DEVELOPMENT OF THE NORTH EAST PRECAST CONCRETE RAIL

George W. Colgrove III, Project Engineer, VTrans Structures Section

Vermont Agency of Transportation (VTrans)
PDD, Structures Section
Drawer33 National Life Building
Montpelier, VT 05633

ABSTRACT
This paper presents research work currently underway in the north eastern states regarding aesthetic bridge railing. Due to increasing public interest in bridge projects, regional Transportation Agencies have needed to increase costs relating to aesthetic treatments on or around bridges. One such treatment has been the use of aesthetic bridge railing – specifically decorative concrete parapets. The Agencies have resisted this, due to the high cost of custom cast-in-place parapets. Resistance to precast rail has been due to the same reason and due to the lack of reliability of the connection to the deck. The public, in turn have been resistant to the "F" shape rail, cast in place or precast. The solution presented in the paper addresses these concerns by expanding on the popular decorative rail treatment developed by the Texas department of Transportation. The proposed precast concrete rail address the connection concerns by using stainless steel anchor bolts, a deck pedestal and a rubber pad seal. Aesthetic concerns are addressed using a modular form concept allowing variability in the rail's appearance. With acceptance, the rail cost should decrease as states and municipalities adopt the rail as a standard.

Keywords: Bridge, Parapet, Railing, Precast concrete, Self compacting concrete, Self consolidating concrete, Aesthetics, Decorative rail,

DEVELOPMENT OF THE NORTH EAST PRECAST CONCRETE RAIL

INTRODUCTION

In recent years, increasing numbers of New England residents have been actively participating in local and state highway and bridge projects. Residents have made appeals to transportation agencies to consider aesthetic treatments on such projects with varying desires, such as building gateways into their township or city; making monuments regarding the importance of their town or city; increasing the aesthetic appeal of a streetscape or simply to preserve the historic nature of a district. One treatment of growing concern is bridge guard rail. The current standard bridge railing alternatives usually meet with criticism on their streamlined blandness, or uninteresting look. A typical complaint is that the bridge is indistinguishable from the roadway. Such distain has forced transportation agencies to look into alternative bridge railing.

The aesthetic treatment of the bridge railing has become a public issue regardless of whether the project is related to maintenance, rehabilitation, reconstruction or on new construction. A large portion of bridges in the north eastern states that have been or will be rehabilitated or replaced have concrete parapets. Replacing the concrete parapets with standard steel or aluminum rail has become increasingly difficult and near impossible in places throughout the region. This problem grows when there is a desire to preserve a community's character. Bridge designers at the same time desire to keep cost down and the construction time to a minimum. These opposing points of view – whether the bridge will be an expensive signature gateway structure or a cost-effective utilitarian streamline bridge – have made the bridge design process increasingly difficult.

To meet the requirements for aesthetic treatments on the bridge, designers have had to seek out alternatives for bridge rail. The choices, however are limited. With requirements to use crash tested rail being enforced, the designer can only select a rail type from previously approved railings. With concrete as the chosen material, the only widely available choice is the standard “F” type (New Jersey) Barrier. Since local resistance would likely be high, the designer may be required to specify a costly and time-consuming cast-in-place rail option such as the Texas 411 parapet. The Texas 411 rail is crash tested for slow speeds.

Cast-in-place rail carries high costs and takes a large amount of time to construct. The primary reason for this is the custom nature cast-in-place rail has. Forms have to be built; setup; torn down and setup again, until the entire rail is constructed. In addition to cost and time constraints, the difficulties in constructing concrete parapets invite quality problems. These problems do not exist with precast rail, however, available crash tested systems are unattractive. The largest problem with any concrete rail is that it is expensive and difficult to repair. Concrete, though a favorite of the public has too many issues that make it undesirable from a bridge designer’s opinion.

On the other side of the material divide, steel solutions have been offered with varying degrees of success. Current rail designs have been modified slightly to aid in needed aesthetic enhancements. Such modifications include painting the steel; using weathering steel in low salt use applications and it has been augmented by decorative add-ons among others. Each of these solutions however do have impacts on the base rail and may compromise the rails crash performance or place additional cost burdens to the project. They may also present possible maintenance issues in the future. Aluminum will not escape these concerns either, and in addition, aluminum costs more than steel. With either material, making the rail more decorative will mean increase of cost and complexity.

With these difficulties, the need to develop a new affordable concrete rail system is growing. The solution will be a one of incorporating all the positive aspects of the current rail systems while avoiding the negative. Therefore, the solution will need to have low cost; be quick and easy to install; have a standard customizable design and be simple to maintain and repair. The final product needs to provide a concrete barrier that has the aesthetic appeal of the cast-in-place parapet like the Texas 411 rail, while at the same time provide the cost effective features of the standard “F” type precast concrete rail. Developing a precast concrete parapet standard will offer New England the ability to meet public demand as well as meeting economical, time and safety constraints that face each bridge replacement project.

NORTH EAST PRECAST CONCRETE RAIL

This paper is intended to introduce the North East Precast Concrete Rail (NEPCR) system. The work herein started by the Vermont Agency of Transportation (VTrans) in 2001 as an answer to the high cost of decorative cast in place rail. It quickly became clear that a single state rail standard would offer no true cost benefit for VTrans. There were no guarantees that the form for the rail would get used enough to pay for it. VTrans felt it would be beneficial to include input from other states with hopes to develop a more regional standard. In 2002 the concept was taken to the North East PCI Bridge Technical committee (PCI-NE). It was taken on as part of a bigger project currently under development with rapid bridge construction. Since, a comprehensive rail system has been developed that is now ready for testing. The NEPCR, as a result of this work, will prove to be a viable alternative for decorative bridge guardrail.

HISTORY

In the late 1920s Vermont was hit with severe weather that resulted with the collapse of a large number of bridges. This event forced the state to construct several truss bridges, cast-in-place concrete slab bridges and steel rolled beam bridges all with construction dates between 1927 and 1928. A large portion of the concrete and rolled beam bridges featured a concrete parapet. Since the event, concrete rail has been used in various forms throughout the state during the following decades. Though the use of concrete parapets faded in the 1960's, and practically eliminated in the 1970's as an alternative, the total number of bridges in the state with concrete rail became significant.

Since the 1960's, design engineers have been choosing more streamlined bridge treatments. Though earlier in this transition, a bridge was still distinguishable from the roadway, later, the bridge became somewhat transparent. This has produced a growing need among local residents and interest groups to preserve the historical nature of the infrastructure. Preservation of the roadway alignment and streetscapes have become as important as preserving buildings and other landmarks. Since many of Vermont's older bridges have concrete rail, the need to replace the concrete rail in kind has increased, to meet historical preservation requirements. To date, the most popular rail replacement system used in the state has been the Texas Type T411. This rail has also been considered throughout the nation as well.

In January, 1992, T.J. Hirsch and C.E. Both from Texas A&M University, presented at the 71st Annual Meeting of the Transportation Research Board in Washington D.C. a paper titled "Aesthetically Pleasing Combination Pedestrian-Traffic Bridge Rail." This was the nation wide introduction of the Texas type T411 rail. The paper described the rail system and reported the results of two crash tests completed on the rail. The conclusion was that the rail was adequate for the current TL-2 performance level as defined in the AASHTO LRFD Bridge Specifications.

Though, desirable, the cost of this rail or other similar rail alternatives are high. The costs of cast-in-place concrete rail can be as high as nearly three times the cost of steel rail. This cost differential has limited the choice of decorative rail to steel or aluminum alternatives. With the desire to preserve the historical nature of an area, replacement in kind is increasing the pressure to use an aesthetic concrete rail system. The increasing use of concrete rail has forced transportation agencies to make the rail more economical. One way of achieving this is using precast techniques.

Precasting concrete rail is not a new concept. Precast concrete rail or parapets essentially started in a large scale in the 1970's. The F-Type rail system or also referred to as the "Jersey Barrier" started at the General Motors testing grounds and has evolved to the shape we see on most highways we travel on. The shape is used in almost every construction project in the nation and has a strong presence in our permanent highway infrastructure. It is used in both cast in place and precast applications. Though the section has been successful in the last few decades due to its structural and safety advantages, it has two major setbacks.

First the connection to the deck or ground has suffered from corrosion, causing catastrophic failures such as one in Pennsylvania. A bridge with prefabricated concrete rails was a site of a fatal accident. A truck collided with the rail. The connection reinforcing had suffered extensive corrosion to near complete section loss. With no resistance, a large section of the rail slid off the bridge and fell below in oncoming traffic. The corrosion occurred because the grout used was substandard. It allowed water saturated with deicing salts to reach the reinforcing.

The Second setback of the rail is that it lacks in aesthetic appeal. Though efficient for high speed highways, the rail section offers little in inspiration and does little to enhance the look of a bridge from the perspective of the traveling public. The parapet however, has been enhanced from the fascia side with success.

To make a precast rail viable, the setbacks of the f-shape rail will need to be addressed. The solution to making a successful precast rail system would need to include blending the structural and safety features of the F-Type Rail with the aesthetic appeal of the Texas T411 rail in a cost effective approach. In addition, modifying the means of connecting the rail to the deck would be required as well.

SURVEY

In January of 2003, the Vermont Agency of Transportation (VTrans) sent out a survey to all the states to inquire about the development of a decorative precast rail. Though about half of the states responded, there were only 2 respondents that had developed decorative precast railing standards. Pennsylvania's rail failed in a crash due to the connection therefore it was shelved, and Virginia's rail is still in development. Of the states that have not developed a standard five states are interesting in doing so in the near future. This included the states of Connecticut, New Hampshire, Oregon, Tennessee and Vermont. The driving reason to develop the rail standard is due to aesthetics. Other reasons were quality, uniformity, speed and ease of construction, and costs.

Regarding details of the railing, since there were only two states that have specifications for decorative precast rail at various stages of development, it was difficult to get any conclusions for developing standards.

Several states offered comments that were valuable in defining how the rail should perform. The comments showed that there was interest in this work. Of the states that have used a non-standard precast railing, they were used mostly as a pedestrian rail behind a crash tested rail. As stated earlier, Pennsylvania had a failure in their connection to the deck. Moisture and chlorides seeped up into the grout and corroded the bolts. Irregularities in the deck caused by construction, cross slope and superelevation make installing the rail difficult. There was a need in communities to have a unique rail.

PERFORMANCE REQUIREMENTS OF THE RAIL

A list of desired requirements can be derived from the historic problems facing precast concrete rail and from what was learned from the survey. The New England Precast Concrete Rail will be required to meet the following list of criteria to be viable:

1. The rail must be cost effective
2. Must provide aesthetic appeal similar to the Texas 411 rail
3. The connection detail needs to be looked at closely to prevent corrosion
4. The rail must be able to conform to irregular surfaces

Additional requirements determined by the PCI-NE were:

1. Needs to be quick and easy to install
2. Needs to be easily customized
3. The rail must be quick to cast at a precast plant
4. The rail must comply with safety requirements for speeds up to 50mph

In choosing the test level criteria, the AASHTO LRFD section 13.7.2 offers some guidance. Of the several test levels, test level TL-3 provided a closer fit to the criteria listed above. TL-1 is used for low speed local streets. TL-2 is used for most local and collector roads with speeds less than 45mph. These roads tend to see a small number of heavy trucks. TL-3 allows for higher speeds, up to 60mph, and is generally acceptable for arterial highways with low numbers of heavy vehicles. With TL-4 essentially required for Freeways or Expressways, and TL-2 limited to 45mph, TL-3 fits the needs defined above.

SHAPE STUDY

Rather than start from scratch, we decided to superimpose the Texas T411 rail over the F-type. In this case we used the Texas T503 rail. This defined the location of the anchor bolt and the width of the base. Using the AASHTO criteria defined below, we needed to widen the rail by three inches to satisfy the setback distance requirements. This also required us to reduce the thickness of the posts by 2". The fascia side remained similar to the Texas T411, however, the traffic side has been modified with an overextended rail and a curb.

Both rail sections has been crash tested and approved for a TL2 for the T411 rail and TL-3 for the T503 rail. Since the desire is to allow for higher speeds, the reinforcing for the 503 rail was used as a starting point. The post need to be set back to reduce the snagging points of the openings. The primary reason why the rail failed at higher speeds was the deceleration rate of the colliding automobile. The openings in the 411 rail section caused several snagging points for the crash vehicle.

Appendix A13 in the 1998 LRFD (2003) code assists with the development of the geometric shape of the rail system. The code addresses contact surface of the rail ("A"), the maximum opening from the lower rail to curb ("Cb"), the maximum opening between posts, and the setback of the posts to the front face of the rail ("S").

The contact area of the rail ("A") should not be less than 25% of rail height. The Texas rail has a height of 32" which is greater than the minimum height of 27" required by section 13.7.3.2 of the LRFD specification. With this height, the area of the face of rail should be a minimum of 8 inch-squared per inch length of rail. According to figure A13.1.1-1 in the LRFD AASHTO code, this area includes all vertical surfaces facing traffic (curb and rail face). The Texas 411 Rail has two faces of 5½" each (11"). This passes the requirement.
The vertical clear opening shall meet the requirements of Figure [A13.1.1-2] (see Figure 4). The balustrades of the Texas 411 rail will be considered as posts. The Texas 411 rail has a vertical opening "C" of 18". Figure 4 shows that the vertical opening is limited to 15". This opening allows for a post setback of a minimum of about 5½". Looking at the Figure 3, this is the distance between the rail face and the point where a perpendicular face to traffic is located.

To meet the requirements of the LRFD figure A13.1.1-2 the rail and curb need to be enlarged to compensate. The difference was distributed evenly. The new rail contact surface became 14" per inch length. This number can now be used with LRFD figure [A13.1.1-3] to compare the setback to the ratio of "A" to the height of rail. This ratio is 14"/32 = .4375. This places the rail in the middles of the shaded area of the acceptable range.

The horizontal opening of the posts for the Texas rail is 6", however for pedestrian requirements, a maximum opening of 5" is allowed. The posts shall be made wider to comply with pedestrian concerns. The post spacing will be the same as the Texas 411 rail at 18".

The changes retained the 5½" setback; however the opening height has been reduced to 13" from 15". This puts us within the "grey" area of Figure 4 of rails that have passed NCHRP 230 safety evaluation guidelines. The contact to height ratio became 18¼" to 32" or .57. For a setback of 5½", this puts us into the preferred area of Figure 5. The geometry of the rail satisfies LRFD A13.1.1.

At this point, we have developed a section that can pass TL-3 requirements. To protect the connection, the committee felt that "lifting" the rail off the deck would be vital to keep the water away from the plane where the deck and rail meet. This required that the rail set on a pedestal. The intersecting plane was placed 1½" above the top of pavement. The runoff would flow up against the pedestal and if any water puddled it would do so and not slowly seep into the space between the deck and bottom of the rail. The pedestal on the deck would have to be as thick as the pavement plus an extra 1½". To enhance this detail, the committee decided to add a ¼" thick elastomeric sheet to seal the plane like a gasket. Using the elastomeric sheet also aids in taking up gaps in irregular surfaces.

CONNECTION STUDY

The largest concern with the precast concrete rail was with the connection detail. Failures in the past were exclusively due to the connection to the deck. Deicing agents used to clear the roads have been instrumental in corroding the connection. In many cases the connection failed when the deicing agent soaked into a poor grout system that was either used to grout the connecting rod or the grout bed the rail sat upon. The solution required must limit the use of grout and must provide some corrosive inhibiting characteristics.

Many connection options were considered. These are detailed below and the evaluation is summarized in Table 1.

Base Plate
This concept was taken from the Texas DOT details for the T504 concrete rail system. The detail included one threaded rod connected to a plate with four smaller steel studs connected to the bottom of the plate. The four studs would connect the plate to the deck and the single threaded rod would be used to connect the rail to the deck by the use of a washer plate and nut.

Looped Reinforcement

Using typical reinforcing lapping reinforcing loops, the rail would be connected in much the way as cast in place concrete rail would be placed. Looped reinforcement would rise out of the deck and out from the underside of the rail. The curb would then be cast in place thereby connecting the rail to the deck.

Drill and Grout Anchor Bolts
The rail in this case would be connected by anchor bolts that were grouted in the deck long after the deck was placed. The contractor would be required to drill the locations for the bolts; set the bolts; then grout them before setting the rail sections. The bolts would then be used to connect the rail by means of a washer plate and nut.

Embedded Anchor Bolt
This concept is very similar to the Drill and Grout concept, however the anchor bolts are set in the precasting plant.

Table 1 Precast Guardrail Connection Alternative Matrix

		Base Plate	Looped Reinforcement	Drill and grout anchor bolts	Embedded anchor bolts
1	**Requires extra materials beyond reinforcement**	YES Base plate 4 anchor bolts 1 threaded stud	NO	YES Anchor Bolt	YES Anchor Bolt
2	**Initial in-Field preparation work**	Place plate and fasten with 4 nuts.	None	Drill holes taking care to not drill through deck reinforcement. Place anchors ensuring proper locations. Place grout material. Allow grout to cure.	None
3	**Description of construction**	Place bearing pad, set rail and bolt down and inject foam sealant into cavities where the base plate are.	Set rail segments along bridge edge with the reinforcing alternating with steel coming out of deck. Install longitudinal steel in curb. Install grout dams and curb face	Place bearing pad. Set rail and bolt down.	Place bearing pad. Set rail and bolt down.

			forms. Place concrete in forms. Allow concrete to cure. Remove forms. Grind out imperfections.		
4	**Equipment reliance other than crane.**	None	None	High Speed Drill	None
5	**Speed of Construction**	Can be done in a day.	May take up to a week for the concrete to cure	Can be done up to three days, depending on grout cure time.	Can be done in a day.
6	**Potential problems during installation**	Alignment Jagged surface under plate	Rebar spacing irregularities: may not be able to bend bar out of way.	Drill through needed reinforcing in decking Alignment	Alignment
7	**Remedies to problems**	Grind down jagged edges. Bend anchor bolts.	Bend Bars out of way. Some bars may be right over each other – cut bar	No real fix – loose bar.	Bend anchor bolts.
8	**Preventative measures**	Slotted holes in base plate and parapet. Set up anchor bolts on a steel channel rig – will better align anchorage as well as smooth the surface for base plate.	Specify alternating spacing in plans and have very good shop/field inspection to ensure the looped bars are alternating	Specify locations to drill in the plant either by indicating the drill point or score a line where it is safe to drill. Must have very good shop/field inspection.	Set up anchor bolts using a channel similar to base plate
9	**Repair/Replacement**	Remove rail by unbolting it, clean out foam seal, remove nuts, remove plate, insert new or repaired base plate and replace nuts, then place new section of rail. (Would be done in a day)	Jack hammer or otherwise chisel out the concrete that was placed in the void ensuring no damage to the deck stirrups. Repair any deck reinforcement (either bending, drilling and grouting new bars, painting epoxy on damaged epoxy coatings). Repair deck (filling any over-chipped areas, clearing deck surface from jagged edges and debris within stirrup cage). Place new rail section. Construct grout dams and curb face forms. Place	Remove rail. Check anchor for damage. If anchor is in good shape, then straighten if needed. If it is damaged, drill out anchor and set a new one. Set rail. (could be a one to two day operation)	(See left)

			concrete. After concrete cures, remove forms. (Would require several days over a period of a week to complete due to concrete cure.)		
10	**Requirements for proprietary products**	None. Uses standard construction methods. All materials have competing options.	None. Standard construction methods. All materials have competing options.	Yes. The only crash-tested method of this type of installation is a propriety product. We could emulate a similar configuration, but it may need to be crash tested. The emulated solution uses standard construction methods.	None. Standard construction methods. All materials have competing options.
11	**"Been done before"**	Yes, by Texas.	Yes, all over the world.	Yes, all over.	Yes, all over.
12	**Potential in use problems.**	A lot of steel, therefore it can corrode and eventually fail. Sealer can shrink over time and leak.	Field placed concrete could be lesser quality than specified, thus forming a wick allowing salt and water to get to reinforcement.	Grout could be porous, allowing water and salt to get to anchor.	See Left
13	**Solutions**	Stainless steel	Higher quality control in the field.	Stainless Steel	Stainless Steel

Rating each of the above conditions on a scale of 1 to 4, 1 being poor and 4 being excellent, we rated the conditions in table 1 based on costs and speed of construction, durability and replacement capabilities. These are summarized in the following Table 2 through Table 5.

Table 2 Construction Costs

	Base Plate	Looped Reinforcement	Drill and grout anchor bolts	Embedded anchor bolts
1	*1*	*4*	*2*	*3*
2	*3*	*4*	*1*	*4*
3	*2*	*1*	*4*	*4*
4	*4*	*4*	*1*	*4*
5	*4*	*1*	*2*	*4*
6	*3*	*2*	*1*	*4*
7	*3*	*2*	*1*	*4*
8	*2*	*1*	*1*	*2*

9	3	1	2	2
10	4	4	1	4
11	3	4	4	4
12	1	1	1	1
13	3	2	3	3
	36	31	24	43

Table 3 Speed of Construction

	Base Plate	Looped Reinforcement	Drill and grout anchor bolts	Embedded anchor bolts
.1	0	0	0	0
.2	2	4	1	4
.3	3	1	4	4
.4	4	4	2	4
.5	4	1	2	4
.6	0	0	0	0
.7	1	1	3	2
.8	0	0	0	0
.9	0	0	0	0
.10	0	0	0	0
.11	0	0	0	0
.12	0	0	0	0
.13	0	0	0	0
	14	11	12	18

Table 4 Durability

	Base Plate	Looped Reinforcement	Drill and grout anchor bolts	Embedded anchor bolts
1	2	3	4	4
2	3	4	2	4
3	4	2	4	4
4	0	0	0	0
5	4	2	2	4
6	3	3	1	3
7	2	1	1	2
8	0	0	0	0
9	4	1	2	2
10	0	0	0	0
11	0	0	0	0
12	2	1	2	2
13	4	2	4	4
	28	19	22	29

Table 5 Replacement

	Base Plate	Looped Reinforcement	Drill and grout anchor bolts	Embedded anchor bolts
1	0	0	0	0
2	0	0	0	0
3	2	1	4	4
4	0	0	0	0
5	4	1	2	4
6	3	2	1	4
7	3	2	1	4
8	0	0	0	0
9	4	1	2	2
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
	16	7	10	18

The rating were summed up to give the option a score. These scores are summarized in Table 6. As can be seen, the embedded anchor bolt seem to be the most practical solution. As a result of the evaluation this detail was selected.

Table 6 Summary

	Base Plate	Looped Reinforcement	Drill and grout anchor bolts	Embedded anchor bolts
Construction Costs	36	31	24	**43**
Speed of Construction	14	11	12	**18**
Durability	28	19	22	**29**
Replacement	16	7	10	**18**
Total Score	94	68	68	**108**

Once the connection detail was selected, the next step was selecting the connection material. Stainless steel is more expensive than other corrosive inhibiting materials; however, the quantity needed for a segment of rail was relatively small. The cost difference in relation to the other materials would be minimal.

Making The Connection the Strong Point

The one thing that plagued the precast rail section in the past has been the connection. To counter this, we made the connection the strong point. There were two reasons for this. The first, was to provide the appropriate resistance to corrosion and rail separation during a collision. The second reason was a practical one. We wanted to be able to replace the rail in the event that a collision destroyed the rail. If the connection survived the collision at the cost of the rail, then it would be feasible to replace the rail section.

Though we had decided to use stainless steel bolts as the connection bolt, we went a step further to provide the two additional measures to further prevent corrosive agents from getting to them as discussed earlier. The first step was to require the rail to be set up on a nominal 1½" pedestal over the pavement surface, and the second was to require a sheet of expansive material to be placed as a gasket between the rail and deck. This eliminates any possibility of corrosion being caused by the use of poor grout.

DESIGN

Using the 1998 LRFD (2003) specification table 13.7.2-1 and table A13.2-1, the loading criteria was determined to be:

1. Speed of small cars and pickup trucks may be up to 60mph..
2. The transverse load shall be 54kips over a 4' length of the rail.
3. The longitudinal load shall be 18kips over the same length.
4. A vertical load on the rail shall be 4.5kips over a length of 18'.
5. The minimum effective height shall be 24" with the minimum height of rail being 27".
6. The railing loads must be transferred to the deck. (LRFD 13.7.3.1.2)
7. Deck overhang must be 200mm min thickness for deck mounted parapets or barriers. (LRFD 13.7.3.1.2)

The rail was designed to withhold the collision force of a 54 kip load spread over 4 feet as specified by the AASHTO LRFD manual. As stated before the bolts were designed to be the strongest component. The rail was made into a finite element model representing the rail (see Figure 8). Results from the model indicated that the current reinforcing steel design for the Texas 411 and 503 rails would be sufficient. The anchor bolts were also determined to be sufficient.

Work is currently under way at the University of New Hampshire by William F. Endicott III under the advisement of Professor Charles Goodspeed III for static loading of the rail design. This work in addition to the finite element analysis and the crash test results will be the subject of a future paper.

The initial results of the static load test indicated that the rail will withstand a static load of 54 kips as specified by the AASHTO LRFD design. All cracks in the rail occurred behind the bolt location, which met with the criteria for the design.

VERSITILITY

At this point, the rail system meets the criteria for ease of installation and provides protection to the connection to the deck. The rail is a close approximation to the Texas 411 rail from the fascia side, however looks very different from the traffic side. By the use of the elastomeric pad, and the fact that the rail is placed in segments, irregular surfaces can be easily accommodated. We also have a rail system that may meet the TL-3 criteria.

The remaining goals we have yet to meet are associated with how the system is precast. This involves methods to make the system cost effective, the ability to easily customize the rail, and finally for slower speeds, provide a rail system that looks like the Texas 411 rail from the traffic side.

The first step to meet these goals is to develop a form that will allow for easy modifications. Since the inserts may vary between designs, these should be allowed to swap out or omitted. This requires an outer shell to the form be employed. The outer shell will have bolt holes to allow the inserts to be connected.

With the inserts separated from the outer shell, many variations of the rail section can be created. Options include leaving every other insert out; changing the shape of the insert; taking out all inserts and replacing them with inch thick panels or attaching form liners. With the basic rail shape and reinforcing steel cage maintained as designed the owner will be able to modify the rail to what ever look is desired. This philosophy now makes the rail universal even though each design could be custom. This adds to its economic appeal.

This modular forming concept will make casting the rail segments simple in the precasting plant. If the rail becomes a standard beyond any single state, the forms would likely be used multitudes of times like other precast components. This leads to encouraging the precasters to invest in durable forms that meet their individual needs. Making the forms universal, would make it easy for precasters to swap inserts or for third party fabricators to produce inserts to rent. Rail segments could become a bread and butter component that helps precasters fill in when they are not running at full capacity.

APPLICATION

After Precasting, the rail would be shipped to the site for installation. The contractor would have been required to complete several steps prior to the rail arrival. First, and most importantly, the anchor bolts would have to be already cast into the deck or deck beams. The contractor would have already prepared a pedestal for the beam to set on, and lastly, the contractor would have rolled out the elastomeric sheet and placed it on the pedestals.

Once these items have been completed the rail is placed over the anchor bolts. The nuts are then turned a few times on the anchor bolts but not fastened. Once all the rail segments are placed, the segments are adjusted to be in alignment with each other. Once it is felt that the rail is set within tolerances, the bolts are tighten. The last step in construction would be filling the joints and the bolt holes with grout.

A large benefit of this rail concept is that after the rail has been damaged by a collision, the segment can be removed and replaced in much the same way as steel. This makes the maintenance of this rail quick and inexpensive with little impacts to the traveling public. Being a standard, a precaster will be able to quickly produce a new section with little time lag.

With quick installation time, this rail also makes a good alternative for rapid bridge construction. Currently, steel rail and concrete “F-Shape” rail has dominated rapid bridge construction projects because of their portability and ease of installation. These rail alternatives has defined the look of a rapidly constructed bridge. This look is typical of those bridges opposed by the public. The NEPCR will provide equal ease of construction, but with the look of cast-in-place.

FUTURE

UNH will soon complete the static testing of the NEPCR. Once the data is compiled and necessary modifications made, the rail will be scheduled for crash testing. It is the intention of the PCI-NE Bridge Technical Committee to provide this rail as a TL-3 qualified rail system. Future developments will be the creation of a taller pedestrian rail that meets TL-2 that is also compatible with the NEPCR form factor.

CONCLUSION

This work could not be the result of a single entity. To benefit from this rail system a greater number of agencies need to adopt this as a standard. New England and New York have put in over a year of work developing this rail system. The result is a rail system that offers great cost effectiveness, safety, utility and aesthetics. The work underway by PCI-NE has produced a precast rail concept that for the first time will provide a viable alternative for decorative bridge guardrail.