MAINTAINING CHARACTER, IMPROVING SAFETY – OREGON’S STEALTH RAIL PROGRAM

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ABSTRACT

For more than a decade, Oregon has been utilizing a concept called “stealth” rail for replacements of bridge guardrails on historic, high profile bridges. Stealth rail refers to a bridge rail where a steel skeleton is used in conjunction with a skin of concrete, timber or masonry to maintain the original appearance of the bridge. Use of this rail can be an innovative way to avoid adverse effects on historic structures that would require costly mitigation. Doing so, though, requires a number of design exceptions, is limited to lower speed locations, and is quite expensive. This paper examines these issues and makes the case for encouraging the continued use of stealth rail.
INTRODUCTION

A common conflict on historic bridge preservation projects arises from the significance of the now obsolete aesthetic bridge railing to the appearance of the original structure. Suited to a slower moving public, these railings are under-designed for modern impact loads and often too low for pedestrian safety standards. “Stealth” Rail is a concept pioneered by the Oregon Department of Transportation (ODOT) to address this conflict by replacing the substandard historic railings with similar modern designs that achieve the required strength through the use of disguised structural steel. Whether skinned with timber, stone, or concrete, the resulting railings replicate the original appearance of the bridge while improving public safety.

WHAT IS STEALTH RAIL?

As used at ODOT, stealth rail refers to any decorative bridge railing designed to meet modern codes using a disguised steel skeleton. One example is shown in Figure 1. These rails replicate the appearance of a historic design, though a similar process could be used for modern designs. The concrete examples generally use precast balusters with the concrete cast around structural steel sections. For timber railings, the timber members are generally backed with heavy steel plate and the traditional timber posts are replaced with steel sections. These posts are then disguised either with paint or through the use of a timber veneer. A planned stone masonry version will use the precast concrete concept, but with a stone veneer. Railings utilizing these principles have been designed by ODOT engineers and by consulting engineers for both state and local agency projects across Oregon.

FIGURE 1 Stealth Rail on Myrtle Creek Bridge.
These stealth rails are different from the more common decorative pedestrian railings that are used in low impact areas or in combination with a separate traffic barrier. Typically, pedestrian railings are made of standard reinforced concrete without a substantial internal steel skeleton. Their usage is limited to low speed areas and local roads. An example is shown in Figure 2. In addition, a limited number of hybrid type railings exist where lightly reinforced decorative concrete railing is fronted by a steel tube railing to transfer impact loads to the main posts. This hybrid rail is distinct from the common two tube rail retrofit in that the posts are rebuilt with heavier reinforcing. An example of this railing is shown in Figure 3.
WHY USE STEALTH RAIL?

There are a number of reasons that lead to the replacement of bridge railing on an existing bridge. One primary reason initiating rail replacement is corrosion, either of the rail or the bridge. In Oregon, stealth rail use is often linked with impressed current cathodic protection projects which are undertaken when chloride content reaches critical levels throughout the bridge. On these bridges, the original railings are also contaminated with chlorides and require replacement. An example of a chloride damaged railing is shown in Figure 4. In addition to chloride corrosion, alkali-silica reaction has also led to the replacement of damaged railing on a few bridges.
FIGURE 4 Chloride Damaged Rail Baluster on Myers Creek Bridge.

Use of stealth rail is also common when widening a bridge deck. In such cases, the original rail is removed in preparation for the wider deck. Stealth rail can be especially useful in an asymmetrical widening where the original railing is left on one side of the roadway. The choice to use stealth rail on a symmetrical widening is often driven by both historic preservation laws and public demands for a decorative railing, making stealth rail the clear choice.

In addition to major rehabilitation projects, bridge railing is regularly replaced along major routes for being substandard according to modern codes. Substandard can refer to a number of issues; one primary problem is crash-worthiness. ODOT’s Bridge Design and Drafting Manual specifies the use of railings meeting a minimum of Crash Test Level 4 on all state routes. A design exception is required for any project that will not bring the rail up to this standard (1). While rare, some crashes have occurred that justify such a stringent requirement (Figure 5).
When a rail is not strong enough to take the impact from traffic, options are often limited. Retrofit is usually attempted before any replacement is considered which typically involves adding a new rail in front of the existing. The new rail may be a modified standard Type-F barrier or a standard steel rail, as shown in Figure 6. There are a number of limitations with these additive retrofits. Firstly, the new railing is placed on the traffic side of the existing rail, which narrows the roadway or sidewalk, which is often unacceptable. Additionally, the strength of the new rail is dependent on the strength and integrity of the older rail or curb to which it is attached, limiting the maximum possible capacity.
FIGURE 6 Rail Retrofit using steel tube rail.

Any sort of retrofit to the existing rail also faces possible challenges from the State Historic Preservation Office. On historic bridges, the rail is commonly the most distinctive feature visible to the public. Adding anything between traffic and this rail is generally considered to be an adverse effect on the historic character of the structure, requiring mitigation that can drastically increase the cost of the project. In these cases, where the rail is understrength on a historic bridge, often the only option to avoid an adverse effect is to add a stealth rail.

Even when strength is not a concern, historic rails can be problematic due to their low height. One of the most commonly used railing designs in Oregon between 1920 and 1936 was “Standard Handrail A” with a top rail height of 38 inches (Figure 7). Other standard bridge rails used before the 1960’s were of similar height or even lower. Modern code, including the AASHTO LRFD Bridge Design Specifications, Article 13.8, now requires a minimum 42-inch high railing in pedestrian locations (2). To meet this requirement, stealth rail designs alter the original elevation in a couple of minor ways.
One alteration is to the height of the curb and top rail cap. On the typical early rail design, Figure 8, the curb is 6 inches high and the cap is 7 inches. When used with a sidewalk, the Oregon Bridge Design and Drafting Manual allows the curb to be a maximum of eight inches high (1), so the new design can gain an additional 2 inches from the curb. The cap can be scaled up similarly, though it must remain similar in appearance to the original. Any additional height required to reach the pedestrian height are usually gained by scaling up balusters. Scaling up the rail also allows additional space for the steel skeleton.

In pedestrian locations, it is also necessary to maintain small enough openings to satisfy AASHTO Article 13.8.1, which specifies that all openings between rail elements shall be small enough that a 6 in diameter sphere may not pass through (2). Closing these openings can be done in a number of different ways, including adding stainless steel loops, running cables along the back of the rail, or thickening the baluster elements to reduce the opening size. The chosen method is generally driven by whichever detail SHPO believes will be least obtrusive. These features are not generally considered to add to the strength of the rail under impact.
PRESERVATION LAWS – CHARACTER DEFINING FEATURE

Generally, much of the detail of the stealth rail is driven by the requirements of historic preservation. All federally funded projects on bridges that are considered eligible for the National Register of Historic Places must comply with both Section 106 of the National Historic Preservation Act of 1966 and with Section 4(f) of the Department of Transportation Act. These acts together ensure that no federal funding can be provided for a project without first determining if it has any effect on any eligible resources, including bridges. If an effect is identified, and it is determined to be adverse to the historic character of the structure, the project may only proceed following an assessment of alternatives. Following that, the action that produces the adverse effect may only be completed if no prudent and feasible alternative exists. In Oregon, state law (3) requires that all state funded projects undergo similar assessment before approval.

On most such projects, the State Historic Preservation Office, which is a branch of the State Parks and Recreation Department in Oregon, provides the authorization. Often this involves making compromises to achieve an acceptable final design. For the purpose of rail replacement, it can be fairly certain that the Oregon SHPO will not approve the project unless a significant effort is made to reduce the visual difference of the new rail from the original. On past projects, approval has been granted for a number of different stealth rail designs with the new rail being considered a non-adverse effect on the historic character of the bridge.

In order to achieve such a ruling, the new design has to meet the Secretary of Interior’s Standards for the Treatment of Historic Properties. The relevant standard is that for
rehabilitation, which requires that “where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials.” (4) In addition, the new rail must be clearly differentiated from the older material, while remaining compatible.

If the new rail cannot meet the requirements, mitigating actions must be taken. Depending on the project, these can range from simply recording the existing structure and adding interpretive displays, to relocation and rehabilitation of the removed sections, to the construction and maintenance of a local museum. As mitigation needs are hard to predict, it is often best to avoid situations that require it.

CONCERNS WITH STEALTH RAIL

While stealth rail is often the only option from a historic preservation perspective, there are often difficulties getting it approved for use. Most of these issues must be resolved through the use of design exceptions from the state standards. The primary difficulty is that the stealth rail is not currently crash tested. AASHTO LRFD C13.4 permits non-crash tested rails in low speed areas where the speed limit is 45 miles per hour or lower, but the Oregon design standards are stricter on this point (1,2). In order to get an exception from this requirement, the bridge must be in a low speed zone, and have no history of significant vehicular crashes. Percentage of truck traffic may also factor into the decision. Crash testing has been considered in the past, but has been considered to be cost prohibitive as most historic bridges have easily met the requirements for the exception.

The timber rail has even more stringent requirements, being used only for roadways with speeds lower than 25 miles per hour and with a very low truck presence. This is related to both the limitations for strengthening a timber rail and to the spacing of supports. Most common on covered bridges or in scenic areas, these restrictions on speed and vehicle size are not generally prohibitive.

An additional issue is related to the lack of a smooth surface next to traffic. The balusters that are an important part of the appearance of the concrete rail are considered snag hazards, and could be dangerous in a vehicle impact. Commonly, this is not a concern at low speed, but it may require alterations to the curb height or shape to reduce snag potential.

On many of our older bridges with sidewalks, the curb between the roadway and the sidewalk is high relative to that required by modern code. When working on the rail without altering the sidewalk height, a design exception is required for this curb. The risk is that a high centered vehicle may be able to launch from a high curb and impact the rail near the top where it is more vulnerable. As with the other challenges, this is not generally an issue at low speed, and the curvature and narrowness of the roadway also tend to prevent vehicles from hitting the curb and rail head on.

Aside from these design exceptions, the new rail designs also have to accommodate deficiencies in the strength of the existing bridge. Due to the steel skeleton and increased height, the new rail is heavier than the original, and often the overhang was understrength to begin with. As modern railing designs must take into account the wheel load of the impacting vehicle, the
critical section is generally in the overhang, rather than the new rail. To prevent failure, the 
overhang must be strengthened. Often this can be achieved through the method of anchoring the 
rail, though some cases may require near surface mounted FRP or titanium to reinforce the 
negative moment capacity of the overhang. Though expensive, this strengthening would be 
required for any rail replacement on these bridges, so should not be a consideration in calculating 
the relative cost of stealth rail.

The most critical drawback to using stealth rail is the cost. With eleven cases of concrete 
stealth rail use, prices have varied from just under $300 per linear foot to nearly $1000 per linear 
foot. It is believed that the variation and some of the high cost is due to the limited number of 
projects that use it. In addition, only one supplier currently provides precast rails of a quality 
meeting the specifications, which also drives up the cost. If more such rails were used across the 
country, both of these issues would soon be resolved and the price would come more in line with 
other precast rails. Despite the high cost of the stealth rails, once the SHPO determines that such 
a design is necessary for the maintenance of the historic character of the bridge, cost cannot be 
used to choose a different design. This is due to the Section 4(f) process, which stipulates that 
the alternative that results in the least harm to the resource must be selected (5).

EXAMPLE PROJECTS
Since the first stealth rail design in 2001, Oregon has constructed ten precast concrete stealth rail 
projects reflecting seven different railing designs. The steel backed timber rail design has been 
used much more extensively as guardrail, but also appears on at least ten bridges. In addition, 
five more stealth rail replacements have been scheduled for the next four years. This includes 
the first masonry skinned stealth rail which will be constructed in 2016 along US 101.

One of the earliest concrete stealth rail designs was constructed as part of a deck 
widening of the Old Winchester Arch Bridge over the North Umpqua River on the old Pacific 
Highway. The bridge, shown in Figure 9, was originally constructed in 1923 under Conde B. 
McCullough, Oregon’s great bridge designer. In its original design, future widening was 
anticipated, greatly simplifying the modern project completed in 2008. As was common for 
McCullough during the early part of his career, the bridge has a gothic theme, which is mainly 
expressed in the shape of the rail balusters and the spandrel walls. During the widening, this 
theme had to be maintained due to the historic nature of the bridge.
**FIGURE 9** Old Winchester Bridge after widening.

Originally consisting of two 9’-8” lanes, the deck was widened to accommodate two 12-ft lanes and a three foot sidewalk on each side. In addition to adding a stealth rail, existing decorative posts and bump outs were recreated on the widened deck. Due to the size of the gothic arched openings in the rail, stainless steel hoops were inserted in the openings, as shown in Figure 10. These hoops were bent to match the pointed shape of the arch. The rail is attached to the sidewalk using epoxy anchors from a precast curb into the deck which resulted in one of the biggest lesson learned on this project. Due to shrinkage and temperature effects, the holes around the epoxy anchors have begun to crack resulting in minor damage to the new rails, though they are not considered to be a structural problem. To address this issue, current projects include a cast-in-place curb that simplifies the attachment detail.
FIGURE 10  Detail view of Winchester Bridge Stealth Rail.

One of the most recent stealth rails to be completed, incorporating the lessons of Winchester, is the Conde B. McCullough Memorial Bridge over Coos Bay in North Bend on US 101, shown in Figure 11. The large steel cantilever span is framed by nearly a mile of concrete approach spans consisting of both deck arch spans and deck girders. It is on these approach spans that the rail was replaced with a stealth rail design over a couple of years ending around 2012 while the south end of the bridge was being given cathodic protection.
As at Winchester, the Coos Bay Bridge features a generally Gothic design, though with a different railing design with narrower openings. Due to the narrowness of these openings, the stealth rail design was able to stay under the 6” maximum opening size by slightly thickening the balusters, shown in Figure 12. While approved originally, SHPO has since changed their opinion on this design and now prefers the use of stainless steel hoops on future projects. Due to the coastal location, all exposed steel on this bridge had to be stainless. This will greatly extend the lifespan of the rail to match the newly extended life of the cathodically protected spans.
In addition to these large scale projects with precast concrete stealth rails, a large number of timber stealth rail designs have been constructed. Given the speed restrictions on where it can be used, the steel-backed timber is most common on smaller bridges, especially the covered bridges. On these bridges, where the historic value is clear, it is extremely important to maintain the appearance of the original rail. One recent project to use this design was the rehabilitation of the Neal Lane Covered Bridge over South Myrtle Creek in Douglas County, shown in Figure 13.

The rail design, shown in Figure 14, looks very similar to the original rail when seen from the roadway, but is strengthened through the use of galvanized steel plates on the back. While left unpainted in this case, these plates can also be painted to match the rail if visibility is an issue. Unlike the concrete railings, the use of galvanized rather than stainless steel does not reduce the lifespan of the rail which is controlled by the timber.

FIGURE 13  Front and back of steel-backed timber rail on Neal Lane Covered Bridge.
CONCLUSIONS AND FUTURE WORK

As shown by these examples, the different varieties of stealth rail can be used on a wide range of projects. While cost has thus far limited its use to historic or scenic locations, the concept can easily be adapted for use on new bridges where appearance is important. Despite the number of successful uses, the use of stealth rail is still regularly challenged. These challenges come both from the roadway designers, who are concerned about safety, from the project planners, who are concerned about cost, and from SHPO, who wish to preserve the original appearance of the bridge and avoid even minor changes to the design. To address these differing opinions, it is important for the railing designer to keep all parties informed from the beginning of design.

Despite these challenges to the use of stealth rail, the concept still serves an important purpose for historic bridge rehabilitation. As evidenced by the number of upcoming projects, the concept continues to advance, incorporating new materials and designs. And the innovation will need to continue as work must be completed on bridges with even lighter railings or larger openings, such as that along the Historic Columbia River Highway, shown in Figure 15.

Overall, stealth rail has proven itself to be a useful tool for historic preservation projects in Oregon. Whether or not it manages to replicate exactly the feel of the original rail, the result is a beautiful product that enhances the safety of the travelling public. It is hoped that in the future the concept can be spread beyond the state, both to encourage the preservation of historic bridges, and to increase the capacity for the production of the rails.
FIGURE 15 Example of railing type requiring further innovation to develop replacement.
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