Comparison of Reviewing Superelevation on Pavement Preservation Projects from Twelve States

REPORT TRQS-01

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The Arizona Transportation Research Center (ATRC) directs the Arizona Department of Transportation (ADOT) research program. The Transportation Research Quick Study (TRQS) program is one of the ATRC research program tools. The TRQS program is designed to provide a fast, low cost response to ADOT problems or issues. TRQS project budgets are limited to $2500. This report documents the work performed for this TRQS project.

This report documents a survey of 12 states to evaluate their criteria related to correcting substandard superelevation on roadway curves. The objective is to provide guidance to the Arizona Department of Transportation in selecting roadway curves to modify using differential milling techniques. Differential milling offers a means to adjust superelevation during roadway resurfacing or maintenance projects.

EXECUTIVE SUMMARY

There are two things all the 12 states have in common, that is, they will all review the project for accident data and then take appropriate action, and they all will use deferential milling/overlay to correct superelevation. After that it starts to deviate and there appears to no consistency.

There are three states, Colorado, Idaho and New Mexico, which do not review the geometrics of the roadway, although Colorado is in the process of developing a 3R policy that will review the 13 controlling criteria.

There are three states, Nevada, Washington and Wyoming, which review only certain classification of roadways and there are seven states, which have their own 3R guides or policies.

The speed the curves are reviewed for varies from the 85^{th} percentile, design, posted and posted plus 10 mph. Eight states use only one maximum superelevation rate and two states use 12 percent as one of the maximum rates.

Of the nine states that review the geometrics, only two will not request a design exception for the substandard element, these are Nevada and Utah. These two states basically state these are pavement preservation projects and in effect, they are just maintaining the project as built.

Of the nine states, which review the geometrics, five use their own design manual and the other four use the AASTHO Green Book.

There are two states, Nevada and Oregon, which will also use method 2 to review the horizontal curves for superelevation. Washington State will only use method 2 to evaluate the superelevation on existing curves, and they may use ball-banking analysis to evaluate the curves.

Although South Dakota uses posted speed to review the geometrics, the use ball banking to review the horizontal curves.

DESIGN EXCEPTION FOR SUPERELEVATION ON PAVEMENT PRESERVATION PRJECTS (3R)

Twelve western states Department of Transportation where contacted to determine the criteria they used in evaluating the existing superelevation and the method used to correct substandard superelevation. Also which method they used in applying superelevation and if they request design exception for curve superelevation from Federal Highway Administration.

The following is a synopsis for each state contacted by telephone, e-mail and their written guides or policies:

Nevada:
Nevada classifies pavement preservation projects into 3 categories, NHS (freeways), NHS (non-freeways) and Non-NHS roadways. For NHS (freeways), the geometrics are reviewed and are improved if they are significantly non-conforming to current standards. In fact, it will require approval not to upgrade the feature that does not meet "capacity" project criteria. For NHS (non-freeways), the criteria need only conform to the era for which it was designed. In fact, it will require approval to upgrade to "capacity" project criteria. However, considerations should be given to improving geometrics that are significantly non-conforming to current standards. For non-NHS preservation projects are to be maintained as originally designed and constructed. No geometric upgrades are allowed unless there is a significant crash history and a significant benefit to cost ratio. Internally they review the superelevation and compare it to method 5 used in the Green Book. If the super does not meet method 5, they will then look to see if it meets method 2. For pavement preservation projects a design exception is not needed for retention of existing substandard features. In effect, NDOT is maintaining the project as built.
Nevada does use differential overlay to correct super, but mostly for drainage problems.

New Mexico:
New Mexico does not do a formal review for geometrics on pavement preservation projects. For reconstruction projects, the super is reviewed and a benefit- cost approach is used for reconstructing the super. As for pavement preservation projects, their approach is, since they are not changing any geometrics, there is no need to do anything. They still look the accident rate and then determine what is to be done with the super.

Colorado:
Colorado does not do a formal review the geometrics for pavement preservation project. They do an internal review, which does not get into the superelevation of the curves, but rather a detailed safety study. This study is more related to accidents and safety features of the roadway rather than the geometrics. Colorado does use differential milling/overlay when they are fixing a curve for superelevation. They are working on a 3R guide for overlays greater than 1.5 inches and they will be looking at the 13 controlling criteria.

Wyoming:
Wyoming does a formal review of the geometrics for the existing roadway and will request a design exception for the superelevation if it is a 4R project. Normally they will try to correct the super using differential milling or overlay. On 3R projects (10 year pavement design) a programmatic evaluation is acceptable when the existing design can be shown to be equal to or greater than the 3R criteria. Wyoming has its own 3R guide, one for Interstate and one for Collectors. For Interstate, the original horizontal alignment will be retained and if the original crown or superelevation has been degraded it will be restored. For collectors, if the current curve geometry is less than 15 mph to the design speed (posted speed) and the projected ADT is greater than 750 vpd, the curve should be reconstructed to current values. For arterials, they review the geometrics according to the criteria for new construction and either correct the super or request a design exception. Posted speed is used to review the curves and they use their own design manual criteria. They use only one maximum superelevation rate, and that is 8 percent. Their construction people do not care for differential overlay and their contractors do not like it because it is hard to get the density on the high side.

Utah:
Utah looks at the accident rate if they are going to improve the superelevation. For pavement preservation projects, less that 1.5 inches, if the super is not the recommended as per Green Book, they will not request a design exception if there are no accidents. For overlays greater than 1.5 inches, they do a Concept Report, which looks at the geometrics of the roadway and if the super is not to standard and no accidents, they will not change the super because it is just a pavement preservation project.

Montana:
Montana does not review the existing geometrics for simple pavement preservation projects. They will look at the accident rate and then determine if the curve needs to be fixed. For minor rehabilitation projects, structural designed overlays, they will review the 13 controlling criteria. On the Interstate they will reconstruct or use differential overlay to correct the super according to their own superelevation rate from their design manual. For non-interstate roadways, a design exception is required if the difference between design speed and existing speed is 25 km/h.

South Dakota:
South Dakota has its own 3R policy for all roadways except Interstate. For 3R projects they use ball banking to check horizontal curves. If the ball bank indicator is equal to or less than 10 degree, no adjustment is made for superelevation. If the ball bank indicator reads greater than 10 degrees at speeds below posted speed, advisory speed plates are posted. They do have a maximum degree of curve and if any of the 3R criteria is not met, they will request a design exception from the State engineer. Their maximum super rate is 6 percent. They also check the accident history on the curves and then take the appropriate action, which either to rebuild or differential overlay.

Washington:
Washington reviews pavement preservation projects for geometrics according to a matrix they developed and to standards of their design manual. They have 5 basic matrixes, 3 for the mainlines and 2 for the traffic interchanges. The mainline consist of Interstate, NHS (except Interstate) and Non-NHS routes. For Interstate mainline the horizontal alignment is evaluated and an analysis is required to determine if the design element is to be upgraded or a design exception is requested. The design exception for 3R projects does not go to FHWA, only for new or reconstruct projects. They not only look at the 13 Controlling Criteria but additional features. They also look at accident history to determine of the horizontal curve is to be upgraded to their standards. They will either reconstruct or do differential overlays. For NHS routes (Except Interstates), the horizontal alignment is designated as DE/M, which means the design element is analyzed with respect to the specified design level. In this case, the level is modified. For non-NHS routes, the curve will not be addressed, because it is beyond the scope this type of project. They use method 2 to evaluate the superelevation on existing curves and for pavement preservation projects, where the existing pavement is to remain in place; the superelevation may be evaluated with a ball banking analysis. They have three maximum superelevation rates, and these are 10, 8 and 6 percent.

California:
California has its own 3R Guide for two-lane and three-lane highways, but for multilane freeways, they are required to meet current geometric standards for new construction. For capital overlays (10 year design), the geometrics are reviewed, and if not to current standards an analysis is made to determine what should be done. If the super is not to be corrected, a design exception is requested. California uses five maximum superelevation rates, 4% and 6% for urban roads and 8,10,and 12% for rural roads. For Interstate, they use 10% or 8% for snow and ice conditions. They do use differential overlays, but they correct the super with the lower lifts.

Idaho:
Idaho does not review the geometrics for pavement preservation project, but they will review for the accident data. Their maximum superelevation rate is 8 percent.

Oregon:
Oregon reviews the geometrics and will evaluate the superelevation and then determine if to correct or obtain a design exception. They have two criteria for their 3R projects with regards to horizontal curvature and superelevation Criteria A is to improve the super if the design speed of the existing curve is less than 15 mph below the ODOT New Construction Standards. Criteria B is to evaluate reconstructing the curve if the existing speed is more than 15 mph below the running speed and the ADT is greater than 2000. They will also look at the accident data and the comfort of the ride. They do use differential overlay, but depending on the amount of correction, they will do it in stages. To check the curve, they use either the 85^{th} percentile or the design speed. And they use their own design manual. Their maximum superelevation rates vary, from 12% to 8%.

North Dakota:
North Dakota reviews the geometrics and they have their own 3R guide. They review the horizontal curves at posted speed and will use differential overlays to correct the super and depending on the amount of correction, they may correct in stages. Their maximum superelevation rate is 6 % and they will use method two for reviewing the curve with a lower percentage of the maximum allowable friction factor. If they do not fix the super, they will request a design exception.

A literature search was done by ADOT and they found five publications/references related to 3R criteria and differential overlays. (See appendix J.) The publication from Washington State comes from a response to a question for a design-build proposal, which refers to differential leveling to correct superelevation, but this was not a 3R project.

From West Virginia there where two publications; one was a Design Directive for non-NHS 3R policy which states, " Within the project limit of the "3R Project" the existing horizontal curvature and superelevation will not be determined for each curve. Reconstruction of the curve, modification of the superelevation, and/or special signing/delineation will be considered as appropriate; however, reconstruction would only be considered cost-effective at higher ADT levels." The other publication was from their Highway Geometric Design Guide and titled "3R/4R Geometric Design Guidelines and this stated where the existing superelevation is less than what is recommended for new construction for the 85^{th} percentile running speed and the superelevation rate is less than the maximum allowable (0.08 m/m), consideration should be given to increasing the superelevation rate. It then gives certain criteria to utilize whether or not superelevation adjustment is warranted.

From Utah the publication was titled "Pavement Design for new Construction" and was not related to 3R projects.

From Missouri from their Design Manual, the publication was chapter VI, Pavement Design for 3R/4R Projects, which talked about applying a leveling course to obtain desired superelevation.

RECOMMENDATION

Let us look how ADOT presently reviews horizontal curves. ADOT uses the AASHTO recommended minimum design speed, which may or may not be the actual design speed used for the project and is certainly not the posted speed. (Design speed and posted speed are normally higher.) Arizona also uses three different maximum superelevation rates, which means for the same design speed and the same degree of curve, there are three different superelevation rates, or in essence, a range of superelevation that can be used for that particular curve. Rather than determining the minimum superelevation required for the curve, (as per method 2 of distributing e and f) method 5 is used to determine the superelevation used for comfort and safety. Sometimes a nebulous result is obtained for the superelevation, not only because the AASHTO recommended minimum design speed selected by ADOT for the AASHTO evaluation can easily be much less than the posted speed, but also the superelevation obtained is not related to the posted speed.

In order to make the review more useful in determining the safety of the curve, the process for review should be changed. Rather than using the minimum design speed, the current posted speed should be used, because roadway users expect this speed to be operationally a safe speed. The minimum "e" required (based on f max allowable) should also be determined because the main concern is the safety of the curve, not necessarily the comfort of the curve. This is a review of an existing roadway (not the design of a new roadway) and rather than determining the minimum "e", the speed of the existing curve should be calculated utilizing the maximum allowable friction factor. This will not only give the relative safety of the curve, but will help prioritize the curves for corrective action. (See Example below)

Degree of Curve	**Superelevation (ft/ft)**		**Speed (mph)**	
(Deg-Min-Sec)	**Existing**	**Required (Method 5)**	**Posted**	**Existing (Method 2)**
3-25-00	0.080	0.100	70	68
1-30-00	0.034	0.054	70	80
1-30-00	0.014	0.054	70	76

As shown above, there are three horizontal curves, one sharper and two relatively flat. The one sharper curve and one flat curve require an additional 2 percent of superelevation according to the maximum superelevation rate of 10 percent. The second flat curve requires an additional 4 percent to bring the superelevation up to the required amount, and according to the present way of thinking, the second flat curve would be corrected first, because of the greater differential in superelevation. However, as can be seen by the calculated speed of the curves, the sharper curve calculates to have an existing speed of 68 mph, which means, if one traverses that curve at 70 mph, the maximum allowable friction factor would be exceeded, and one would feel very uncomfortable going around the curve. However, the calculated speed for the flat curve, which requires an additional 4 percent, is 76 mph. This means that traversing the curve at 70 mph, one would feel quite comfortable and it would not be until

one reached the speed of 76 mph, that we would start to feel uncomfortable. This is an indication that maybe the sharper curve should be fixed first, rather than the flat curve, which is off by 4 percent.

To correct the sharper curve to obtain a 70 mph speed would require the superelevation rate to be increased by 1.5 percent. This will start to bring up a constructability problem. To increase the superelevation of a 40 ft roadway 1 percent, an additional 0.4 ft of AC would be required on the high side of the road, and of course a 2 percent increase would require an additional 0.8 ft of AC, compaction of the AC and fore slopes would start to become a real problem. With this in mind, maybe there should be a limit on the amount of additional superelevation applied. Conversely, some curves may only require a minimum amount of additional superelevation, and since this would be relatively easy to construct, the improvement would be recommended. Constructability considering the impacts of traffic control will be critical. Materials and Construction personnel should determine guidelines and policies to establish these limits.

Since as-built data may not always be correct or up to date, ball-banking data should be used to supplement the review of the horizontal curves.

The following steps are suggested to revise the review process for horizontal curve superelevation:

1. Review the accident data for the project

2. Use posted speed instead of AASHTO recommended minimum design speed for review of the existing horizontal curve superelevation. A future evaluation is necessary to determine if the posted speed should be used only to review the horizontal curve superelevation or if it should be used in the review of all the pertinent AASHTO Controlling Design Criteria

3. Calculate the existing speed of the curve utilizing method 2, utilizing all of the allowable friction factor

4. Supplement the review by obtaining existing ball-banking data of the existing curves

5. Design exception are only requested for curves when the calculated existing speed is less than the posted speed

DESIGN EXCEPTION FOR SUPERELEVATION FOR PAVEMENT PRESERVATION PROJECTS

	California	Colorado	Idaho(1R)	Montana	Nevada	New Mexico	N.Dakota	S.Dakota	Utah	Washington	Wyoming	Oregon	Idaho(3R)
Accident Review	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Geometric Review	YES	NO****	NO (7)	YES	YES/NO(1)	NO	YES	YES	YES	YES/NO(12)	YES/NO	YES	YES
3R Guide/Policy	YES*	NA	1R	NO	YES	NA	YES	YES (2)	YES	NO	YES(5)	YES	YES
Design Manual	YES	NA	NA	YES	AASHTO	NA	AASHTO	YES	AASHTO	YES	AASHTO	YES(10)	YES
Review Speed	Design	NA	NA	Design	Running	NA	Posted (9)	Design**	Design	PS+***	Design(6)	85%tile	85%tile(8)
Design Exception	YES	NA	NA	YES (11)	NO	NA	YES	YES	NO(3)	YES	YES	YES	YES
Maximum Super-%	12,10 & 8	8	8,6,4	8	8 (4)	8	6	6	AASHTO	10,8,6(4)	8	12 to 8	8,6,4
Differential overlay	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

* Yes, for two-lane or three-lane roadways. New construction criteria for multilane express and freeways

** Design speed equals to current posted speed; horizontal curves for non-interstate are checked by ball-banking

*** Posted speed plus 10mph for freeways, plus 5mph other than freeways and at posted 45mph and below; use method 2 or ball-banking

**** A 3R procedure will be developed which will review the geometrics

(1) NHS (freeway) and NHS (non-freeway) will review; non-NHS no, except for safety problem

(2) 3R policy is for non-interstate only; still waiting for interstate; separate 3R criteria for NHS and non-NHS

(3) If there are no accidents, the super is left as is and no design exception is required

(4) Nevada and Washington will review the curve utilizing method 2; Washington may utilize ball banking to evaluate a curve

(5) Guides are for Interstate and Collectors; they are working on a guide for Arterials

(6) Interstate use design speed however the horizontal alignment will be retained; Arterials use posted speed; for collectors, if the existing speed is 15 mph less than the design speed and the ADT is over 750, then the curve should be reconstructed; the design speed of collectors can be the design speed may also be the 85% tile or running speed.

(7) For 1R Projects, only roadway width is maintained; no design exception; non-NHS must meet state standards

(8) For Interstate follow the Green Book; for NHS where curve safe speed is less than 85% tile super upgraded; for non-NHS 15 mph below curve safe speed may be retained, however super improvement should be considered; safe speed is obtained by ball-banking

(9) Will also review curve utilizing method 2 but use a lower percentage of maximum allowable friction factor

(10) Freeway uses AASTHO, rural and urban non-freeway use 3R Standards from their Design Manual for superelevation.
Non-freeway has 2 criteria; A-improve super if existing speed is <15mph than design; B-reconstruct if 15mph below running and ADT>2000

(11) For non-Interstate DE is required if existing speed is less than 25km/h than design speed and accident cluster
If milling is involved, then super is corrected.

(12) Interstate and NHS(except Interstate) are reviewed, non-NHS are not reviewed

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