Why Caltrans Should Adopt the New National Standard for Bicycle Railing Height

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Introduction and Summary

Recently, the national standards body that sets safety standards for highways and bridges, AASHTO, lowered the minimum bridge railing height for bicyclist protection for 54" to 42". The new height is consistent with the 42" minimum height specified in the 1999 AASHTO *Guide for Bicycle Facilities.*[1]

Despite the certification of 42" as safe by AASHTO, and despite the normal acceptance of AASHTO standards by Caltrans, Caltrans has not accepted the new standard. <u>According to Roberto Lacalle, Chief of the Office of Design and Technical Services and chair of the committee, the committee has serious reservations about adopting the new 42" standard.</u>

In my conversation with him, Mr. Lacalle said that the AASHTO committee that adopted the new standard ignored the findings of a technical report of the National Cooperative Highway Research Program (NCHRP).[2] Also, he said that Caltrans' California Bicycle Advisory Committee had voted unanimously against lowering the 54" standard.

My interest in this issue derives from my desire to see that bridges in scenic areas have railings that harmonize with the setting and are visually transparent. <u>A 54" railing is an aesthetic disaster for bridges in scenic areas.</u> A 42" railing would increase greatly the possibilities for designing railings that harmonize with the setting and are visually transparent.

<u>The current California scenic railing of choice, the Noyo or ST-10 railing could be modified to make an attractive, visually transparent bicycle barrier by adding a single, horizontal railing at 42".</u> When used solely for auto and bicycle protection, no intermediate rails would be needed for safety. This new railing would visually harmonize with the combination use of the ST-10 and pedestrian railing on the sidewalk side of a scenic bridge.

Following my conversation with Mr. Lacalle, I reviewed the NCHRP report he referenced. I also read the minutes of the AASHTO committees that recommended the 42" height[3], later formally adopted by AASHTO. <u>Later sections of this document contains excerpts from the NCHRP report, together with my comments.</u>

In summary, my reading of the NCHRP report and the minutes of the railing committee meetings supports the following observations and conclusions:

- The AASHTO nonmotorized committee considered NCHRP Report 20-7 when making its recommendation on railing heights for bicycles. It concluded that the data and discussion in the NCHRP report did not justify the 48" height. It decided that, as there were no "compelling arguments" for taller railings, it would recommend a 42" railing height for bicycle railings (the same height as pedestrian railings), with exceptions for unique high risk situations.

- The recommendation of the nonmotorized committee was reviewed, discussed, and accepted by the Committee on Technical (Geometric) Design, providing a second level of technical review.
- The AASHTO Bridge Committee accepted the recommendation of the Design Committee in May, 2006 (providing a third level of technical review). It will appear in the official AASHTO document on bridge design standards in 2007.
- NCHRP Report 20-7 recommends a minimum of 48". The text of the report does not provide a substantive safety argument for this height. To the contrary, the report is critical of the engineering justification underlying a 48" height.
- NCHRP Report 20-7 did extensive review of accident data and made surveys and outreach to safety agencies. It found almost no documented bicycle accidents involving bridge railings. ***The results of the safety analysis show that bridge rail height is an insignificant factor in bicycle accident rates.***
- Many states have for some years used 42" rails for bike paths and some states for bridges. None of the states contacted by the authors of Report 20-7 reported any accidents involving 42" railings.
- The NCHRP Report 20-7 surveyed bicyclist advocacy groups and state bicycle coordinators and bridge designers. ***Both groups preferred 42" over 54" rails by two to one margin. Only 17% of advocacy representatives gave blanket preference to 54" railings.***
- ***The authors of NCHRP Report 20-7 repeatedly make clear their belief that aesthetics and protection of visual resources should be given little or no weight in specifying railing heights. This position is contrary to federal legislation and highway design guidance and to a Caltrans' policy directive "to build environmental compatibility into projects at the basic design level and to achieve fundamental consent to project designs and features."***
- ***The recommendation of Report 20-7 for a 48" minimum railing height flies in the face of most of the report's findings, but the discrepancies are never addressed.***
- ***One has to wonder, "What was the basis for the 48" recommendation of Report 20-7?" Certainly it was not the evidence and analysis presented in the report.***

My review leads to the same conclusion as that of the AASHTO safety committees: <u>Report NCHRP Report 20-7 does not provide any safety justification for bicycle railing heights greater than 42" in most circumstances.</u> Bicycle railings are used primarily in scenic settings. When scenic, visual, aesthetic, and environmental values are important, as on bridges in scenic areas, the arguments overwhelmingly support 42" bicycle railing heights.

Caltrans has no technical basis for rejecting the national AASHTO standards. If it does so, it will once again demonstrate its imperious disregard not only for the public's expressed wishes to appropriately balance safety and quality values, but also for engineering analyses that don't support its prejudices.

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[1] *Guide for the Development of Bicycle Facilities*, AASHTO, 1999.
[2] *Determination Of Appropriate Railing Heights For Bicyclists*," NCHRP Report Project 20-7 (168), July 2004
[3] Minutes of July 12, 2005 Meeting of AASHTO Technical Committee on Nonmotorized Transportation in Woods Hole, MA. See Appendix A.

Excerpts from and Comments on "Determination Of Appropriate Railing Heights For Bicyclists," NCHRP Report Project 20-7 (168)

Note: the full report is available at:
http://www.bridgerailings.org/publications/pub_top.htm

My comments in the following section are in this text. Quotes from the NCHRP Report are in this text.

History of 54" Standard

> In preparation for the 1999 update of the "*Guide for Development of Bicycle Facilities*," the AASHTO Task Force on Geometric Design researched the history of the 1.4-meter (54-inch) railing height requirement. **The Task Force's research efforts found that the 1970's CalTrans railing height recommendation was chosen arbitrarily, with no empirical evidence for its defense.** The Task Force's research also discovered that several bicycle path structures were constructed with the standard 1.1-meter (42-inch) pedestrian railing height, and the lower railing height did not affect the safety of the structures. (Page 5, emphasis added.)

Adoption of 42" Standard in 1999 *Guide for Development of Bicycle Facilities*

> During the preparation of the 1999 update, the Task Force received several public complaints stating that the 1.4-meter (54-inch) railing height obstructs scenic views along bike trails, and does not appear to increase safety. Public sentiment, research findings, and lack of crash evidence convinced the Task Force to change the minimum railing height to 1.1 meters (42 inches). (Page 5.)

Engineering Analysis

The following is technical. It summarizes the only engineering analysis that has been done of the collision of bicyclists with bicycle rails. For the non-technical, the major finding is that 46" is higher than the "center of gravity" of 95% of people on bicycles. Railings of this height (or less, for reasons explained later), will effectively ensure that errant cyclists will not fall over the railing. A second pertinent question, considered later, is "How often do cyclists collide with bridge rails?"

> David Orr of Texas A&M University, Texas Transportation Institute, documented the COG [Center of Gravity] of a 50th and 95th percentile person in *"A Study on the Required Height of a Bridge Railing to Accommodate Bicycle Impacts,"* for his Master of Engineering degree research paper. Orr's paper was initiated based on discussion of the height requirement for bicycle railings on bridges at a conference of state transportation officials in 1993. In the engineering paper, Orr determined the COG of a 50th percentile and 95th percentile adult male on a bicycle. A "percentile" is the point on a distribution curve for a specified variable where that percent of the measured (or calculated) values would be less. For

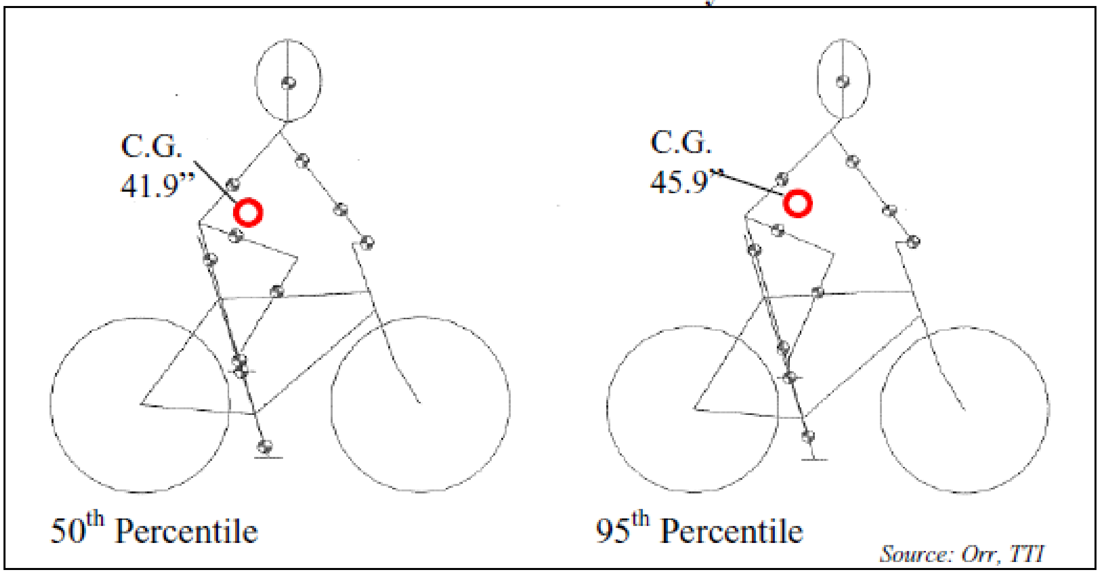
example, if the 95th percentile test score were 80 points, then 95% of the total population would have scored less than 80 points.

A mountain bicycle was selected for the study because the proper posture of a mountain bicycle rider has a higher center of gravity, regardless of saddle height. Using a Giant ATX 760 mountain bike, Orr determined the appropriate railing height through two crash scenarios. The first scenario assumed that the railing height must be at least as high as the COG of the person on the bicycle. This scenario assumed that if a lateral force were applied to a rider, half the rider's mass would attempt to topple over the railing, while the other half would attempt to prevent the rider from toppling over the railing. This scenario is similar to a crash event where a bicyclist is traveling parallel to a railing and collides with the railing in a glancing fashion. The bicyclist's body collides with the railing because of a lateral force caused by a collision with an object or another bicyclist, an evasive action to avoid a collision, a sudden cross wind, or other incident that causes a lateral force on a moving bicyclist. (Page 14.)

The second scenario considered by Orr is a head-on collision of a bicycle with a railing. This scenario does not apply to bridges, but rather to bicycle paths with sharp curves.

Orr's first scenario revealed that the COG of a 50th percentile adult male on a bicycle, as estimated by a 50th percentile anthropometric dummy, is located 1.1 meters (41.9 inches) above the ground. The height of the COG of the 95th percentile person on a bicycle, as estimated by a 95th percentile anthropometric dummy, is 1.2 meters (45.9 inches). The 95th percentile height of an adult human male is 1.8 meters (72.8 inches). The first scenario concluded that the COG for both percentiles is well below the 1.4-meter (54- inch) recommended railing height in the AASHTO "*Standard Specification for Highway Bridges*." Figure 7 illustrates the 50th and 95th percentile COG of a male bicyclist. (Page 14.)

Figure 7
Center of Gravity



(Page 15.)

Deficiencies in the Engineering Analysis

The report discusses important limitations of the above engineering analysis. In particular, it notes that AASHTO requires guard rails for vehicles be only 27" in height, deeming this sufficient to prevent even large vehicles and trucks from vaulting over the barrier. The reasoning behind this is that there will generally be insufficient inward (toward the railing) velocity to rotate the vehicle mass over the seemingly low barrier.

The same considerations apply in determining the safe heights for bicycle railings. As a cyclist will normally encounter a guard rail when he or she swerves off course, the velocity into the rail will generally be quite minimal and insufficient to lift the cyclist over a rail considerably lower that his or her center of gravity.[4]

> Orr's findings are based on the simple theory that the bicyclist's COG must be below the height of the railing to prevent a bicyclist from falling over the railing. This theory does not take into account any of the other dynamics of a collision with a railing. For example, when a bicyclist is traveling parallel with a railing, a lateral force must be from a redirection of the bicyclist's momentum due to loss of control of the bicycle or a collision with an object prior to the collision with the railing. The lateral force of the collision with a railing is directly related to the sideways momentum of the bicyclist or the angle of the collision with the railing.
>
> As the COG represents the center of a much larger mass, the point of contact of the body with the railing would not likely occur at the COG, but at a distance equal to approximately one-half the width of the body away from the COG. The lateral force applied to the body must be adequate to rotate the COG over and around the point of contact. Therefore, it is possible that a railing lower than the

height of the bicyclist’s COG would prevent the bicyclist from falling over the railing. This is the same phenomenon that often prevents a large vehicle or truck from vaulting over a 0.7-meter (27-inch) high railing during a crash event. A simulation or modeling of the lateral force necessary to vault a bicyclist over a railing lower than the bicyclist’s COG would be difficult to accomplish without crash testing to verify or calibrate the assumptions and variables. (Pages 15, 16, emphasis added.)

Survey of Planners and Bicycle Advocacy Groups

The study reported the results of two bicycle railing height surveys: one for state [facilities planning] representatives and one for bicycle advocacy groups. There were 34 respondents in the first group and 27 in the second. The results are summarized in the following figures.

Figure 9 - Preferred Railing Height of Advocacy Groups

	Height	Count	%
1	42"/1.1m	13	43%
2	54"/1.4m	5	17%
3	Other	12	40%

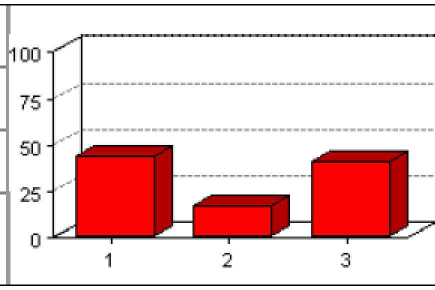
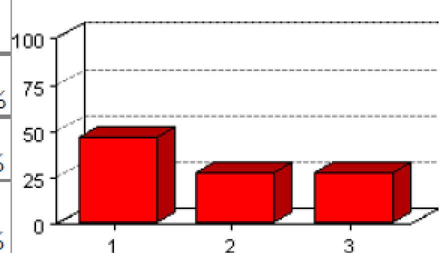


Figure 10 - Preferred Railing Height of State Representatives

	Height	Count	%
1	42"/1.1m	17	46%
2	54"/1.4m	10	27%
3	Other	10	27%



(Page 19)

In the charts, the first column measures those who unqualifiedly preferred 42" railings and the second, 54" railings. The third column were those who had more complex responses. A review of the more complex answers indicates that a high proportion prefer 42" except for specially hazardous situations, e.g., very long bridges, very windy conditions.

Among bicycle advocates, 78% of unqualified responses favored 42" railings. Among state planners, 63% unqualified responses favored 42" railings

Crash Data

The NCHRP report authors tried hard to collect and analyze bicycle accident data. The most telling result of their effort is how few bicycle/railing accidents the authors were able to find. For example, among the respondents to the railing surveys from 37 state planning agencies, detailed data was provided for only one bicycle/railing accident on a bridge. In this one accident, the cyclist fell over the railing – but the railing was estimated to be only 26" high. Among the bicycle advocates, 4 out of 40 were familiar with accidents, in part through researching databases. The following table summarizes the results:

Table 2 - Documented Bicycle Crashes

Country	Location	Railing Height	Description
U.S.	Roadway Bridge	<1.1 m	Bicyclist hit by overtaking vehicle and fell over railing
U.S.	Roadway Bridge	<1.1 m	Bicyclist fell over bridge vehicular railing. (Cause unknown)
England	Roadway Bridge	<1.1 m	Bicyclist veered off course due to slippery surface and fell over railing
U.S.	Roadway Bridge	N/A	Motor vehicle collided with two bicyclists who were thrown over railing
U.S.	Roadway Bridge	Approx. 1m	Collided with obstruction and fell over railing
U.S.	Shared use path	1.4 m	Bicyclist traveling too fast lost control while turning into curve, collided with and vaulted over railing
England	Shared use path	N/A	Single vehicle incident. Details unknown
Canada	Shared use path on Bridge	1.4 m	Bicyclist traveling too fast collided with bridge structure (did not collide with railing)
Canada	Shared-use Path on Bridge	Not provided	Bicyclist collided with pedestrian and fell into path of motor vehicle traffic

(Page 22.)

Note that the <1.1 m generally refers to vehicle barriers, which are generally 27-32".

There were only 4 reported accidents on bridges in the U.S. Of the 3 where the railing height is known, none were as high as 42".

Not a single case was reported in the U.S. where a cyclist fell or was propelled over a railing as high as 42". This does not mean this never occurred, but it clearly is extremely rare.

The authors also examined state and national databases of accident data, but found all of them inadequately detailed bicycle accidents to make them useful. In the one state database (North Carolina) that allowed them to determine bicycle-automobile collisions that occurred on bridges, they found only 27 accidents out of 6,027 that occurred on bridges -- less than one-half of one percent. Among these, there was no way of knowing how many of these involved guard rails in any way.

What emerges clearly is that automobiles are the overwhelming danger to cyclists. The few bridge accidents that could be identified where cyclists fell over barriers involved vehicular barriers that are significantly lower than 42".

Views and Aesthetics

The overwhelming reasons for preferring a lower railing are aesthetics and protection of views. The authors of the report say they reviewed a number of documents related to bridge aesthetics, but only one document related to aesthetics is listed as one of the report's sources. **The report uses language that tends to minimalize aesthetics as a factor in deciding on railing height.**

Here, for example, is the entire summary of the five pages that examine aesthetics and views:

> *Summary*
>
> A reference to "aesthetics" is used extensively in the preference of a 1.1-meter (42-inch) height railing over a 1.4-meter (54-inch) railing. However, no attributes related to form or scale have been identified as the determining factor in the objection to the 1.4-meter (54-inch) height. It would be difficult to assess the aesthetics of a railing system without understanding the setting and surrounding visual environment.
>
> The more pertinent issue of visual impact occurs when a railing is placed within a scenic view, and man-made objects can be visually offensive. In this regard, the smaller 1.1- meter (42-inch) railing height may have less of an impact than the higher 1.4-meter (54- inch) railing height.
>
> Additionally, a 1.4-meter (54-inch) high railing would have a greater impact on the sight
> line of users of a bikeway than a 1.1-meter (42-inch) high railing. (Page 28.)

The above is the entire summary section on aesthetics. The reader would be hard pressed to think that aesthetics had any significant relevance for choice of railing height.

Below are additional examples of this minimalization of aesthetics from within the section on aesthetics and views:

Based on the available guidance on bridge and structure aesthetics, it is difficult to determine any general suggestions, principles, or guidelines regarding the size, scale, or form that would render a railing system aesthetically objectionable. (Page 24.)

A higher bridge railing could appear disproportionate with the thin section of a bridge. However, the visual quality or beauty of a railing system would have to be judged based on its physical setting. (Page 24.)

The greatest concern regarding aesthetics is presumed to be the deterioration of visual quality resulting from the introduction of a man-made object, such as a railing, into the foreground of a scenic view... (Page 25, emphasis added.)

Overall, the implication of the survey comments is that a 1.1-meter (42-inch) railing height has less of an impact on aesthetics and visibility than a 1.4-meter (54-inch) railing height. (Page 25.)

Note the indirect and passive way of reporting the survey results above. One could have said, "A strong majority of those surveyed felt the aesthetics and visibility of a 42" railing were much better than those of a 54" railing."

Fear of Falling

Aesthetics is covered in a chapter entitled " Issues related to Bicycling Railing Heights." Noteworthy is that this chapter begins not with aesthetics but with a discussion of the "perceived fear of falling."

The authors begin the section with "… an important concern to a number of survey respondents was the perception of safety when traveling along a bridge. (Page 23.) They then cite concerns from "some respondents" that a 42" railing does not provide a sense of security.

When one examines the cyclist survey responses, however, the attention focused on this issue is seen to misrepresent the responses. Only one respondent cited the feeling on insecurity from lower railings, and he said his experience did not support this conjecture:

as a tall (6'5") cyclist, i can see how the 42" height could in some cases bother someone who was sensitive to heights. However, I've never heard a cyclist complain about a low (42") railing feeling unsafe, ... (Page A-27, emphasis added.)

Two other tall cyclists said they preferred 48" railings, but neither cited insecurity as a reason.

In the summary of this section, the authors greatly overstate the importance of "perceived safety" to survey respondents. They say "many of the responses", yet only one appeared in the detailed responses. They say "there appears to be a consensus," but no consensus is visible in the data.

> *Summary*
>
> Perception represents a strong force in an individual's determination of personal safety when traveling along a bicycle path adjacent to a steep slope or high drop-off. <u>Despite the lack of empirical evidence proving that a 1.4-meter (54-inch) railing height provides added protection</u>, **many of the responses** from the survey and outreach process indicated that a 1.1-meter (42-inch) high railing was inadequate, and that the additional height provides an added sense of security. **There appears to be a consensus** that an increased level of comfort is experienced when bicycling across a bridge with a 1.4-meter (54-inch) high railing. (Page 24, Emphasis added.)

Note the underlined sentence, which states that there is no empirical evidence that a 54" railing is safer than a 42" railing. Generally highway designers place the highest emphasis on safety findings. Here the authors virtually dismiss the safety findings in order to emphasize psychological considerations.

Especially because of its placement, just prior to the discussion of aesthetics and views, this section seems designed to provide a (greatly exaggerated) counterpoint to the strongly expressed concern of respondents about aesthetics, bicycling pleasure, and views.

Railing Cost

The report notes that: "During the study process, the cost of bicycle railing was cited as a reason supporting a lower railing height." The report did a cost analysis and found that for a 300-foot bridge a 54" railing as compared to a 42" railing would cost $22,500 more. They conclude, "However, the additional cost can be considered negligible to minor when compared to the overall cost of a bridge."

There is no argument that railing costs are "negligible to minor" in the overall economics of bridge construction.

Findings and Recommendations

The "Findings" section of the final chapter of the report reasonably accurately summarizes the findings of the preceding sections. When it moves on to "Recommendations", however, there is a complete disconnect from the findings.

The recommendation, for a 48" minimum railing height, flies in the face of most of the report's findings, but the discrepancies are never addressed.

The authors state, " It is reasonable to conclude that the 'one size fits all' approach to bicycle railing design is not adequate." But, then they never seriously consider a 42" railing height. The only exceptions from 48" that they consider are for higher railings.

One has to wonder, "What was the basis for the 48" recommendation of Report 20-7?" Certainly it was not the evidence and analysis presented in the report.

Conclusion

A careful review of NCHRP Report 20-7 shows that the recommendation for a minimum 48" height for bicycle railings is not supported by the findings and analysis in the report. This is the conclusion I reached and have supported herein.

The AASHTO committee on non-motorized traffic reached the same conclusion about NCHRP Report 20-7. It then brought its recommendation for the 42" bicycle railing height to the AASHTO Committee on Technical (Geometric) Design, where once again NCHRP Report 20-7 was reviewed and discussed. The design committee dismissed the Report 20-7 48" height recommendation and supported the 42" height, with exceptions for "unique locations" with higher risks.

The 42" height recommendation was based on a careful evaluation of data and analysis by highway and bridge engineers. Caltrans has no technical basis for rejecting the national AASHTO standards. If it does so, it will once again demonstrate its imperious disregard not only for the public's expressed wishes to appropriately balance safety and quality of life values, but for engineering analyses that don't support its prejudices.

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[4] The actual physics of the collision of a bicycle with a rail are complex and would need to be calibrated using crash testing. However, a simplified calculation suggests that lowering a rail 4" below the center of gravity of a cyclist (to 42" from 46" for the 95th percentile male), would have minimal effect on safety. For low speed collisions (velocity toward the rail of 1.5 to 5 mph), which would cover most cases, the downward force of gravity would halt the upward and outward motion of the cyclist in .02 to .05 seconds, well before he or she would be lifted over the rail.

Appendix A

Excerpts from Minutes of July 12, 2005 Meeting of AASHTO Technical Committee on Nonmotorized Transportation in Woods Hole, MA

Attendance:

Committee Members: Amy Bell (VT), Paul Ahlenius (KS), Tom Dodds (SC), Tom Huber (WI), Eric Glick (NV), Charlotte Claybrooke (WA), Dave Bachman (PA), Caryn Giarratano (MO), John Balicki (ME), Dwight Kingsbury (FL), Richard Moeur (AZ), Dick Albin (WA) chair, John Fegan, FHWA rep, and Jim McDonnell, AASHTO staff rep.

Guests: Ray Derr, (NCHRP), Theo Petritsch (Sprinkle Consulting Inc), and Josh Lehman (MA).

Agenda Items:

1. Review of Activities and Ongoing Research:

- **NCHRP 20-7 (168) "Determination of Appropriate Railing Heights for Bicyclists "** The current AASHTO Bike Guide recommends a railing height of 42 inches and the current AASHTO Bridge specification calls for a height of 54 inches. This study reviewed the available literature, conducted a survey, and concluded that 48 inches was slightly higher than the center of gravity of an average male cyclist. The study also found that there was minimal evidence that bridge railing height was responsible for bicyclists falling over these railings. The study recommended a compromise figure of 48 inches for both documents, except on downhill segments, where higher speeds may be expected and up to 54 inches was recommended. The Committee discussed the study and the consensus was to recommend that since there was no compelling argument for taller railings, the 42 inch height would be the value recommended to the Geometric Design Committee which had been authorized by the Bridge Committee to make the final decision.

…

Joint Meeting with AASHTO Technical Committee on [Geometric] Design

A half-day joint meeting was held with members of the AASHTO Technical Committee on Design. The following topics were discussed:

1. **Recommended Bicycle Railing Height**: After a review of the research on this topic and discussion, the preference of the meeting was to recommend a height of 42 inches with provision for higher rails in unique locations where a high speed, high angle impact is more likely to occur

(such as short radius curves with restricted sight distance or at the end of a long descending grade) This recommendation was to be taken back to the AASHTO Bridge Committee.[5]

…

[5] This recommendation was accepted by the AASHTO Bridge Committee in May, 2006. It will appear in the 2007 Edition of the LRFD Bridge Design Specs.