TWO-RAIL STEEL-BACKED TIMBER GUARDRAIL SYSTEM

Crown Point Highway
Multnomah County, Oregon

Final Report

OREGON EXPERIMENTAL FEATURE PROJECT #OR92-03

by

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16. Abstract

In 1920, to provide for the safety of drivers on the Columbia River Highway, two-rail timber guardrail were installed. Subsequently, the two-rail timber guardrail were replaced by more modern guardrail. Recently, the Historic Columbia River Highway Advisory Committee requested that the Oregon Department of Transportation (ODOT) install the old style two-rail guardrail on the Historic Columbia River Highway (HCRH). To satisfy the current crash testing standards, ODOT staff modified the guardrail by reinforcing the rails with galvanized steel. The two-rail steel-backed timber guardrail was successfully crash tested and installed on the HCRH.

In March 1992, the guardrail was installed using Douglas-fir for the posts and rails and galvanized steel as backing for the rails. The guardrail was installed with few delays, although it was more time consuming than standard guardrail installation. The cost to install the two-rail steel-backed timber guardrail was $134.50/meter ($41.00/foot), which is about 3-½ times more costly than the typical Type 2A guardrail. The wood was pressure treated with ammoniacal copper zinc arsenate (ACZA), which leached out, discoloring the paint and corroding the galvanized steel.

ODOT Research Unit staff evaluated the two-rail steel-backed timber guardrail for two years as part of an Experimental Features research project. Recommendations from this research include: 1) pressure wash, seal and repaint the existing guardrail, 2) continue the evaluation of the guardrail by maintenance staff, 3) identify a funding source for routine maintenance, 4) revise the ODOT specifications for drying guardrail posts and rails, and 5) for future projects, the sealant and paint should be specified in the Special Provisions.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

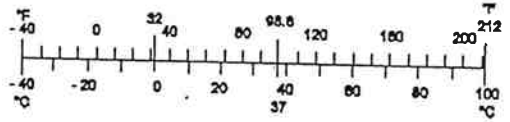
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

(4-7-94 jbp)

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DISCLAIMER

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1.0 INTRODUCTION

In 1920, to provide for the safety of drivers on the Columbia River Highway, two-rail timber guardrail were installed. Subsequently, the two-rail timber guardrail were replaced by more modern guardrail. Recently, the Historic Columbia River Highway Advisory Committee requested that the Oregon Department of Transportation (ODOT) install the old style two-rail timber guardrail on the Historic Columbia River Highway (HCRH). To satisfy the current crash testing standards, ODOT staff modified the guardrail with steel. The two-rail steel-backed timber guardrail was successfully crash tested by the Texas Transportation Institute (TTI) (*1*) and approved for use on federally funded projects by the Federal Highway Administration (FHWA). The crash tests were in accordance with the National Cooperative Highway Research Program (NCHRP) Report 230 (*2*). The two-rail steel-backed timber guardrail provides an alternative to the standard guardrail used in Oregon.

ODOT Research Unit staff evaluated the two-rail steel-backed timber guardrail for two years as part of an Experimental Features research project. The results of this research are contained in this report including the construction process, maintenance guidelines, maintenance and construction costs, performance, conclusions, and recommendations for the guardrail.

2.0 LOCATION

This project is located on the Historic Columbia River Highway (State Highway 100), formerly known as the Crown Point Highway (State Highway 125), between mile posts 8.03 and 9.22 in Multnomah County, approximately 16 km (10 miles) east of Troutdale, Oregon (see Figures 2.1 and 2.2). This area is characterized by wet, mild winters and warm summers. The coolest month is December with an average temperature of 3°C (37.4°F) and the warmest month is August, average temperature 21.5°C (70.7°F). The annual precipitation is 997.0 mm (39.25 in.).

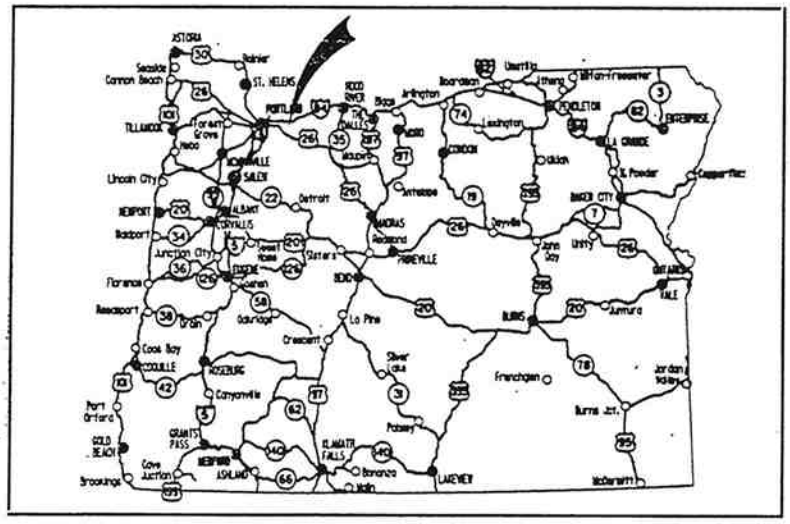

Figure 2.1: Project Location

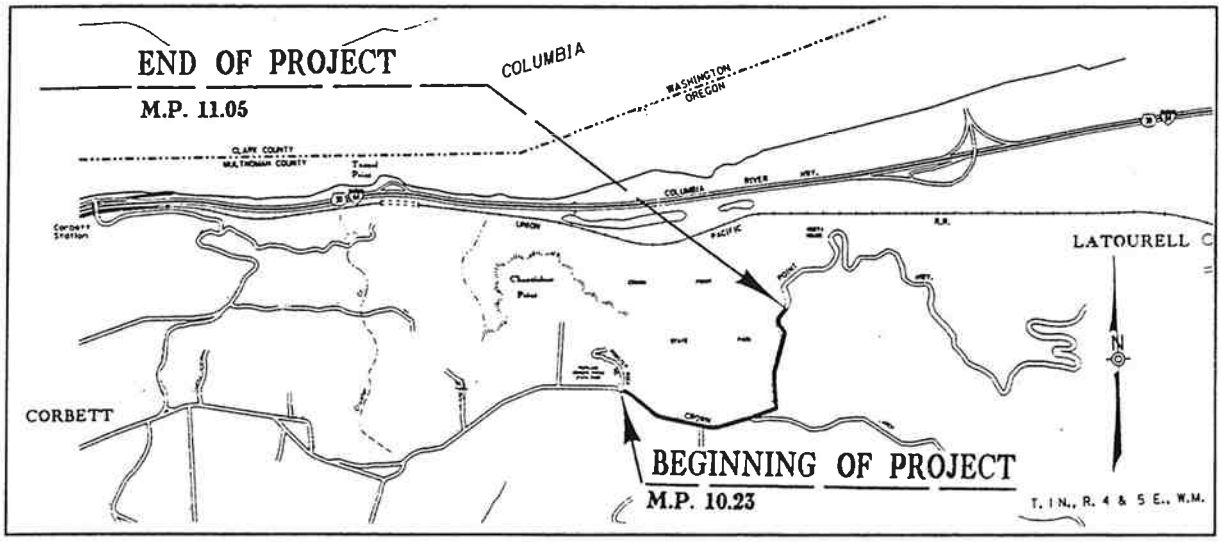

Figure 2.2: Location of Project Site

3.0 DESIGN AND CONSTRUCTION

3.1 DESIGN

The guardrail was designed to closely approximate the timber guardrail that was installed on the Historic Columbia River Highway in the 1920s. This design differs from the conventional guardrail design not only in materials, but in post size and spacing as well. The posts are larger than the typical 150 mm × 200 mm (nominal) [6" × 8" (nominal)] posts and the plans called for the guardrail posts to be spaced at 2.4-meter (8-foot) intervals on center for the majority of the project. Terminal points required different spacings depending on circumstances. The posts were placed with 0.84 meter (2'-9") exposed to allow the rails to be fastened.

The Douglas-fir rails were reinforced with 10 mm (⅜") thick galvanized steel backing. The steel backing was fastened to the wood rail with a series of lag screws along the center section. The end sections of the steel backing were fastened to the wood rail and steel splice plates with carriage bolts.

The plans called for the rails to be fastened to the posts by passing a bolt through the steel splice plate and post. The plate washer would be placed between the nut of the bolt and the wooden post. The rails would be placed at heights of 260 mm (10-¼") and 610 mm (24") along the length of the guardrail system.

3.2 MATERIALS

The materials for the two-rail steel-backed timber guardrail can be separated into four categories: rails, posts, hardware, and structural coating.

The materials used for the rails consisted of both wood and galvanized steel. The wood railing was a Douglas-fir 100 mm × 200 mm (nominal) [4" × 8" (nominal)] select structural plank. This was treated with ammoniacal copper zinc arsenate (ACZA) to a retention of 6.5 kg/m^3 (0.40 lbs/ft^3), used to protect the wood from decay by organisms and insects. The timber rail was backed with a 10 mm × 180 mm (⅜" × 7") galvanized steel plate that ran the length of the Douglas-fir (*3*).

The posts were also fabricated from ACZA pressure treated Douglas fir, but were 200 mm × 250 mm (nominal) [8" × 10" (nominal)] in cross-section. Two different lengths of posts were used in the project. When the back slope was relatively flat, a 2.0 m (6'-6") post was used. If the back slope was steep, a 2.4 m (8'-0") post was used to give additional resistance (*3*).

The purpose of the hardware was to fasten the steel backing to the railing and the railing to the posts. The hardware was galvanized steel and included the following: 1) splice plates, used to fasten two rails together, 2) carriage bolts with hex nut and washer, used to connect the rail to the steel backing and splice plate, 3) bolt with hex nut and plate washer, used to connect the splice plate to the posts, and 4) bolt with hex nut and plate washer, used to connect the rail and backing to the posts where no splice was present.

The steel-backed timber rails and posts were painted with Acrilite Latex 7000 (Miller Paint), a 3:1 by weight mixture of white lead and zinc oxide in raw linseed oil and turpentine drier. This was pre-approved and found to be compatible with the preservative used.

3.3 TESTING

The unique design of this guardrail necessitated crash testing to ensure that the guardrail could perform satisfactorily. The Texas Transportation Institute (TTI) performed the analysis and testing on the steel-backed timber guardrail through a combined program of computer simulation and full-scale crash testing. The computer analysis identified the limits of performance, which were more than adequate, and resulted in a reduction of the thickness of the steel back-up plates, from 13 mm to 10 mm (½" to ⅜ ") for both rails. This produced a savings of approximately $16.73/meter ($5.10/foot) of guardrail (*1*). Splice connections were also modified to accommodate the 10 mm (⅜") plates.

The heights of the rails were examined prior to crash testing. It was determined that the current spacing between rails would allow bumpers of large cars to wedge between the rails and snag on the guardrail posts. Therefore, the upper rail was lowered 80 mm (3") to allow the front bumper to engage the rail. The lower rail height remained unchanged.

These minor modifications were implemented and the design was further evaluated with a series of full-scale crash tests, conducted in accordance with the procedures outlined in the NCHRP Report 230 (*2*). TTI found the steel-backed timber guardrail to be in compliance with the recommended impact performance criteria for multiple service level 2 (MSL2) impacts and recommended it for field implementation (*1*).

3.4 CONSTRUCTION

Dirt and Aggregate Interchange, Inc. began removing the old guardrail along the HCRH from the Portland Women's Forum State Park to approximately 0.5 km (0.3 mi) west of the Vista House, Crown Point, on March 3, 1992. The contractor then proceeded with the installation of the two-rail steel-backed timber guardrail. Construction was monitored by Robert Heard (Project Manager) and inspected by Raydel Killgore, both from the ODOT construction office in Troutdale.

The installation of the guardrail was completed on March 12, 1992 with few delays. The contractor was able to adapt available equipment to drive the larger guardrail posts, rather

than having to auger holes for the posts and fill them in, as was reported in *Two-Rail Steel-Backed Timber Guardrail System, Construction Report* (*3*). This expedited the project and reduced costs for the contractor.

The posts and railings for the guardrail were treated with ACZA and air dried for a period of 30 days prior to use, but did not appear dry upon arrival to the project site. The contractor applied a prime coat of paint to the wood prior to installation. After the guardrail was installed, a second coat of paint was applied, covering the posts, rails and hardware.

Construction Problems and Solutions (*3*):

Problem: The contractor used an auger to drill a hole between two sections of a masonry wall to install a guardrail post. The masonry wall separated near the hole and the end piece started to fall down the hill.
Solution: The contractor wrapped a chain around the fallen section to hold it in place. While it was secured, a mason placed concrete underneath it to act as a footing.

Problem: The ACZA was leaching out of the Douglas-fir causing the posts and rails to turn a blue-green color.
Solution: To cover the discoloration, a second coat of paint was applied to the entire guardrail system, and a third coat was applied to approximately 610 m (2000') of the guardrail. This did not solve the problem; the guardrail is still discolored.

4.0 EVALUATION

4.1 COSTS

The two-rail steel-backed timber guardrail cost $134.50/meter ($41.00/foot) over 886 m (2906 feet), for a total bid price of $119,146. If a Type 2A guardrail had been installed, the cost would have been approximately $36.09/meter ($11.00/foot), for a total of nearly $32,000. Therefore, the timber guardrail was more than 3-½ times the cost of the traditional guardrail (*3*).

The inflated cost can be attributed to the additional labor anticipated to install the guardrail. With the two-rail steel-backed timber guardrail requiring larger posts than the Type 2A guardrail, the contractor originally thought that holes would need to be augered for the posts and filled in. However, the contractor was able to modify the equipment used to drive typical guardrail posts to accommodate the larger post size.

The labor and materials used to attach the rails and steel backing to the posts contributed to the higher cost of the guardrail. The steel-backing was attached to each rail with eleven lag screws; then attached to the splice plate with three bolts, washers and nuts at each end; and finally attached to the posts with a bolt, plate washer and nut. This was a time consuming process which contributed to the high cost of the guardrail (*3*).

4.2 INSTALLATION

Although more time was required to install the two-rail steel-backed timber guardrail, there were few complications. It appears to be well designed and went together nicely. A future project includes the installation of 8534 meters (28,000 feet) of the two-rail steel-backed timber guardrail along the Historic Columbia River Highway.

4.3 SITE VISITS

The site was first visited by ODOT Research Unit staff on August 11, 1992, five months after installation was complete. In addition to the discoloration that occurred from the preservative leaching out, there were problems with hardware corrosion and peeling paint (*3*).

A second site visit was conducted on April 22, 1994, approximately two years after installation. There appeared to be minimal change in the discoloration of the guardrail and the corrosion of the hardware since the 1992 site visit, indicating that the leaching of the preservative has ceased. This is supported by photographs taken during the second inspection.

the guardrail. One section of the guardrail consists of 58 guardrail posts, of which 37 (64%) had visible signs of the galvanized steel corroding (*3*). This was a good representative section of the guardrail. The corrosion was caused by the leaching preservative, whereby the ammonia carrier of the preservative attacked the zinc galvanizing of the steel hardware.

Figure 4.1: Corroded Hardware in Contact with ACZA, 1992

Figure 4.2: Corroded Hardware in Contact with ACZA, 1994

Although corrosion has occurred, it is minor and at this time will not affect the satisfactory performance of the guardrail.

Figures 4.3 and 4.4 show the end grain section of a guardrail post. The photo shows the prominent discoloration and the flaking and peeling of the paint, which occurred on the tops of the posts, where the preservative did the majority of leaching.

The peeling paint noted on the first site visit was much worse upon the second site visit. As noted above, the worst damage is at the tops of the posts, but the rails are now being affected as well. Figure 4.5 shows peeling on a typical section of rail. The peeling paint may have been initiated by the leaching preservative. However, this behavior is typical of the weathering process of painted wood.

There have been no accidents reported involving the timber guardrail, but it was apparent that two vehicles had struck the guardrail. Bumper marks were visible on a section of guardrail at M.P. 8.82. The wood was slightly frayed and one bolt was misaligned on the top rail which had a slight bend in it near the post. The bottom rail appeared unharmed. No significant damage was apparent. A second vehicle struck the guardrail at M.P. 8.85 and the only damage was a bent bolt on the top rail. Chipped paint around other bolts suggests that the rail flexed against the force of the vehicle but returned to its original position.

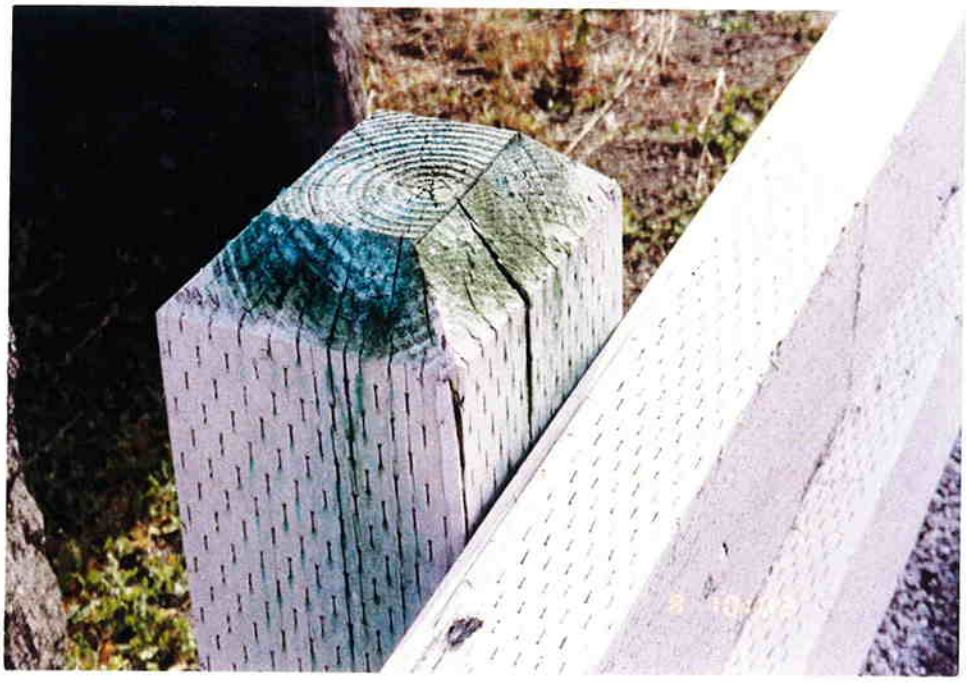

Figure 4.3: Typical Post Showing Discoloration and Peeling, 1992

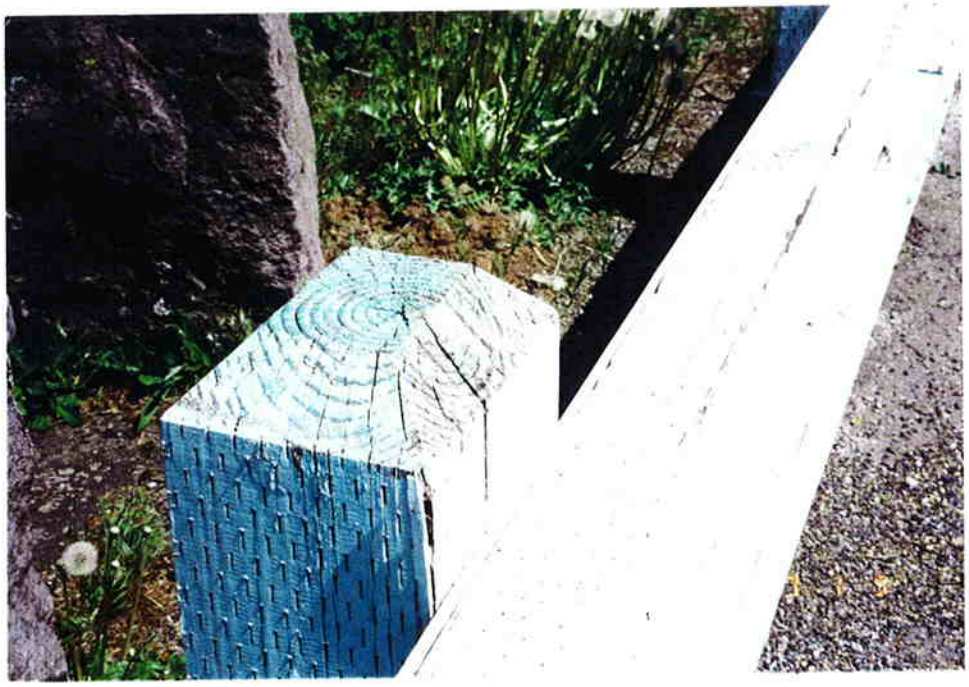

Figure 4.4: Typical Post Showing Discoloration and Peeling, 1994

Figure 4.5: Peeling Paint on Typical Section Two Years After Installation

5.0 MAINTENANCE

Since the installation of the two-rail steel-backed timber guardrail in 1992, no maintenance of the guardrail has been necessary. However, the guardrail will eventually need to be repainted.

A routine maintenance schedule should be adopted for the two-rail steel-backed timber guardrail. The guardrail shall be repainted as necessary to maintain the standards of the Historic Columbia River Highway. The guardrail paint must be compatible with the wood preservative and shall be specified for each project in the Special Provisions.

Prior to repainting the guardrail, the guardrail should be pressure washed to remove chipped or flaking paint and residue. Spot sanding may also be necessary at some locations. A sealant primer should be applied to the guardrail to reduce the risk of further bleeding and need for repainting. The sealant should be compatible with the wood preservative and the paint and be approved by the ODOT Structural Coating Quality Coordinator.

A latex paint comparable to the original Acrilite Latex 7000 paint should be used to repaint the guardrail. The estimated cost of this process, including sealant and paint, will initially be $11.50/linear meter ($3.50/linear foot) of guardrail. The cost will decrease to $10.50/linear meter ($3.20/linear foot) after the first maintenance painting since the sealant only needs to be applied once. This maintenance process will need to be repeated approximately every five years.

Should damage occur to the two-rail steel-backed timber guardrail, it should be treated as any other guardrail and repaired as soon as possible to provide safety to the travelling public.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

1) The two-rail steel-backed timber guardrail has been approved by the FHWA and is therefore suitable for future placement along the Historic Columbia River Highway, or other areas of interest.

2) The installation of the two-rail steel-backed timber guardrail is more time consuming and costly than the standard Type 2A guardrail due to the labor involved in assembly and the materials used.

3) The intent to restore the Historic Columbia River Highway to its 1920s style was not entirely met. The wood preservative, ACZA, leached out, causing discoloration and peeling of the paint and corrosion of the guardrail hardware. This was due to the nature of the preservative which tends to turn a blue-green color if the wood is not completely dried after preservation treatment.

4) The performance of the two-rail steel-backed timber guardrail over two years is acceptable. However, only minor impacts to the guardrail have occurred.

6.2 RECOMMENDATIONS

1) When possible, guardrail posts should be mechanically driven into the ground rather than augering and filling holes.

2) The existing guardrail should be pressure washed, coated with a sealant and repainted with a latex water-based paint. The sealant and paint shall be specified for each project in the Special Provisions.

3) Evaluation of the guardrail by maintenance staff should continue in order to monitor its performance. If any problems occur with the two-rail steel-backed timber guardrail, ODOT Maintenance staff should contact ODOT Research Unit staff to investigate the problems.

4) A funding source for routine maintenance of the two-rail steel-backed timber guardrail should be identified.

5) A second paragraph should be added to Section 02190.20 in the ODOT Standard Specifications for Highway Construction: "Where the finished product is to be painted, the wood should be kiln dried for a minimum of 2 days (3 to 4 preferably) using a drying

schedule appropriate for that species. Where kiln drying is not possible, the wood should be stored in a stickered state so that the wood moisture content in the outer inch falls below 25% as measured using a resistance type moisture meter. Wherever possible, the wood should be subjected to a post-treatment aqua fixation period prior to removal from the treatment cylinder to reduce surface deposits" (4). The aqua fixation will help drive the ammonia out of the wood and will leave the surface smooth for better adhesion with the paint.

6) For future projects, the sealant and paint shall be specified for each project in the Special Provisions.