5.0 CHAPTER 5 - BRIDGERAILS

5.1 PURPOSE OF BRIDGERAILS

Bridgerails (traffic barriers) are provided on both sides of highway bridges to delineate the superstructure edge and to reduce the consequences of vehicles leaving the roadway. Where there is a sidewalk for pedestrian traffic on a bridge structure, there is normally a bridgerail between the roadway and the sidewalk for vehicle traffic and a pedestrian rail on the outside of the sidewalk for the pedestrians.

5.2 HISTORY/BACKGROUND

Bridgerails have developed and changed over time. The very early bridgerails were mostly used to delineate the edge of the structure and there was very little design for the forces of vehicle impact. Bridge codes in the 1950's had design forces and procedures for design of bridgerails which were based on experience and static loading. Bridgerails were often designed with appearance as a major factor and not much consideration was given to the dynamic effect of a vehicle striking the rail and how it would react and be re-directed. Many of the bridgerails built in this period had features that could potentially be hazardous to the vehicle and its passengers such as large concrete end posts with no protection from front end collisions.

During the 1960's a number of agencies started carrying out crash testing of bridgerails which showed the importance of not having blunt ends on bridgerails but smooth continuous rails which would not snag impacting vehicles. Bridge codes changed in the late 1960's with specifications for the shape and height of bridgerails. The Canadian bridge code was a leader in many of these changes. The bridgerails designed to these new codes were mostly continuous steel tube or flex-beam railings with some concrete barrier type railings. Also, these new codes required that the approach railings to a bridge structure be attached to the bridgerail.

Over the next 25 years there were a number of minor changes and revisions to the bridgerail design procedures in the bridge codes. There were a number of changes requiring better transition between the approach railing and the bridgerail. Crash testing of bridgerails continued and in the 1990's some agencies started to require all new bridgerail designs to be crash tested. Bridge codes started to change and the 2000 edition of the Canadian Highway Bridge Design Code required crash testing of all bridgerails and approach transitions to certain performance levels. The new Canadian bridge code specifies three performance levels: PL1 which is intended for low traffic volume bridges with no unusual safety hazards, PL2 for moderate to heavy traffic volumes, and PL3 for heavy traffic volumes with a high percentage of truck traffic and/or other unusual safety hazards. Since 2000, the Department has adopted crash-tested standard bridgerail barriers for these three performance levels together with standard transition sections between the bridgerail and the approach guard railing for all new construction.

5.3 BRIDGERAIL TYPES

5.3.1 EARLY BRIDGERAILS (1950 TO MID 1960)

Timber Bridgerails

Timber rail bridgerails are generally on timber posts bolted to the side of the exterior girders and consist of one or two timber plank rails. There are also some single timber plank rails on steel posts. This type of bridgerail is not commonly found on bridge structures today. It is sometimes found on timber bridges and short standard precast concrete bridges on very low volume roads or land access bridges (see picture Figure 5.1). The main defect found with these bridgerails is rotten timber.

Figure 5.1 Timber Bridgerail

Vertical Steel Bar Panel Bridgerails

Vertical steel bar panel bridgerails consist of vertical bar panels supported between steel or concrete posts (see picture Figure 5.2). This is probably the most common type of bridgerail on bridges built in the 1950's and early 1960's. Whether they have steel or concrete post this type of bridgerail generally has large concrete end posts at the end of bridge. These type of rails do not have a smooth continuous face for impact and even low speed collisions may cause considerable damage to the bridgerail panel as well as to the vehicle. A common defect for these bridgerails with concrete posts is deterioration of the post due to corrosion of reinforcing steel in the post. Also, paint deterioration and corrosion of the panels is a problem. Many of these types of bridgerails have had the steel panels hot dipped galvanized as part of a rehabilitation of the bridge.

Figure 5.2 Vertical Steel Bar Bridgerail

Horizontal Steel Rail Bridgerails

Horizontal steel rail bridgerails consist of a number of horizontal steel rails supported on steel and sometimes concrete posts (see picture Figure 5.3). These bridgerails were generally used on bridges where better horizontal visibility was required. The horizontal rails are not continuous and vehicles may get snagged on impact. Common defects of these types of bridgerails are deterioration of paint and corrosion of the steel.

Figure 5.3 Horizontal Steel Rail Bridgerail

Lattice Panel Bridgerails

Lattice panel bridgerails consist of panels of relatively thin steel bars crossing at 45 degrees to the horizontal. This type of bridgerail is commonly used on through trusses where they are attached to the truss members (see picture Figure 5.4). On other bridges they can be supported on steel posts. These lattice panels will also sustain considerable damage in minor collisions.

Figure 5.4 Lattice Panel Bridgerail

Retrofit Bridgerails

Due to the problems resulting from collisions with the above noted steel bridgerails, the Department developed a retrofit for these bridgerails which increased the ability of the bridgerail to withstand impact, helped prevent snagging, and minimized the damage from minor collisions. This retrofit consists of a large tubular steel section which is attached to the post of the existing bridgerail with a circular steel tube spacer between the rail and the post which deforms on impact and distributes the horizontal loading to a number of posts (see picture Figure 5.5).

Figure 5.5 Retrofit Bridgerail

5.3.2 SECOND GENERATION BRIDGERAILS (LATE 1960'S TO LATE 1990'S)

Double Tube Bridgerails on Safety Curb

The double tube bridgerail consists of two continuous square steel tube sections supported on square steel tube posts. The post has a steel base plate which is attached to the concrete curb by large anchor bolts (see picture Figure 5.6). The steel railing, post and anchor bolts are hot dipped galvanized after fabrication. This is the most common type of bridgerail used on major bridges in Alberta in the 1970's, 1980's and 1990's. The first standard for this type of bridgerail was developed in 1969. There have been a number of revisions over the years with a metric version of bridgerail being developed in the mid 1970's. The major revision to the original standard has been the increased number of post anchor bolts from 4 to 5 bolts. The bridgerail can sustain minor to moderate impact of a vehicle without significant damage. It has also shown that it can withstand major impacts with moderate damage. Common defects with this type of bridgerail are anchor bolts with insufficient thread projecting above the anchor nut, missing anchor nuts and corrosion of the steel post at the base plate due to improper drainage of water which gets inside the post.

Figure 5.6 Double Tube Bridgerail on Safety Curb

Double Tube Bridgerail for Standard Prestressed Girders

The double tube bridgerail for standard prestressed girders looks very similar to the double tube rail on major bridges. However, it was developed for use with the curbs on the standard VS, SM & SC girders which were narrower than curbs on major bridges. The front of the horizontal tubes was closer to the face of the curb and the height was less than the bridgerail on major bridges. Also strandard prestressed girder bridges normally do not have wing walls at the abutments. The horizontal tube of this type of bridgerail slope down at the end of the bridge and are anchored into the ground (see picture Figure 5.7). Common defects found with this type of rail are similar to major bridge double tube bridgerail i.e. missing anchor nuts and corrosion of the steel post at the base plate due to improper drainage of water which gets inside the post.

Figure 5.7 Double Tube Bridgerail on Standard Prestressed Girders with Soil Anchors

Concrete Barrier Bridgerails

Concrete barrier bridgerail consists of a solid concrete barrier that has a short vertical face and two sloping faces (see picture Figure 5.8). This barrier is commonly referred to as a New Jersey barrier. The barrier can be either cast-in-place or precast and is usually connected to the deck. However, when this type of barrier was precast the joints between the barrier and the deck and between units have had significant maintenance problems. Therefore cast-in-place barriers are more common. This type of barrier has been shown to perform very well in major impacts without sustaining significant damage. However, they can cause problems with snow drifting and snow clearing on bridge decks and have not generally been favoured by highway maintenance staff. A common defect with this type of barrier is corrosion of the reinforcing steel in the barrier due to low concrete cover causing delamination of the concrete.

Figure 5.8 Concrete Barrier Bridgerail

Double Layer of Flex-beam Bridgerail
Double layer flex-beam bridgerail consists of a double layer of flex-beam generally on steel posts with steel base plates attached to the top of the concrete curb with anchor bolts (see picture Figure 5.9). This type of bridgerail was generally used on smaller bridges on low volume roadways. The two layers of flex-beam are nested together with the joints in the flex-beam sections staggered. The joints are lapped with the outside in the direction of traffic. This type of railing generally runs continuously unto the bridge approach railing with a transition from a double to a single layer. Common defects with this type of railing are missing anchor bolt nuts, missing flex-beam splice bolts and improper lapping of flex-beam splices.

Figure 5.9 Double Layer Flex-beam Bridgerail

5.3.3 CURRENT BRIDGERAIL TYPES

With the changes to the bridge barrier in the 2000 edition of Canadian Highway Bridge Design Code (CHBDC) the Department developed a series of standard drawings and details to meet the new code requirements for the three specified performance levels (PL1, PL2, PL3). The new code requires that all bridge barriers be crash tested for the design performance level. Since crash testing of a new type of bridge barrier is very expensive, the Department decided to develop bridgerail standards based on bridgerail types that had already been crash tested. Details were modified and standardized to fit the type of bridges commonly found in Alberta.

Before the latest code changes, bridges normally had a curb and a bridgerail. Generally the curb was concrete but was sometimes timber and occasionally steel. The curb allowed for minor impact and re-direction of a vehicle and directed water on the bridge deck into deck drains or off the structure. Crash testing of bridge barriers showed that the bridge curbs as previously designed actually were a hazard for high speed vehicle collision since the vehicles would often mount the curb and become airborne before striking the bridgerail.

Bridgerails performed better in crash tests without a curb or when the face of the bridgerail lined up with the face of the curb so that the vehicle impacted both at the same time.

PL1 Bridgerails

PL1 bridgerails are used on roadways with low traffic volumes and no unusual safety hazards. A number of the PL1 bridgerails that had been successfully tested, at 70 kph, did not have curbs and the bridgerail posts were attached directly to the deck. These bridgerails were fairly economical because they eliminated the cost of the curbs. However, curbs are also used to direct deck drainage. Without curbs rain water on the deck will run down the side of the girders. If the bridge is on a roadway which receives de-icing salts, chloride in this water can cause deterioration of the exterior face of the girder. However, on low volume local roads that do not receive de-icing salts, water draining down the side of the bridge would not be a problem. Therefore, the Department developed two PL1 bridgerails without curbs. The bridgerail consists of a single horizontal Thrie Beam supported on steel H-shaped post with steel base plate and four anchor bolts into the concrete deck (see picture Figure 5.10). The normal height of this bridgerail is 803 mm above the roadway surface. A 706 mm low height version is also available for bridges narrower than 9 metres. The Thrie Beam runs off the end of the bridge and transitions to a flex-beam approach guardrail. This type of bridgerail is used on small bridges on local roads which do not receive de-icing salts.

Figure 5.10 PL1 Thrie Beam Bridgerail without Curb

PL2 Bridgerails

PL2 bridgerails are used on roadways with moderate to heavy traffic and would normally be used on roadways where de-icing salts are expected. Therefore, the PL2 standards developed by the Department all have curbs or barriers to prevent water draining over the side of the girders. The Department has developed four types of bridgerails in this performance level.

One of these bridgerails is a horizontal Thrie Beam supported on steel H-shape post with steel base plate bolted to a concrete curb (see picture Figure 5.11). The face of the Thrie beam lines up with the face of the curb. The total height of the curb and bridgerail is 826 mm above the roadway surface. This type of bridgerail would normally be used on bridges shorter than 20 metres.

Another one of the PL2 bridgerails consists of two horizontal square steel tubes supported by steel H-shape posts with steel base plates and four anchor bolts into a concrete curb (see picture Figure 5.12). The face of the horizontal tubes is lined up with the face of the curb. The total height of the curb and bridgerail is 850 mm above the roadway surface. This type of bridgerail would normally be used on major bridges.

The third type of PL2 bridgerail is a concrete barrier. It consists of a single vertical sloped face which is 850 mm high (see picture Figure 5.13) and is generally used on urban bridges.

The fourth type is a PL2 combination bridgerail, which is mainly used on urban bridges where there is combined vehicle and bicycle use. It consists of a 850 mm high single slope concrete lower portion, extended to 1420mm high by a double tube steel portion on top.

Figure 5.11 PL2 Thrie Beam Bridgerail on Concrete Curb

Figure 5.12 PL2 Double Tube Bridgerail

Figure 5.13 PL2 Concrete Barrier Bridgerail

PL3 Bridgerails

The PL3 bridgerail is required on roadways with very high traffic volumes with high percentage of truck traffic and/or other unusual safety hazards. Only a very small percentage of bridges in Alberta require a PL3 bridgerail.. .The Department's PL3 bridgerail consists of double tube HSS 127 x 127 railing on top of a 600 mm high concrete base for a total height of 1270 mm.

5.4 BRIDGERAIL TRANSITIONS

5.4.1 BACKGROUND

Along highways that have steep banks or other hazards near the side of the highway, it has been common practice for many years to place some type of barrier along the shoulder of the highway to prevent vehicles from leaving the roadway at these locations. Generally the section of the highway immediately adjacent to a bridge structure will require such a barrier. The most common type of roadway barrier used in Alberta is a flex-beam steel rail on timber posts placed into the ground. Recycled plastic posts are sometimes used in place of timber.

This flex-beam type railing deflects significantly on impact with the post breaking but the railing staying intact preventing the vehicle from leaving the roadway. However, barriers on bridge structures cannot tolerate larger horizontal deflections and bridgerails are designed as rigid barrier systems which have only small horizontal deflections on impact. This incongruity between the bridgerail and the approach rail systems creates the need for a transition between the approach and the bridgerail systems.

5.4.2 TRANSITION TYPES

Early Transition Sections

The early attempts of transition did not involve connecting the approach railing to the bridgerail. The flex-beam approach rail on the approaching traffic side was stopped at the beginning of the bridge with the face of the flex-beam inside of the face of the bridgerail and lined up with the face of the curb (see picture Figure 5.14). The post spacing of the approach flex-beam was closer than normal for the few panels next to the bridge to reduce deflection as one approached the bridge. At the end of the bridge where the traffic was leaving, the face of the flex-beam was lined up with the face of the bridgerail (see picture Figure 5.15). This type of transition was used for bridges built in the 1950’s to mid 1960’s. This type of transition functioned reasonably well for impact of vehicles with the approach railing some distance from the end of the bridge where there was enough distance for the flex-beam to re-direct the vehicle back onto the roadway surface before reaching the bridge. However, for impact of the approach railing near the bridge, the vehicle would pocket the flex-beam and impact the end of the curb and bridgerail. This type of transition can still be found on some older structures on low volume roads and/or where it is difficult to change to a better transition which connects the approach railing to the bridgerail without causing a hazard from a protruding concrete curb.

Figure 5.14 Approach Flexbeam lined up with face of curb

Figure 5.15 Exit Flexbeam line up with bridgerail

Late 1960's to Late 1990's Transition Sections

In the late 1960's bridge codes started to require the approach railing to be connected to the bridgerail. The stiffness of the approach railing was to be increased as it approached the bridge and there was to be a smooth connection to the bridgerail with no projections such as concrete curbs to snag the vehicle. The approach rail was stiffened by decreasing the post spacing and using a double layer of flex-beam near the bridge, and the concrete curbs were tapered at the end of the bridge (see picture Figures 5.16). Based on accident history and crash testing, the transition section changed over time with closer spacing of the transition posts and blocking of the flex-beam out from the post to prevent snagging of the vehicle on the post.

Figure 5.16 Flexbeam attached to Double Tube Bridgerail

Current Transition Sections

The new code now requires the transition section to be crash tested to the performance levels of the bridgerails (PL1, PL2, PL3). The new standards developed by the Department involve the use of a Thrie beam section for a certain distance past the end of the bridgerail before transitioning to a flexbeam section. For PL2 and PL3 bridgerails the Thrie beam is supported on steel H-shape posts with a fairly close spacing which changes to timber posts at the flex-beam transition. The railing is blocked out from the posts to reduce the potential for snagging a post. Pictures of a current bridgerail transition are shown in Figure 5.17 & 5.18.

Figure 5.17 PL2 Approach Transition Section

Figure 5.18 Back of PL2 Transition Section

5.5 BRIDGERAIL PERFORMANCE LEVELS

In the Canadian Highway Bridge Design Code (CAN/CSA-S6-00) the bridgerail performance requirements at a bridge site are based on the expected frequency and consequences of vehicle accidents at a bridge site. The frequencies and consequences of vehicle accidents at a bridge site are a function of many variables. These variables include: traffic volume, percentage of truck traffic, highway type, barrier clearance from traffic, highway curvature, highway grade, highway design speed, superstructure height, people and hazards beneath bridge and the bridgerail performance. The optimal (desired) level of bridgerail performance is the one that gives the least life cycle cost for the cost of supplying and maintaining the bridgerail, as well as, the costs of the accidents expected with the use of that bridgerail. The code has a procedure for determining the desired performance level (PL1, PL2 or PL3). There is a formula for calculating a Barrier Exposure Index which includes traffic volume, highway type, highway curvature, highway grade and superstructure height. This Barrier Exposure Index is used to enter a series of tables which include the variables of design speed, percentage of truck traffic and barrier clearance to determine whether performance level PL1, PL2 or PL3 is required. Using this procedure for bridges in Alberta has shown that a PL1 bridgerail will meet the performance requirements on most local roads and a PL2 bridgerail will meet requirements for most highways with PL3 bridgerails required in a few cases.

This page was intentionally left blank.