

NV-RDT-06-008

NDOT Research Report

Experimental Study on Installing Tilted Signs to Prevent Snow Accretion on Sign Surfaces

Final Research Report

October 2006

A Report on Research Sponsored by

Nevada Department of Transportation
Carson City, Nevada

and

Federal Highway Administration



Disclaimer

This work was sponsored by the Nevada Department of Transportation. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of Nevada at the time of publication. This report does not constitute a standard, specification, or regulation.

Acknowledgements

While many people contributed to the development of this report, the authors express appreciation to them. First, there is the research technical panel that consisted of Debra Starnes (District II – Traffic) Chair, Tom Lumpkin (District II – Maintenance), Scott Thorson (Headquarters – Traffic Engineering), Maria Ardila-Coulson (T2 Center), and Reed Gibby (Headquarters – Research). Additionally, several maintenance personnel of District II assisted with the fabrication and installation of the traffic signs used in this research project. However, the authors take full responsibility for the data, analysis, opinions, findings, conclusions and recommendation expressed in this report. Others who were involved in earlier stages of this project were Richard Nelson (formally District II – District Engineer, currently Assistant Director – Operations) and Tie He (Headquarters – Research).

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NV-RDT-06-008		2. Government Accession No.	3. Recipient-s Catalog No.
4. Title and Subtitle Experimental Study on Installing Tilted Signs to Prevent Snow Accretion on Sign Surfaces-Interim Report		5. Report Date October 2006	
7. Author(s) A. Reed Gibby, Debra Starnes, Thomas Lumpkin		6. Performing Organization Code	
9. Performing Organization Name and Address Nevada Department of Transportation Research Division 1263 So. Stewart Street Carson City, NV 89712		8. Performing Organization Report No.	
		10. Work Unit No.	
12. Sponsoring Agency Name and Address Nevada Department of Transportation Research Division 1263 So. Stewart Street Carson City, NV 89712		11. Contract or Grant No. 29716000	
		13. Type or Report and Period Covered	
15. Supplementary Notes		14. Sponsoring Agency Code NDOT	
16. Abstract Snow accretion and snow cover on signs can decrease or obliterate the message of traffic signs thereby causing a variety of problems for motorist. Motorists could miss a sign message altogether or could become so distracted trying to read a partially obscured message that they neglect the proper navigation of their vehicles. A completely missed sign message could be mere inconvenience such as missing a destination or street name. In contrast, if motorists miss seeing a sign message such as "stop" or "Do Not Enter," serious and undesirable safety consequences can occur and may be, in fact, likely. From a field trip to Japan, an executive of the Nevada Department of Transportation discovered the use of tilted signs, which appeared to be effective in Japan. Consequently, this research project was initiated. The primary purpose of this research was to evaluate the effectiveness of the vertically tilted sign in reducing the snow accretion under Nevada conditions. The top of the sign faces was tilted vertically toward the motorists. The research tasks were: 1) Installation of ground-mounted signs at various vertical angles 0, 3, 6, 9, and 12 degrees for three different directions – West, South and North; 2) Field evaluations that were documented with digital photographs during eight storms for two winters; and 3) Develop guidelines for when and how to install tilted signs. The major conclusion was that the amount of snow accretion on a sign face decreases as the angle of tilt increases.			
17. Key Words Traffic Signs, Snow Accretion, Sign Tilting, Retroreflectivity		18. Distribution Statement Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. Of Pages 16	22. Price

**Experimental Study On Installing Tilted Signs To Prevent Snow
Accretion On Sign Surfaces**

TABLE OF CONTENTS

	Page
1.0 Introduction	1
1.1 Background	1
1.2 Purpose	1
1.3 Research Methodology	2
2.0 Field Installation	3
2.1 Overview	3
2.2 Location Of Field Test	3
2.3 Orientation Of Signs	4
3.0 Data Collection	6
3.1 Overview	6
3.2 Sign Face Retroreflectively	6
3.3 Photographs During Snow Storms	6
4.0 Findings, Conclusions And Recommendations	11
4.1 Major Findings	11
4.2 Major Conclusions	11
4.3 Recommendations	11
5.0 Implementation Issues	12
6.0 Appendix	14
6.1 References	14
6.2 Guidelines for the Installation of Tilted Signs	

List of Tables

Table 3-1. Retroreflectivity Readings of Sign Faces	7
---	---

List of Figures

Figure 2-1. Vicinity Map for Experimental Study on Tilted Signs	3
Figure 2-2. Location of Experimental Study on Tilted Signs	4

Figure 2-3. Illustration of Vertically Tilted Sign Installation	5
Figure 3-1. Night Time View with Vehicle Headlights On	8
Figure 3-2. Illustrates Very Little Difference in Snow Accretion and Tilt	8
Figure 3-3. Illustrates the Progression of the Snow Accretion Reduction as the Degree of Sign Tilt Increases	9
Figure 3-4. Illustrates Major Difference	10
Figure 3-5. Illustrates Inconsistent Pattern of Snow Accretion	10
Figure 3-6. In Some Storms the Message of 12° Tilted Sign Cannot Be Read	10

Experimental Study on Installing Tilted Signs to Prevent Snow Accretion on Sign Surfaces

1.0 INTRODUCTION

1.1 BACKGROUND

Snow accretion on signs can decrease or obliterate the message of traffic signs, thereby causing a variety of problems for motorists. Motorists could miss a sign message altogether or could become so distracted trying to read a partially obscured message that they neglect the proper navigation of their vehicles. A completely missed sign message could be mere inconvenience such as missing a destination or street name. In contrast, if motorists miss a sign message such as “Stop” or “Do Not Enter” serious, undesirable safety consequences can occur and, in fact, may be likely.

The mechanics of snow accretion is complex because there are a number of factors that affect snow accretion on traffic signs. These factors include wind direction and speed, snow moisture content, air temperature, sign surface temperature, and sign backing material. In general, when wind blown snow arrives perpendicular to a sign face, a stagnation zone develops near the middle of the sign face. The snow tends to form a cone as it builds up on the windward side of the sign. Theoretically, the area of the stagnation zone reduces as the wind direction angle of incidence decreases. Snow with high water content (“wet” snow) will adhere to a frozen sign surface more readily than “dry” snow. Consequently, dry snow accretion occurs when the wind speed exceeds approximately 10 mph. Another means of snow accretion is the eddy currents that develop in the wake of the air streams as they pass by the edge of signs. In this case, the snow accretion occurs on the leeward side of the sign. (Takeuchi, 1979)

Some research has been performed to develop various methods for controlling snow and ice on road signs. These methods include: 1) devising structural shapes; 2) improved treatment of sign surface; and 3) use of external energy, such as heat and vibration. However, none of these methods have been completely successful in controlling snow and ice accretion. (Kizaka, 2002)

Nevada Department of Transportation (NDOT) has a particular concern about critical sign messages such as “Wrong Way,” “Do Not Enter,” “Stop,” and signs at median barrier breaks directing motorists to the right side of the barrier. During a tour of sites in Japan, NDOT personnel observed signs that were installed and tilted forward vertically several degrees. NDOT personnel learned that those tilted signs can be effective in reducing the snow accretion on sign surfaces. Consequently, this reduction in snow accretion would reduce the likelihood of serious crashes during inclement weather conditions.

1.2 RESEARCH OBJECTIVES

As discussed above, snow accumulating on traffic signs, particularly on directional signs at the front of median barriers and “Wrong Way” signs, can cover up the messages of traffic signs and impose a risk of collisions to motorists and passengers. To reduce this risk, Japan has

installed signs that were tilted forward several degrees. Because of severe snowstorms with high wind speeds in northern Nevada, this research project was developed. The primary objectives of this research were two-fold: 1) to evaluate the effectiveness of the vertically tilted sign in reducing snow accretion and 2) if effective under Nevada conditions, to develop guidelines for installing such signs. A research technical panel was established to direct the research effort so that these objectives would be attained.

1.3 RESEARCH METHODOLOGY

Briefly, the research tasks consisted of several steps. First, the installation of ground-mounted signs at various vertical angles occurred and each sign was identified by black lettering on a white background indicating the amount of vertical tilt in degrees. The signs were installed on a state right-of-way along a frontage road adjacent to US 395 between Carson City and Reno. Although most of the signs were visible to drivers traveling on US 395, the sign messages were of no value to the drivers. Next, retroreflectivity measurements were taken in the field to determine whether the reflectance of the signs were nearly the same. Third, during and immediately after snowstorms, field observations were made and documented with digital photographs to determine the effectiveness of the vertical tilt of the signs to prevent snow accretion. Finally, based on the results of the above tasks, guidelines were developed for installing tilted signs.

2.0 FIELD INSTALLATION

2.1 OVERVIEW

The field installation consisted of two major concerns, namely, the location of the test and the directional orientation of the signs. Naturally, the primary selection criteria for the location included snowfall and wind. The main criterion for the orientation of the signs was the wind direction. The best location of the field test was determined to be Washoe Valley because of the amount of snowfall, and wind frequency, directions, and speeds. The vertical angles (tilt) of the traffic signs were selected to provide considerable variation for the field test. The top of the sign face was tilted vertically toward the motorists.

2.2 LOCATION OF FIELD TEST

Washoe Valley is located approximately twenty (20) miles south of the Reno-Sparks area and five (5) miles north of Carson City as shown in Figure 2-1. US 395 traverses the western portion of Washoe Valley that is commonly subject to significant wind action. With an elevation above 5000 feet, the valley receives considerable snowfall. Coupled with frequent strong winds, Washoe Valley is probably the best location for the field test. Additionally, the close proximity to Reno and Carson City enhances the location. The major wind directions include: 1) from the south, 2) from the north, and 3) from the west. Wind speeds are frequently in excess of 50 mph. At the southern end of the valley, there is a frontage road along the east side of US 395 for approximately ½ mile north of the US 395 Interchange with East Lake Boulevard (SR 428). It is on this frontage road where the tilted signs were installed approximately ¼ mile north of East Lake Boulevard. Figure 2-2 provides the general location of the field test.

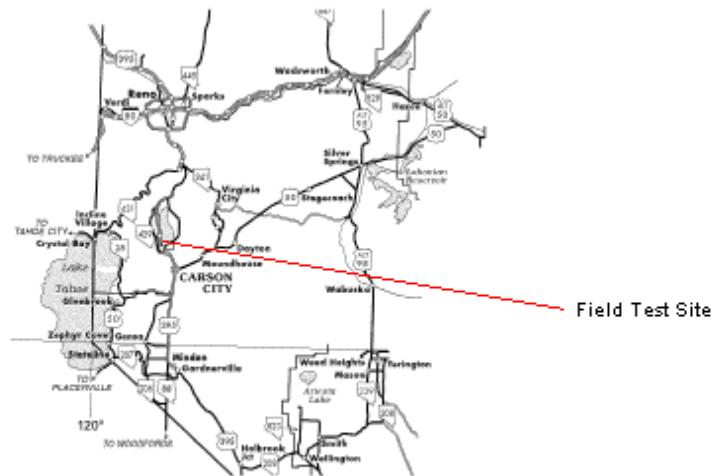


Figure 2-1. Vicinity Map for Experimental Study on Tilted Signs

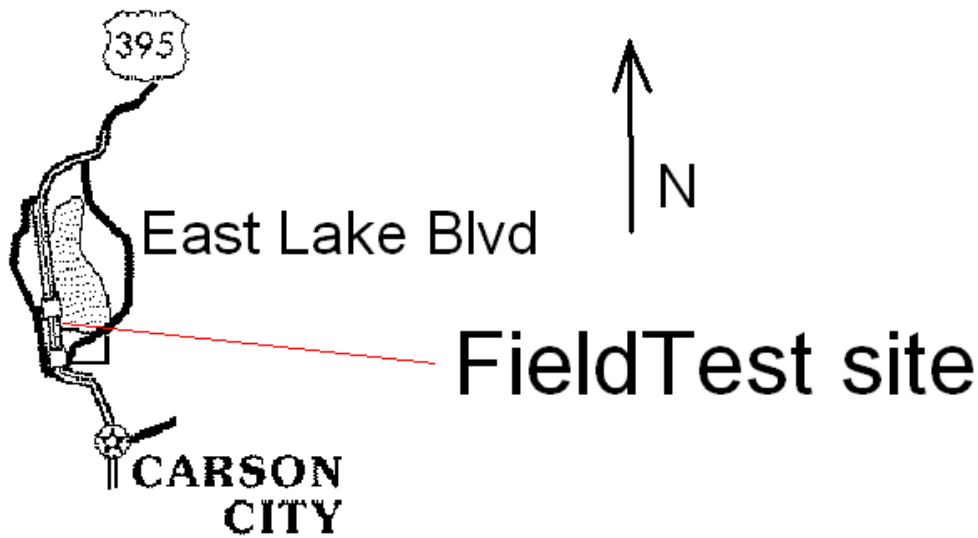


Figure 2-2. Location of Experimental Study on Tilted Signs

2.3 ORIENTATION OF SIGNS

In Washoe Valley there are major winter storms from generally three directions: South, West and North; consequently, three sets of signs were installed facing each of these directions. Each of the three sets consisted of five signs that were 36"x48" in width and height with black letters on a white background. The sign messages contained the direction the sign faced and the degrees of vertical tilt. Each of the five sign sets was vertically tilted at 0, 3, 6, 9 or 12 degrees. For example, the sign message "WEST 6" was on the sign facing West with a vertical tilt of 6°. The signs in each group were installed randomly in the following order:

3° facing North,
9° facing West,
6° facing South,
12° facing North,
0° facing North,
9° facing South,
3° facing West,
6° facing North,
12° facing South,
0° facing South,
3° facing South,
12° facing West,
0° facing West,
6° facing West, and
9° facing North.

The signs were placed with adequate spacing so that there would not be any interference with regards to snow accretion among the signs. The top of the sign face was tilted vertically away from the signpost.

Figure 2-3 illustrated one the signs showing the sign face and a side view. Of particular note is the side view illustrating the mounting bracket at the top of the sign, which District II Maintenance personnel needed to fabricate in order to provide a rigid sign mounting system. There was some concern about the structural stability of the signs with the larger angles of tilt. In response to a request the Bridge Division provided a qualitative review and was not concerned with the structural stability. The fabrication process became more difficult as the angle of tilt increased, especially for the angles of 9 and 12-degrees. However, smaller signs would not be as difficult.



Figure 2-3. Illustration of Vertically Tilted Sign Installation

3.0 DATA COLLECTION

3.1 OVERVIEW

The data collection effort consisted of two primary types of information. The first type was the ability of sign faces to reflect the light from headlights at night, which was measured by the retroreflectivity level of the signs. This data included actual field measurements with a retroreflectometer. The second type of data was photographs of the signs taken during or immediately after storms that were examined to discover whether apparent differences occurred as a result of the angle of tilt of the signs.

3.2 SIGN FACE RETROREFLECTIVELY

Since the research is concerned with the ability of a motorist to see the sign messages and most of the wintertime 24-hour day includes darkness, the retroreflectivity of the sign face was a significant feature. The major concern was that the apparent brightness might affect the apparent snow accretion. Consequently, it was desirable for the retroreflectivity of each sign to be the same, or nearly the same as the other signs within each set. Therefore, on January 24, 2005, retroreflectivity readings were taken on the surface of the signs with a portable Retro Sign Retroreflectometer, which was placed in contact with the sign surface. The retroreflectivity measurement unit is candelas per lux per square meter (cd/lx/m^2).

The results of the measurements are contained in Table 3-1. The most extreme variation within the three sets occurs within the WEST set of signs. The “WEST 0” sign was 43 cd/lx/m^2 eighteen percent (18%) below the average for the WEST set. The average of the other West signs is 253 cd/lx/m^2 , so the ‘dimmer’ “WEST 0” sign reading is 54 cd/lx/m^2 twenty-two (22%) below the others. However, it would be difficult for the human eye (motorists) to detect any difference in brightness between “WEST 0” and the other signs. Consequently, all of the signs would appear to have the same brightness regardless of the angle of tilt. The retroreflectivity measurement did not reveal a pattern sequence of brightness from zero to twelve-degree tilts, but rather the pattern appeared to be random.

There was another concern that differences in the observed brightness of the signs with different angles of tilt may affect the perceived snow accretion during nighttime storms. Signs that seemed brighter may appear to have less snow accretion than seemingly dimmer signs when, in fact, they had more snow accretion. To explore this concern the nighttime retroreflectivity issue including the effect of the tilt, one set of signs (the South set) was relocated to the northern end of the east side frontage road in June of 2005. This location was approximately $\frac{1}{4}$ mile to the north of the initial installations and the signs were placed side by side for each comparison. The South sign set was the best choice because the retroreflectivity readings had the least variation among the five signs; consequently, any perceived differences in brightness would result from the angle of tilt. Three research technical panel members visited this set of signs and could not detect any difference in the apparent brightness among the five signs. A digital photograph is included, Figure 3-1, that illustrates the lack of apparent differences. Clearly, the tilt angle did not affect the apparent brightness of the sign faces.

3.3 PHOTOGRAPHS DURING SNOW STORMS

Weather dependant field studies involved a considerable risk. During the winter of 2003-2004 data for only three storms was able to be collected; consequently, the fieldwork continued for another winter so that more data could be collected. The winter of 2004-2005 enabled data to be collected from five additional storms involving considerably more snow. Of course, there were other storms that occurred during the two winters, but for various reasons data was not able to be collected. One example was the limited manpower on a holiday weekend when a large snowstorm passed through the area and made it impractical to have someone travel to the site and take pictures.

Table 3-1. Retroreflectivity Readings of Sign Faces

<u>Sign Identification</u>	<u>Retroreflectivity of Two Readings</u>		
	<u>Right Side</u>	<u>Left Side</u>	<u>Average</u>
North 0	259	288	273.5
North 3	259	283	271.0
North 6	268	259	263.5
North 9	233	237	235.0
North 12	275	282	278.5
Mean			263.4
South 0	265	289	277.0
South 3	272	289	280.5
South 6	267	292	279.5
South 9	268	290	279.0
South 12	268	292	280.0
Mean			279.2
West 0	186	212	199.0
West 3	235	265	250.0
West 6	249	261	255.0
West 9	258	266	262.0
West 12	227	260	243.5
Mean			241.9

Note: the units are in candelas per lux per square meter (cd/lx/m²)

During two winters, 2003-04 and 2004-05, the fieldwork resulted in an accumulation of digital photographs from the eight storms listed below:

1. January 2004
2. February 26, 2004
3. March 2, 2004
4. December 29 and 30, 2004
5. December 31, 2004
6. January 7, 2005
7. January 11, 2005
8. March 20, 2005

Digital photographs were obtained for each of the eight storms and typical photographs are shown herein. Figure 3-2 provides an example of the situation where there is very little difference in the snow accretion as a function of tilt. However, most of the photographs revealed a clear pattern and the set of photographs in Figure 3-3 is representative of the majority of the photographs. The reader should note the date of the storms when the photographs were taken is shown immediately after the figure title. Figure 3-4 illustrated that during a heavy storm, part of the sign message of a conventional sign, 0° tilt, cannot be read, while the sign with the 12° tilt can be read. Figure 3-5 shows that the snow accretion on some signs developed inconsistent patterns.

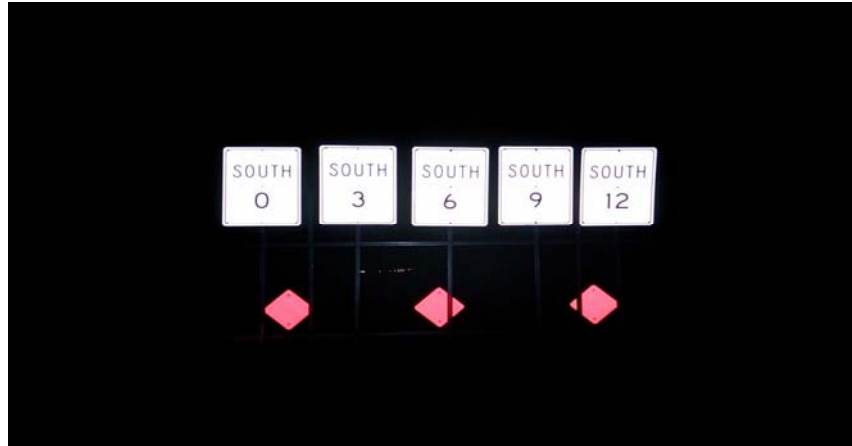


Figure 3-1. Nighttime View with Vehicle Headlights On

Note: The red diamonds indicate the end of frontage road



Figure 3-2. Illustrates Very Little Difference in Snow Accretion and Tilt
(Storm date 12-29 & 30-2004)

Although the trend was that the sign face with 12° angle of tilt accumulates the least amount of snow, Figure 3-6 illustrates that even the message of these sign could not always be read. However, the pattern was clear, there was generally less snow accretion as the angle of tilt increased.

With the unusually heavy snowfall during the winter of 2004-2005 there were occasions when the accumulation of snow of the backside of the signs were substantial, especially for the sign with a 12° tilt.



(Storm Date January 2004)

Figure 3-3. Illustrates the Snow Accretion as Function of Sign Tilt
(Storm date 2-26-2004)



Figure 3-4. Illustrates Major Difference
(Storm date 12-29 & 30-2004)



Figure 3-5. Illustrates Inconsistent Pattern of Snow Accretion
(Storm date 1-11-2005)



Figure 3-6. In Some Storms Even the Message of 12° Tilted Sign Cannot Be Intirely Read
(Storm date 3-20-2005)

4.0 FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

4.1 MAJOR FINDINGS

From an examination of the photographs, a clear pattern was observed. The degree of snow accretion decreased as the angle of tilt increased from 0° to 12°. However, there were examples when there was little or no advantage in tilting the signs depending on wind direction or heavy snow fall.

The maximum snow accretion occurred with a temperature range of 28 to 31°F that is characteristic of wet snow. This finding is consistent with the literature; which indicated that, wet snow has a greater accumulation than dry snow. Lower temperatures would produce drier snow and, therefore, less snow accretion.

While the signs with the largest angle of tilt produced the least snow, there is concern for the structure stability of the signs with the larger tilts. Additionally, there was difficulty with the fabrication of the top mounting brackets for the signs with the larger tilts. For practical reasons, a tilt of 6° appears to be the most reasonable for larger signs.

4.2 MAJOR CONCLUSIONS

There were three major conclusions developed from this research project. The first conclusion, being consistent with the literature (Takeuchi, 1979), was that the most snow accretion occurred with temperature ranging between 28 and 31°F. The second conclusion was that the signs with largest tilt (12°) had the least snow accretion although there were some observations that were exceptions. The final conclusion was that because of some concerns about the fabrication process and stability of the tilted signs, there might be practical limitation. The desirable tilt, from a safety standpoint, should be 12° while the minimum tilt should be 6°.

4.3 RECOMMENDATIONS

The major recommendation of this research is to approve guidelines for the application of tilted signs as described in the Implementation Issues section.

5.0 IMPLEMENTATION ISSUES

The major items regarding the implementation issues include the description of guidelines that address several questions:

- What signs are to be tilted?
- Who will make the decision?
- Where are tilted signs to be installed?
- When are tilted signs to be installed?
- How are tilted sign to be installed?

These various questions have been studied and discussed. Specific input was requested from the Districts, especially Districts II and III where most of the snow accretion problems occur. The major result of the deliberations is the development of the guidelines shown below. If the Department uses a substantial number of tilted signs it may be more economical to have the tilting brackets manufactured.

The “Guidelines For The Installation Of Tilted Signs” is contained in Appendix 6.2.

6.0 APPENDICES

APPENDIX 6.1

REFERENCES

1. Takeuchi, M. Snow Accretion on Traffic Control Sign Boards and Its Prevention. *Snow Removal and Ice Control Research*, Special Report 185, Transportation Research Board, Washington, D.C., 1979.
2. Kizaka, k., Imazu, R. and Tomabechi, T. Fundamental Study on the Control of Snow Accretion and Snow Cover on Road Related Facilities. *New Challenges for Winter Road Service*. XIth International Winter Road Conference. World Road Association-PIARC, La Defense Cedex, France, 2002.

APPENDIX 6.2

GUIDELINES FOR THE INSTALLATION OF TILTED SIGNS

GUIDELINES FOR THE INSTALLATION OF TILTED SIGNS

The purpose of these guidelines is to provide suggestions to the districts regarding the installation and use of tilted signs.

1. Type of Signs to be Tilted

Generally, regulatory signs are good candidates for tilting, especially those that have a propensity to directly affect safety – Stop, Wrong Way, and Do Not Enter. There may be situations where warning signs, which directly affect safety, should be tilted. Normally, destination signing will not affect safety, but will create inconvenience if motorists cannot read the messages.

2. Decision Process for Installing Tilted Signs

The District Engineer or designee, based on recommendations from the District Traffic Engineering and District Maintenance personnel, will make decisions regarding the installation of tilted signs.

3. Locations for Tilted Sign

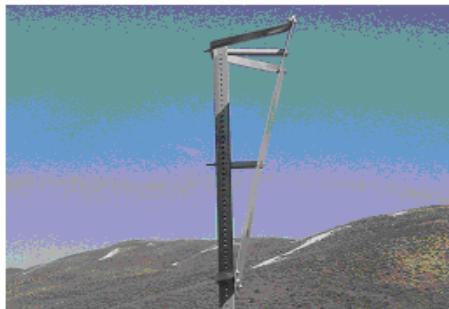
Tilted signs are to be installed based on several factors: a) History of significant blowing snow. b) Reports of snow covered signs by maintenance personnel or public. c) Obstruction of a sign's message creates a clear risk to drivers. and d) Reports of accidents when motorists cannot see sign messages.

4. Tilt Angle

The desirable angle of tilt is 12 degrees and the minimum is 6 degrees depending on the size of the sign.

5. Fabrication of Signs

The tilt is to be at the top of the sign and angled toward the driver. For a 6-degree vertical tilt, a 1.25" offset for 12" of height is needed. For a 12-degree vertical tilt, a 2.5" offset for 12" of height is needed. Metal bracing, made of typical z-bar available in NDOT sign shops, is to be used to tilt the signs. The photograph below illustrates how the tilt is provided. If the Department uses a substantial number of tilted signs it may be more economical to have the tilting brackets manufactured. Also, in some instances it may be possible to slant the sign post rather than use brackets.





Kenny C. Guinn, Governor

Nevada Department of Transportation
Jeff Fontaine, P.E. Director
Tie He, Research Division Chief
(775) 888-7220
the@dot.state.nv.us
1263 South Stewart Street
Carson City, Nevada 89712