hazards from existing roadways. It is recognized that a limited amount of funds are available for roadway construction, and it is believed that the Commission is in a better position to evaluate the many factors involved in deciding how these funds could best be spent to provide the maximum benefits to the Iowa public.

The recommendations listed under Traffic Operations pertain primarily to signing and marking procedures. Since the scope of this report does not include the review of the Commission's signing standards, it is not known whether their current standards reflect the recommendations of the AASHO Report.

IMPLEMENTATION OF AASHO SAFETY PROGRAMS BY OTHER STATES

The implementation of the AASHO Safety Program as it pertains to geometric design is shown in Table 1. There are, however, additional programs being undertaken by highway departments to improve highway safety. The following is a listing of some of these programs.

1. A special task force was set up by the highway department to comply with the AASHO Safety Program and to implement a "highway safety program second to none". The task force is headed by the State Traffic Engineer and includes as members the Attorney General, Secretary of Administration and Budget Sectetary, Secretary

of Health, Superintendent of Public Instruction, Commissioner of State Police and Secretary of Revenue.

2. A Highway Department developed a special computerized accident analysis system which has pinpointed some 250,000 accidents in the state during the past year. It is expected to play an important roll in future designs and the upgrading of existing highways.

3. One Highway Department set up the following safety program:

   A. Helicopter evacuation of accident victims in metropolitan area.

   B. Engineer-State police-physician teams to review highway accidents.

   C. New type steel median guard rail between travel lanes on expressways.

   D. Emergency phone service in metropolitan area and along eastern sections of Interstate 80.

   E. Development of 11 accident review teams across the State.

   F. Emergency patrol services by maintenance crews on holiday weekends.

   G. Supplying accident data to municipalities to recognize hazard areas and to upgrade local roads.

   H. Spot safety improvement program to eliminate high frequency accident areas.

   I. First compilation of new traffic signs and signal regulations since 1955.

4. Requires operational investigation on all major highway projects

between 6 months and 12 months after highway is open to traffic. Review teams consist of a representative from Design, Traffic, Maintenance and Construction Departments. The team reports deficient areas and corrective action is taken.

5. Established a safety review committee composed of at least one engineer from the Traffic Department and one engineer from the Design Department. The committee reviews all highway plans at an appropriate stage of development to identify elements which may constitute potential hazards and make recommendations for increased safety.

6. Made inventory of high accident locations and locations of other hazards such as guardrail ends, unprotected pylons, bridge rail and other hazards mentioned in Safety Report. Plans for correction were to be drawn up by October 1, 1967.

7. Field reviewed all completed expressways, set up and programmed projects to correct following items:

   A. Extending approach ends of guard rails and anchoring.

   B. Replacement of bridge rail that must be replaced.

   C. Removal of heavy signs from gores and replacement in accordance with present standards.

   D. Removal and/or protection of heavy signs and supports adjacent to shoulders.

   E. Protection at piers and abutments closer than 30′ to edge of pavement by use of beam guard rail.

   F. Converting existing guard rail (heavy posts) to new type guard rail (with light posts) including making W sections tension members and anchorage at far end. (This is in addition to Item 1).

G. Review sign texts and locations. If necessary, change texts, change locations, remove unnecessary signs and add signs if needed.

H. Installation of median barriers in medians less than 36′ wide. This may require some grading and drainage work depending on the geometrics of the mall. The slope to the median rail should not be steeper than 1 on 5 and should preferably be 1 on 6. This could, in addition to grading, require underdrain, raising of catch basins, etc. The catch basins located closer than 30′ - 35′ from the pavement should be such that they are <u>not</u> hazardous to a car out of control.

8. Replace existing light poles with those having a break-away base.

VI. CONCLUSIONS

The geometric design criteria and standard road plans presently being used by the Commission are in conformance with national policies, recent research findings, and the latest safety standards, with the exception of the minor points listed in Chapter II, Geometric Design Criteria.

The Design Department Manual was found to be a clear, concise engineering manual which contained the current geometric design criteria and standards being used by the Commission.

It is believed that the Commission should evaluate the following design features for possible inclusion in the Iowa design standards:

1. Increase guard rail height to 27".

2. Set standards for use of guard rail in areas of high fill or steep slopes.

3. Use 6:1 foreslopes from the shoulder line to a point 30' from normal edge of pavement to provide a more adequate recovery condition.

The geometric design criteria and standard plans reviewed in this report have been revised to conform with the recommendations of the AASHO Safety Report.

There are portions of the completed interstate roadways that require upgrading to conform with current safety standards.

The rest areas and information centers on the interstate highways are of outstanding design and would be considered one of the best tourist service facilities in the nation.

APPENDIX

Field Review of Completed Interstate Roadways In Iowa

FIELD REVIEW OF COMPLETED INTERSTATE ROADWAY IN IOWA

INTRODUCTION

This portion of the report was added in the hopes that it might be of some use to the Commission. The four-day review was conducted November 13 through November 16, 1967, with the primary purpose of affording the opportunity to view on the ground the roadways resulting from the application of the Commission's geometric design criteria both past and present. It was thought that since the trip was going to be made, it could well serve a secondary purpose of checking the completed interstate system for compliance with current safety standards.

It should be noted that since the review of signing standards and criteria was not a part of this contract, the comments regarding signing should be regarded as observations since they do not reflect the same in-depth study given the geometric design criteria.

It is generally recognized that all interstate routes completed in the early stages of the interstate program need spot improvements to conform to the present thinking in regard to highway safety. These early interstate roadways were designed in accordance with the interstate roadway standards in effect at that time. However, improving highway technology, much of which is a direct result of observing traffic on these early sections, now indicates that the design standards used were too conservative in certain areas. It is in these areas that the spot improvements are needed. To provide uniformity and to facilitate the checking procedure, an Interchange Check List, Figure A-1, was prepared and used to evaluate some 100 interchanges on Interstate Routes I-29, I-35, and I-80.

LOCATION____________________

TYPE____________ CROSS ROAD______

1. Approach
   A. Is Sight Distance to Ramps Adequate____________________
   B. Is Advance Signing Adequate____________________

2. Are There Obstructions at Ramp Noses____________________
   Guard Rail__________ Signs__________ Other________

3. Are Lengths of Speed Change Lanes Adequate____________________

4. Are There Obstructions Between Main Line and Ramps__________
   If so, Type____________________

5. Is Sight Distance at Cross Road Adequate____________________

6. Are Foreslopes too Steep__________ Can They be Improved________

7. Are Obstructions Protected by Guard Rail____________________
   A. Length of Guard Rail - Leading__________Trailing__________
   B. Are Ends Anchored____________________
   C. Distance Between Guard Rail and Obstructions__________
   Piers__________Signs__________Lights__________Other____

8. Drainage
   A. Type of Median Drain__________Hazardous__________
   B. Type of Ramp Drain__________Hazardous__________

9. Signing
   A. Are Guide Signs Placed on Cross Street Bridges__________
   B. Are There Overhead Sign Structures____________________
   C. Could Overhead Signs be Placed on Bridge____________________
   D. Could Sign Posts be Reduced in Size____________________
   E. Could Signs be Better Placed for Safety____________________
   F. Are Signs in Good Repair__________Uniform in Color__________
   Text Arrangement__________Markings__________
   G. Is There a Need for Additional__________or Fewer________Signs
   H. Are Breakaway Signs Used____________________
   I. Other Comments____________________

10. Are Flat Landings Provided at Ramp Intersections with Cross Streets

____

11. Other____________________

INTERCHANGE CHECK LIST

Figure A-1

ROADWAY REVIEW

November 13, 1967

1. I-35 from Osceola to I-80 Interchange west of Des Moines

This section was opened to traffic in November, 1958, and was one of the first interstate highways completed in Iowa. There are design features which should be upgraded to meet minimum standards. A portion of this section has 260′ acceleration lanes, compared with the present standard of 1074′. The remaining accel-lanes are 625′ long. Some of the deceleration lanes are 350′ and the remainder are 675′, as compared with the present standard of 510′. It would seem advisable that the 260′ acceleration and the 350′ deceleration lanes be lengthened in accordance with the new standards. This would be considered a Priority 2 improvement.

There are ramp exits with inadequate advance sight distance due to adverse vertical or horizontal alignment, or a combination both. One particular ramp exit from N.B. I-35 to St. Charles, was located on a horizontal curve just over the crest of a vertical curve and in a cut section. The ramp exit sign located in the gore was not visible from an approach distance of 1/2 mile, as the exit was approached the sign became visible but the ramp exit was still not visible because the steep cut slope blocked the view. This condition could be improved by applying one or all of the following corrective measures.

A. Remove exit sign and guard rail in gore and replace with a cantilevered exit sign.

B. Lay back the cut slope to make the ramp visible from a greater approach distance.

C. Provide advance signing 1/2 mile from the exit.

It is believed that the implementation of Items 1 & 2 would be the most desirable, and would also be in accordance with recommendations set forth in the AASHO Safety Report. This improvement would be given a Priority 2 rating.

The use of additional guard rail in this area should be considered. There are high fills with steep foreslopes that are not protected, the length of guard rail at signs and bridges is too short and terminal sections are not anchored.

It is recommended that the guard rail in this section be upgraded to current standards and that consideration be given to placing guard rail in areas of high fill. This would be considered Priority 1 work.

The horizontal sight distance on the ramp from I-35 S.B. to Iowa 60 east, is poor. This is a left turn movement from a diamond ramp onto Iowa 60 east which has a vertical curve cresting over I-35. The sight distance is obscured by the bridge railing and by the crest of the vertical curve. The top of an auto westbound on Iowa 60 becomes visible some 250′ from the intersection. The distance at which the vehicle is readily discernible is less than 250′. The traffic volume making this left turn is relatively high since this is the airport interchange. However, the traffic crossing the bridge from the east is low and traveling at a slow rate of speed since Iowa 60 ends at I-35 and most of the traffic is making a left turn onto the ramp leading to I-35 S.B.

It is believed that this intersection is deserving of a thorough study, under Priority 1, to determine a method of providing additional horizontal sight distance.

The I-35 pavement north of Osceola has been resurfaced with some 6″ of asphalt. When the asphalt was laid, the machine evidently was not equipped with the vibrating attachment that tapers the edges on a 4 to 1 slope; therefore, a 4″ to 6″ drop-off occurs along the edge of shoulder. This is believed to be a definite safety hazard since a car leaving the shoulder at a high rate of speed would probably lose control when the wheel encounters this drop-off.

It is recommended that these drop-offs be eliminated either by adding additional tapered asphalt or topsoil and seed. This would be considered a Priority 1 improvement.

2. I-35 from I-80 Interchange north of Des Moines to Ames

This section was completed in November, 1965 and has no significant safety hazards.

There are foreslopes that could be flattened but this would be considered Priority 3 work.

The comments on guard rail in this area are the same as those in paragraph 1A.

November 14, 1967

I-80 was traveled from Des Moines east to the Illinois state line. The various sections in this area were opened to traffic between the dates of November, 1960 and November, 1964.

This section had no major safety hazards.

There were some ramp exits that had inadequate advance sight distance. It is believed that the corrective measures outlined in paragraph 1A could also be applied in this area.

The same guard rail comments made in previous sections would also apply here.

It is believed that ramp sight distances and foreslopes could be improved by site grading within the interchanges. This would be considered a Priority 3 improvement.

November 15, 1967

1. I-80 from Interchange with I-35 west of Des Moines, west to I-29

   The middle sections of this area were opened to traffic in 1959 and 1960, and the ends were opened in 1965 and 1966.

   Generally, the same comments listed in paragraph 2 would apply in this section.

   There are sections in the western part of this area where it is recommended that guard rail be placed on high fills.

   The entrance to the Scenic Overlook just east of I-29 is not readily discernible. There is an overpass which obscures the view and the exit is paved with asphalt. It is recommended that additional advance signing be provided and that the deceleration lane be paved with concrete to the exit nose, in order to make the exit movement more prominent. This would be considered a Priority 2 improvement.

2. I-29 from Council Bluffs to U.S. 30

   This section was opened to traffic in November, 1958.

   This section has the 1958 standard acceleration and deceleration lanes, 260' and 350' long respectively, which should be upgraded to meet current standards in Priority 2 work.

   The guard rail should be upgraded to conform to the latest standards under Priority 1.

3. U.S. 30 from I-29 to Ames

   This section of primary road was two-lane roadway with the exception of nine miles of four lane divided, controlled access roadway west of Denison and 11 miles bypassing Boone.

The roadway was in good repair, well maintained, and had adequate drainage. The intersections in the controlled access portions were well designed with effective use being made of channelization.

A new section of U.S. 59 between U.S. 30 and Iowa 141 was traveled and found to be an excellent example of primary road design. This was a four-lane roadway with a 50′ median and stabilized rock shoulders. The traffic was effectively channelized at the intersection with U.S. 30. Ditch drainage was effectively handled with drop-box culverts to provide erosion control.

There are no definite recommendations for improvements in this area since it is believed that the existing U.S. 30 roadway is adequate to handle the present traffic.

November 16, 1967

1. I-35 from Interchange with I-80 east to the Interchange with I-80 west

   This section was opened to traffic in November, 1958 and November, 1959.

   The speed change lanes in the Iowa 64, Douglas Avenue, U.S. 6 and Local Road interchanges are of the 1958 design (260′ and 350′) and should be updated to current standards as a Priority 2 improvement.

   Guard rail in this section should also be upgraded to current standards under Priority 1.

   The I-35 south to I-80 west movement is a two-lane turning movement which narrows down to something close to one lane at its junction with I-80 west. This narrowing down is not apparent to the motorists until he approaches the vicinity of the nose, at which point the driver on the left must merge to the right. It is believed that striping the merging lane would be one method of warning the drivers of the transition from two lanes to one lane. This would be considered a Priority 1 improvement.

2. I-235 in Des Moines

   The various areas in this section were opened to traffic in 1961, 1963, and 1966.

   It is believed that with the lower design speed, the speed change lanes in this section are adequate.

   There is a lack of uniformity in the placement of guard rail in this section. It is recommended that guard rail be upgraded to current standards under Priority 1.

SIGNING REVIEW

The signing was also reviewed on this field trip, with the realization that the review of signing standards was not within the scope of this contract. It was thought, however, that since this review could be performed concurrently with that of the other roadway items, at no additional cost, that the general observations resulting from the field review should be included in the report. It should be noted that the present signing standards and criteria are not known and that very possibly the current standards reflect many of the observations noted on the field trip.

Sign Sequence

The general sequence of advance guide signs as practiced in Iowa is as follows:

1. A ground mounted sequence mileage sign 1 1/2 to 2 miles in advance of exit ramp.

2. A ground mounted destination guide sign 1 mile in advance (Iowa ID-4D)

3. A "Services Sign" 1/2 mile (approx.) in advance

4. A ground mounted directional sign at beginning of deceleration lane (ID-39)

5. Exit sign mounted in gore (ID-38)

Sight Distance At Exit Ramps

In the Interstate Segments built from 1958 to 1964, incl., there were locations where the ramp exit began just over the vertical crest on the main roadway and, therefore, did not have sufficient sight distance to the deceleration lane and to the ID-39 directional sign.

Following are locations of exit ramps where this problem exists:

I-35 N. B.	- St. Charles Exit	- 18 miles N. of Osceola
I-80 E.B.	- Victor Exit	- 4 miles E. of Iowa 21
I-80 E.B.	- Morengo Exit	- 3 miles W. of Iowa 149
I-80 W.B.	- Iowa 149 Exit	- 39 miles E. of Newton
I-80 W.B.	- Iowa 218	- 5 miles W. of Iowa City
I-80 W.B.	- Durant Exit	- 16 miles W. of Davenport
I-80 W.B.	- Iowa 150	- Davenport
I-80 E.B.	- Earlham Exit	- 20 miles W. of Des Moines
I-80 E.B.	- Anita Exit	- 5 miles W. of Iowa 6
I-80 W.B.	- Iowa 64 Exit	- Iowa 64

There are several methods that could be used to alleviate this problem. The first, and considered to be the most desirable, solution would be to erect a cantilevered directional sign with exit arrow (ID-39) approx. 150' to 250' in advance of the gore area and with the proper protection for the motorist as provided for in the AASHO Highway Safety Report of 1967. By erecting this overhead sign, the sight distance to the exit sign would be improved. With this type of overhead, it would then be possible to remove completely the "Exit" sign and the guard rail in the gore area, which is the area of greatest accident rate.

However, if it is thought necessary to retain the "Exit" sign in the gore, the guard rail could be removed and a breakaway-type post used with the concrete footing flush with the adjoining ground level.

The second, and less desirable, method that could be used would be to retain all signs as they are now placed and add a modified ID-40 destination sign with the bottom line reading "Keep Right" (12"). This would be a ground mounted sign 1200 to 1800 feet in advance of the beginning of the deceleration lane. This would inform the driver to be alert for the direction sign when it comes into view as he tops the crest.

In this method the "Exit" sign in the gore would be retained, but the gore area could be upgraded by using breakaway-type posts with flush concrete footings and by removing the guard rail.

Interchange Sequence And Mileage Signs

The practice of combining mileage to small towns that are a considerable distance off the Interstate - some as much as 15 to 20 miles - with other towns off the Interstate and with major destinations results in confusion.

It seems to be the general practice to place sequence mileage signs two to four miles in advance of the next interchange. Such a sign might read as follows:

Belle Plaine	22
Iowa City	44

This sign gives the impression that the Belle Plaine exit is 22 miles ahead and the Iowa City exit is 44 miles ahead. The Iowa City exit is correct; however, the Belle Plaine exit is only three miles ahead as it is located 19 miles north of the Interstate on Iowa 21.

Since this sign is located three miles in advance of the exit Interchange, the motorist within two miles will see another sign which reads as follows:

Belle Plaine
Exit 1 Mile

This results in confusion to the motorist since the previous sign had given the impression that it was 22 miles to the Belle Plaine exit.

Following are additional examples of the above:

I-35 and Iowa 92	- Indianola and Winterset
I-35 and Iowa 210	- Maxwell and Polk City
I-80 and Iowa 63	- Tama and Montezuma
I-80 and Iowa 38	- Tipton and Muscatine
I-80 and Iowa 25	- Greenfield and Guthrie Center
I-80 and Exira	- Exira

A solution to this problem might be to place a mileage sign two to four miles (where possible) in advance of an Interchange giving the mileage to the nearest major destination that is on the Interstate - in the above instance "Iowa City 44" - and the next major destination - "Davenport 95".

Most small volume local interchanges are sufficiently signed with 1 mile advance guide signs and no 2 mile advance guide sign is needed. However, after eliminating the advance mileage sign to the local towns if it is felt that it is necessary to further advance sign for them, the following sign could be added at the proper place.

21
Belle Plaine
Exit 2 Miles

The mileage sign to these local towns should be placed at or near the end of the exit ramp.

The advance mileage signs need not be placed between every Interchange but could be placed approx. every 15 to 20 miles.

Some of the Interchanges are signed for as many as three different towns exiting from the same interchange and all on state routes. This gives an excellent opportunity to sign only for the numbered state routes.

Iowa 60 instead of Madrid
Iowa 64 instead of Dallas Center
Iowa 141 instead of Perry

The motorist exists from I-35 to all of the above routes at the same interchange.

Merging Signs

Merging signs on the older sections are in general located too close to the entrance nose.

A recommended distance back of the nose would be 40 per cent of distance between crossroad (over or under) and entrance nose.

Yield Signs

Yield signs have been used on all entrance ramps. Ramps having adequate acceleration lanes (1965-66 & 67 design) do not require yield signs. The elimination of the yield sign moves merging traffic onto the main roadway faster.

Directional Arrows

Numerous directional arrows used at exit ramp are placed at 30°. It is suggested that 45° be used instead of the 30°. The 30° slant does not show enough differential from a vertical line to be readily discerned by all drivers.

Letter Size

It was noted in some areas that on Interstate advance guide signs the "Exit 1 Mile" was constructed of 8" letters and 12" numbers. This size letter is recommended for high-type expressways; however, for both rural and urban Interstate it is recommended that 10" letters and 15" numbers be used. The small text is not considered adequate for 70 mph.

Overhead Signs At Exit Gores

The use of large type butterfly type and cantilevered signs in the gores of exit ramps is now considered contrary to safe practice. Future signing and upgrading should use sign bridges (where warranted), cantilevers from ramp edge, and breakaway posts to eliminate these dangerous hazards.

CONCLUSIONS

There is a lack of uniformity concerning the use of guard rail. Until just recently, the construction plans did not include guard rail, as it was placed by maintenance crews after the project was completed. This procedure has now been revised and guard rail is now a plan item, which should provide greater uniformity. It is believed that a Priority 1 item would be the upgrading of all guard rail on the interstate system to conform to the latest standards. Consideration should also be given to the use of guard rail on high fills.

There are a number of ramps with inadequate sight distance. It is believed that where possible these conditions should be improved as Priority 2 work.

There are ramps with inadequate length of speed change lanes. It is recommended that upgrading the 1958 design (260′ acceleration and 350′ deceleration) to current standards be given a Priority 2 rating. The acceleration lanes built in 1959 to 1964 ranging in length from 625′ to 650′ should be upgraded, but on Priority 3.

There is a lack of uniformity in interchange types. Some interchanges have movements in all four quadrants, others in three, and still others have movements in only two quadrants. It is recognized that right of way considerations and traffic are major factors in setting interchange types. Regardless of these design considerations, this varying interchange shape does tend to confuse many motorists.

It is believed that this situation would be improved if the motorist was given advance information on the type of interchange ahead. One possible method of accomplishing this would be to mount a schematic diagram of the interchange on the one-mile advance sign. Since it is believed that this type of sign has not been used before, it may be advisable to consider using it on one or two selected interchanges on an experimental basis to determine its effectiveness.

The rest areas in Iowa would have to rate among the highest in the nation in appearance and in serviceability.

The information center recently opened in the rest area near Davenport should prove to be of outstanding service to the tourist. This combination of information center and rest area should provide one of the best tourist service facilities in the nation. This concept could well be used throughout the interstate system. Every effort should be made to develop advance signing to inform the tourist of the services available at this facility.

ADDENDUM

ADDITIONAL CHANNELIZED INTERSECTION DATA

During final report printing additional information was received from the State of California regarding the channelization studies discussed on page 31. This additional information contained a detailed breakdown of the accident data regarding the 13 intersections channelized by curb and/or raised bars and indicated that there was a 67 per cent reduction in total accidents in urban areas and a 57 per cent reduction in total accidents in rural areas.

Thus, in comparing curbed channelization with painted channelization in rural intersections, it was found that curbs actually permitted a 7 per cent greater reduction in accidents than paint. Such a slight difference, however, is not regarded as significant especially in view of additional study in California which indicated that paint was just as effective, if not more so, than curbs at zoned speeds of 55 mph or greater.

In urban areas the difference in accident reduction between curbed and painted channelization was far more pronounced. Curbed channelization reduced total accidents by 57 per cent while printed channelization reduced accidents by only 15 per cent – a difference of 42 per cent.