

Debris Mitigation Methods for Bridge Piers



Final Report
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DEBRIS MITIGATION METHODS FOR BRIDGE PIERS

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TABLE OF CONTENTS

ACKNOWLEDGMENTS	vii
EXECUTIVE SUMMARY	ix
INTRODUCTION	1
LITERATURE REVIEW	2
Debris Types	2
Debris Sources	2
Debris Transport	3
Debris Accumulation	3
Methods of Mitigation	4
Debris Mitigation Method Selection.....	18
NATIONAL SURVEY	22
Survey Questions and Answers	22
Survey Observations	26
CONCLUSION.....	28
REFERENCES	29

LIST OF FIGURES

Figure 1. Debris fins upstream of bridge piers (Lagasse et al. 2010)	4
Figure 2. Debris fin upstream of bridge pier (Bradley et al. 2005)	5
Figure 3. Debris fins independent of bridge pier structure (Bradley et al. 2005)	5
Figure 4. Treibholzfange debris detention device (Wallerstein and Thorne 1997)	6
Figure 5. Debris basin constructed from metal. (Bradley et al. 2005)	6
Figure 6. Debris basin constructed from gabions (Bradley et al. 2005)	7
Figure 7. Debris basin constructed of precast concrete sections (Bradley et al. 2005)	7
Figure 8. Weirs on outer bank of river (Bradley et al. 2005)	8
Figure 9. Iowa Vanes on outer river bank (Iowa DNR 2006)	8
Figure 10. Kellner jacks used to redirect flow patterns (Bradley et al. 2005)	9
Figure 11. Debris deflector looking upstream (Bradley et al. 2005)	10
Figure 12. Debris deflector schematic (Bradley et al. 2005)	10
Figure 13. Single column debris deflectors (Lyn et al. 2003)	11
Figure 14. Debris accumulation at single column debris deflectors (Lyn et al. 2003)	12
Figure 15. Plan view of hydrofoil deflector (Oppenheimer and Saunders 1995)	12
Figure 16. Profile view of hydrofoil deflector (Oppenheimer and Saunders 1995)	13
Figure 17. Debris sweeper (Bradley et al. 2005)	14
Figure 18. Debris boom protecting surface turbine (Tyler 2011)	15
Figure 19. Debris rack installed upstream (Bradley et al. 2005)	16
Figure 20. Steel debris rack (Bradley et al. 2005)	16
Figure 21. Timber debris rack (Bradley et al. 2005)	17

LIST OF TABLES

Table 1. Debris scenarios seen at bridge sites	2
Table 2. Debris-control countermeasures matrix adapted from Bradley et al. 2005	19
Table 3. Debris mitigation options and review adapted from Sheeder and Johnson 2008	20
Table 4. Survey results summary	26

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EXECUTIVE SUMMARY

Debris accumulation on bridge piers is an on-going national problem that can obstruct the waterway openings at bridges and result in significant erosion of stream banks and scour at abutments and piers. In some cases, the accumulation of debris can adversely affect the operation of the waterway opening or cause failure of the structure. In addition, removal of debris accumulation is difficult, time consuming, and expensive for maintenance programs.

This research involves a literature search of publications, products, and pier design recommendations that provide methods to mitigate debris accumulation at bridges. In addition, a nationwide survey was conducted to determine the state-of-the-practice and the results are presented within.

Numerous methods have been used nationwide with varying degrees of success; even so, no apparent “best” option exists. Site-specific information (e.g., debris sources, classification, and transport), along with the balance of many factors (e.g., cost, aesthetics, and environmental impact) will best direct the method of mitigation used.

INTRODUCTION

Debris accumulation on bridge piers is an on-going national problem that can obstruct the waterway openings at bridges and result in significant erosion of stream banks and scour at abutments and piers. In some cases, the accumulation of debris can adversely affect the operation of the waterway opening or cause failure of the structure. In addition, removal of debris accumulation is difficult, time consuming, and expensive for maintenance programs.

Only limited research has been conducted to determine the best method(s) for debris mitigation. Several methods have been employed; yet objective comparisons of multiple methods have rarely been completed.

The objective to this phase of the study was to determine the current state-of-the-practice for debris mitigation by performing a literature review and national survey of state departments of transportation (DOTs) and to make comparisons of performance and cost effectiveness of employed methods. Lastly, tools to assist decisions regarding future implementation by the Iowa DOT will be offered.

LITERATURE REVIEW

A number of researchers and practitioners have made efforts to address the mitigation of debris accumulation at bridge structures through circulated papers and implemented methods around the US. As such, it can be argued that certain methods are most effective when used in specific locations and debris flow scenarios. Even so, it's quite possible that the recommended mitigation technique was subjectively selected, rather than selected based on the collection of research and previously implemented methods.

The following discussion first aims to give a brief overview of debris types, sources, transport methods, and accumulation tendencies. The reader is referred to the many resources referenced in these sections for a more extensive discussion of these items. Secondly, debris mitigation techniques and the characteristics of each method are presented to provide direction for where each may be most useful and cost effective.

Debris Types

The effects of debris flow must be uniquely evaluated for each structure built over rivers and streams. Types of debris vary from site to site and should be considered when developing a mitigation technique or in future construction. Bradley et al. (2005) classify debris scenarios that are commonly seen at bridge sites and these classifications are listed and briefly defined in Table 1.

Table 1. Debris scenarios seen at bridge sites

Debris Classification	Typical Debris Examples
Very Small Buoyant Debris or No Debris	N/A
Small Floating Debris	Small limbs or sticks, prunings, leaves, and refuse
Medium Floating Debris	Tree limbs or large sticks
Large Floating Debris	Logs or trees
Fine Detritus	Fine detritus consists of silt, sand, and fine gravel
Coarse Detritus	Coarse gravel or rock
Boulders	Large rock
Flowing Debris	Varied mass of clay, silt, sand, gravel, rock, refuse, trees, and/or branches
Ice Debris	Accumulation of ice in waterway

Debris Sources

Similar to the types of debris, the sources of debris can widely vary. The types listed in Table 1 can be attributed to more than one source including, but not limited to, bank erosion, landmass failures, wind action, biological decay and old age, loss of foliage at changing seasons, windthrow, ice loading, animal activities, and riparian zone erosion.

Even though debris can come from a number of sources, problems are most common on rivers and streams with active bank erosion and those that drain wooded or forested areas or corridors (Lagasse et al. 2010). A majority of debris usually enters the river during the first big flood of the

season and it can be expected that debris problems will be worse when there are long periods between floods (Chang and Shen 1979). Additionally, streams exhibiting distinct meanders have been known to have higher rates of debris supply because of the migration commonly seen. Floating debris is composed mostly of old plants and trees that have been scattered along the banks of a stream channel and on channel bars for, sometimes, 10 or more years.

Debris Transport

Not surprisingly, debris transport is the largest unknown when predicting debris accumulation. Even at individual locations, the behavior of river and stream flow is inconsistent as the water level inherently rises and falls with meteorological events. In addition to the varying volumes of water present, a channel varies in width, depth, and slope – all characteristics that greatly influence the transport of debris.

The amount of debris found flowing in a river or stream increases when the depth and width of the channel grow due to the introduction of additional quantities of water. Studies have shown the greatest influx of debris occurs within a relatively short period following the rise beginning on the rising slope of a hydrograph. A majority of debris will be moved at the first opportunity once the hydraulic forces required are large enough, rather than later when water levels begin to drop. One study that shows direct evidence of this phenomenon was conducted by Lyn et al. (2006). As part of this study, three bridges in Indiana were equipped with video cameras, which were employed to capture debris flows following meteorological events. It was shown that a majority of debris flow occurred within 12 hours of a hydrologic event regardless of the event size. Consequently, two specific observations were made by the researchers; 1) there is little correlation between the size of the event and amount of debris flow and 2) the debris-contributing area may be only small part of the entire watershed area.

It is common for debris to float in the thalweg on strait channels and move toward the outer banks when the channel bends. Likewise, during the rising stage of a flood, floating debris tends to move in the thalweg in fairly straight streams and outward to the banks at the receding stage (Chang and Shen 1979). Seldom is debris observed floating in large masses or congregations in a large river (Chang and Shen 1979). Rather, drift collects into short-lived clumps and is quickly broken apart by turbulence, impact with channel banks, or other stationary objects.

Debris Accumulation

The rate of accumulation is largely dependent on the concentration of debris and the magnitude of the flood (Chang and Shen). During a normal flood, it may take several hours before debris could accumulate enough to pose a threat to a bridge, whereas in the rare events of landslides or dam breaks debris could accumulate at a much quicker rate.

Diehl (1997) proved in his studies that debris accumulation is highly dependent on the relationship between the length of debris and width of upstream channel. The design log length, used to estimate the potential for drift accumulation, was defined based on these studies as the

minimum of 1) the width of the channel upstream from the site, 2) the maximum length of sturdy logs, and 3) 30 ft plus one quarter of the width of the channel upstream from the site.

Debris Fins

Debris fins are walls or rows of piles placed directly upstream of bridge piers for which protection from debris accumulation is desired. Though commonly direct extensions of the bridge pier structure – sometimes referred to as “pier nose extensions” – debris fins can also be independent of the bridge. The fins are oriented parallel to the flow of the river to maximize effectiveness, as a greater possibility exists for debris collection when flow is oblique to the fin. In addition, when the debris is oriented in the direction of flow and the debris does not squarely make contact with the pier, the impact is lessened, reducing the effects on the bridge pier (Haehnel and Daly 2002). Note that Haehnel and Daly found the likelihood of direct impact to be rare even when debris has been aligned with the direction of flow.

The effectiveness of fins varies and is most dependent on flow velocity. Debris fins are most effective in higher velocity flows and have been shown to be very effective in areas where large amounts of debris are present (Federal Preservation Institute 2002). Though largely effective, note that debris fins may require some regular debris removal. Examples of debris fins can be seen in Figure 1, Figure 2, and Figure 3.



Figure 1. Debris fins upstream of bridge piers (Lagasse et al. 2010)



Figure 2. Debris fin upstream of bridge pier (Bradley et al. 2005)



Figure 3. Debris fins independent of bridge pier structure (Bradley et al. 2005)

Methods of Mitigation

In-Channel Debris Dams and Basins

Dr. J. Knauss at the Institute of Hydraulics, Technical University of Munich, performed a study in 1985 on what would later be coined the Treibholzfange debris detention device. His study found that driving circular posts into the channel bed, spaced to match the minimum length of debris for which entrapment was desired, was most effective in capturing debris without impeding water and sediment flow. Several varying post configurations were tested in a flume. These configurations can be seen in Figure 4.

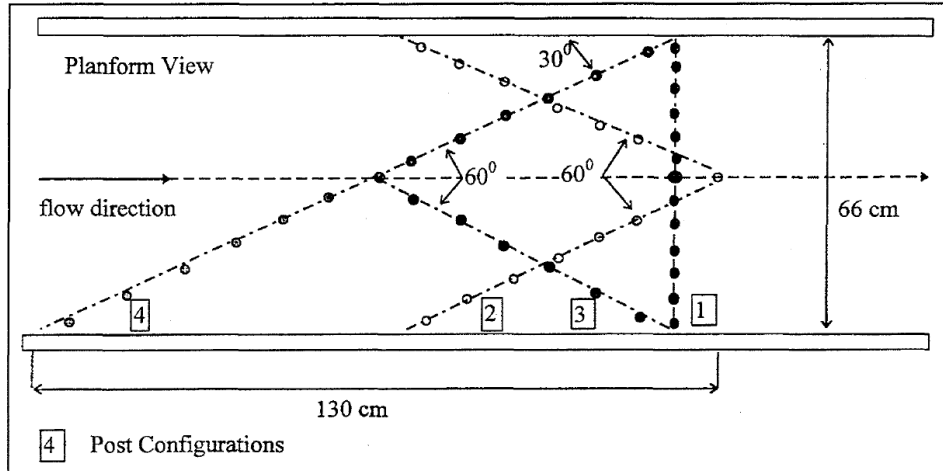


Figure 4. Treibholzfange debris detention device (Wallerstein and Thorne 1997)

Knauss found the downstream pointed V (configuration 2) to best retain debris in addition to limiting backwater effects. Debris was likely to be pushed up and over configuration 1 while, at the same time, restricting flow and increasing backwater effects. The backwater effect of configurations 3 and 4 were less desirable than that of configuration 2 (Wallerstein and Thorne 1997).

Another alternative to upstream debris mitigation is an in-channel debris basin (Figure 5, Figure 6, and Figure 7). These structures are placed across well-defined channels to form basins that impede the flow and create debris storage (Bradley et al. 2005). As one might assume, these structures have considerable capital costs and require regular maintenance and debris removal. However, the basins effectively restrict debris from downstream structures.

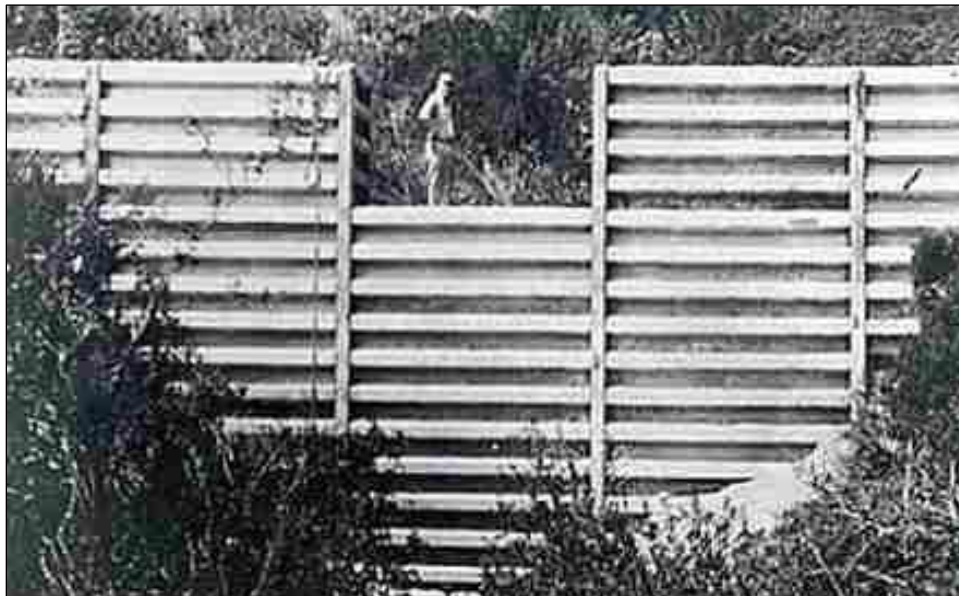


Figure 5. Debris basin constructed from metal. (Bradley et al. 2005)



Figure 6. Debris basin constructed from gabions (Bradley et al. 2005)



Figure 7. Debris basin constructed of precast concrete sections (Bradley et al. 2005)

River Training Structures

Debris flow is primarily directed by the currents within a river, thus one can assume if the currents can be controlled then so also can the debris. One method of controlling the river flow is through the use of jetties or weirs. Figure 8 shows an example of weirs located on the outer bank of a river.



Figure 8. Weirs on outer bank of river (Bradley et al. 2005)

Eddy currents are formed on the downstream side of the weirs thereby trapping debris in the created vortex. Likewise, Iowa Vanes (Figure 9) perform a similar function.



Figure 9. Iowa Vanes on outer river bank (Iowa DNR 2006)

The effectiveness of each method may be specific to location as the functionality may be lessened in locations of straight river channels. Similarly, the total cost of implementation is greatly dependent on location as site conditions can vary considerably from site to site.

Kellner jacks (Figure 10) became popular in the mid-1950s and early 1960s and have been used primarily to redirect flow patterns to reduce outer bank erosion.



Figure 10. Kellner jacks used to redirect flow patterns (Bradley et al. 2005)

A Kellner jack field will trap sediment and debris during flood events and essentially create a levee to confine the river channel (Grassel 2002). Note that the primary function was not to trap debris, but rather to create a levee. Even though the jacks proved effective in many locations, more cost effective measures exist today that render the use of new jacks obsolete.

Crib Structures

Bridge piers are sometimes constructed with an open-pile configuration and debris is easily caught and accumulates in these bents necessitating manual removal. A crib structure reduces or eliminates the open pile configuration by creating walls with the addition of cribbing or sheathing between the piles. When cribbing is used, the openings between boards should be minimized to avoid trapping debris in a similar manner to the original bent. Sheathing consisting of timber or metal is preferred as the spacing and ability to capture debris is minimized. Note that either method is susceptible to severe damage by ice and large debris (Chang and Shen 1979).

Debris Deflectors

Debris deflectors are most often composed of steel columns driven into the river bed in a V-shaped pattern directly upstream of the bridge pier for which protection is desired (Figure 11 and Figure 12).



Figure 11. Debris deflector looking upstream (Bradley et al. 2005)

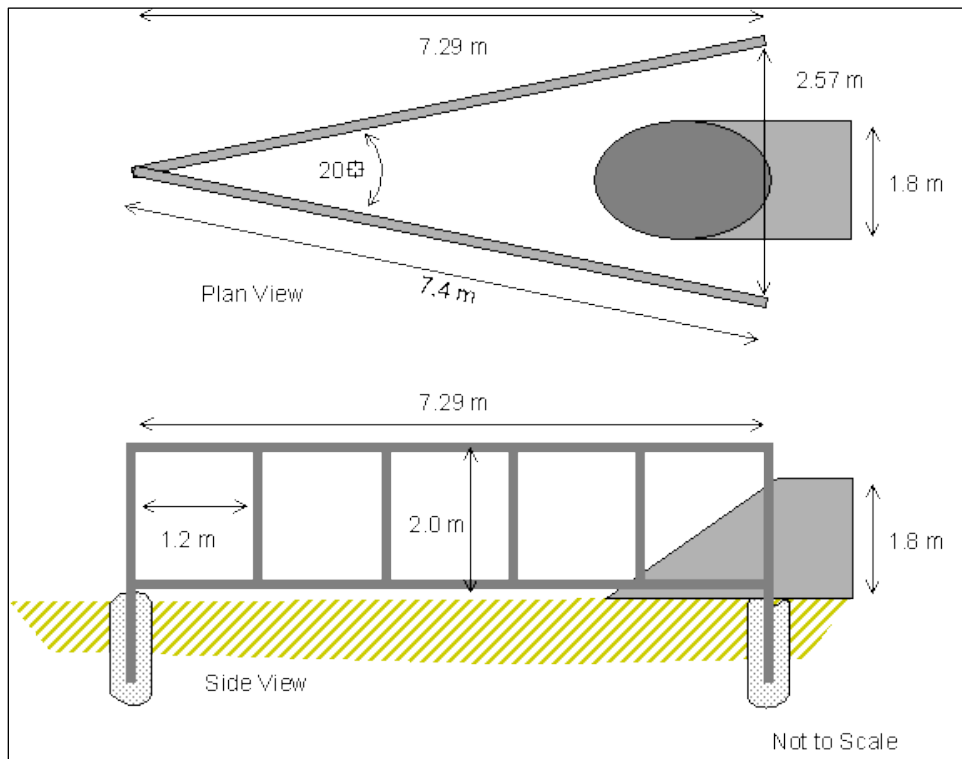


Figure 12. Debris deflector schematic (Bradley et al. 2005)

The V is pointed upstream and is therefore able to shed debris away from the bridge pier. One advantage to this method when compared to the Treibholzfange detention method is the relative size. While Treibholzfange requires driving a river-wide pattern of columns, the debris deflectors are localized to the area of the bridge pier – a more cost effective endeavor.

Debris deflectors tend to be an open grid of vertical members with horizontal members tying each together. The open grid allows water to pass relatively unimpeded and, though largely effective for deflecting debris, the chance exists that debris will be captured by the deflector. As such, one should expect some regular maintenance and debris removal.

A different configuration that has shown little success is shown in Figure 13.



Figure 13. Single column debris deflectors (Lyn et al. 2003)

Individual piles are driven into the riverbed upstream of the pier(s) with the intent to deflect debris. Purdue University (Lyn et al. 2003) conducted a laboratory and field study specific to the configuration and noted that in each case the piles were likely to trap, rather than deflect, debris (Figure 14). The trapped debris proved to be even more ineffective in deflecting subsequent debris. In the field observation, debris collection at the piles would intermittently dislodge and form a single mass of debris that could become reestablished at the bridge pier – a largely undesirable effect.



Figure 14. Debris accumulation at single column debris deflectors (Lyn et al. 2003)

Though very different from the debris deflectors previously discussed, the lunate-shaped hydrofoil deflector created by Saunders and Oppenheimer (US Patent #5839853) is also classified as a debris deflector (Figure 15 and Figure 16).

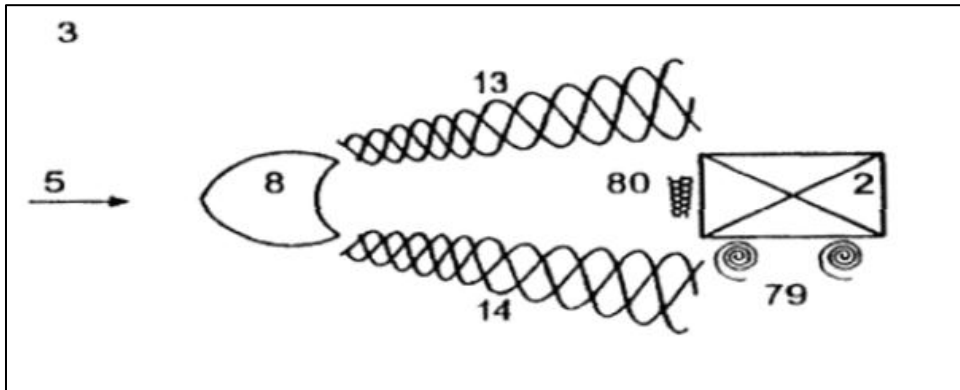


Figure 15. Plan view of hydrofoil deflector (Oppenheimer and Saunders 1995)

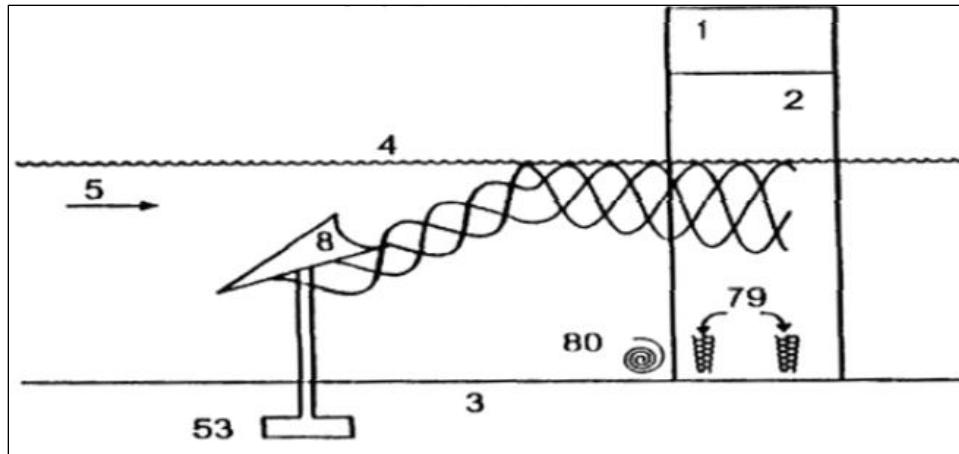


Figure 16. Profile view of hydrofoil deflector (Oppenheimer and Saunders 1995)

The hydrofoil sets below the surface of the water, inclined to generate vortices immediately downstream that guide the debris past the pier. The hydrofoil is pole mounted or tethered to the riverbed upstream of the pier and remains at a given height. In most situations, the water level would be higher than the hydrofoil making the chances of damage from debris flow unlikely.

One disadvantage to this method, however, is the inability of the hydrofoil to rise and fall with the water levels. When water levels fall below the hydrofoil, the hydrofoil becomes inoperative and can be susceptible to damage from debris flows. Saunders and Oppenheimer completed laboratory studies that proved the hydrofoil to be a viable option. Nonetheless, a hydrofoil has never been installed in the field. (The figures show the schematic diagrams from Saunders' and Oppenheimer's original.)

Debris Sweepers

Debris sweepers (Figure 17) were made popular by Debris Free, Inc., which holds the patent (US Patent #6406221) and the sweepers have been used around the US in locations where debris has been known to accumulate at bridge piers.

The sweepers are mounted directly upstream of the pier for which protection is desired and are composed of a vertically aligned water-velocity powered turbine. The rotation of the sweeper aims to deflect the debris to either side of the bridge pier for easier pass-through. One attractive feature is the ability of the sweeper to rise and fall to match the water surface level, achieved by filling the cylinder with a buoyant material.

Even though the debris sweeper proved effective in some locations, some reservations were expressed at the 2007 spring conference of American Association of State Highway and Transportation Officials (AASHTO). Among the observations were device failures due to clogging, being crushed by large debris, and being dislodged from the mounts (Tyler 2011). In addition, the effectiveness and robustness of the debris sweeper in icy conditions was questioned.



Figure 17. Debris sweeper (Bradley et al. 2005)

Debris Booms

Debris booms (Figure 18) offer the advantage of not requiring extensive permanent fixtures in the riverbed like many of the previously discussed methods of debris mitigation.



Figure 18. Debris boom protecting surface turbine (Tyler 2011)

Rather, debris booms are floating deflectors that are tethered to anchors implanted in the river bank. The booms aim to direct surface debris to a more suitable path that will minimize the effect of downstream structures. Up until now, booms have had limited use with respect to bridges and have been used more for protection of hydroelectric generation structures (Tyler 2011).

Some disadvantages of using debris booms exist. Debris travelling below the water surface, as is common with trees with root masses intact, will be affected minimally by booms. In addition, booms require considerable capital cost and are expensive to maintain (Wallerstein and Thorne 1997).

Debris Racks

Debris racks are structures built across a river or stream that aim to capture debris prior to reaching the bridge (Figure 19).



Figure 19. Debris rack installed upstream (Bradley et al. 2005)

Configurations and materials vary among many of the racks. Figure 20 and Figure 21 provide examples of steel and timber racks, respectively.



Figure 20. Steel debris rack (Bradley et al. 2005)



Figure 21. Timber debris rack (Bradley et al. 2005)

Most racks are constructed vertically and at a right angle to the river flow. Others are constructed inclined to the vertical plane, which allows debris to ride up and onto the rack, while even others are constructed skewed to the river flow to help deflect debris towards the river banks. In locations where significant debris exists, debris racks can become packed which impedes water flow and creates backwater issues. The water tends to flank the debris rack eroding the bank and potentially scouring areas downstream where reentry to the channel occurs. Additionally, debris removal from the racks can be necessary and costly because of the inherent propensity to collect debris, frequently more than what would be collected at a bridge pier. (Diehl 1997)

Design Features

Prior to bridge construction and where debris accumulation is anticipated, the opportunity exists to implement design features into the bridge that will minimize mitigation efforts. Examples are freeboard, pier type, location, and spacing, and a special superstructure.

Freeboard is the addition or maximization of space between the anticipated high water level and the lowest member of the bridge superstructure. Accumulation of debris can hopefully be minimized during flood events, which are especially prone to gathering debris, as the ability for debris to be captured by the superstructure is lessened by the increased height of the water. The recommended minimum freeboard of a bridge structure should be 2 feet where there is high potential for floating debris. The freeboard should be increased to 3.3 to 3.9 feet where debris is abundant and known debris problems exist (Bradley et al. 2005). The potential for increased cost to create additional freeboard exists and, accordingly, a cost-risk analysis should be performed to determine the optimum bridge elevation.

Pier type, location, and spacing can all have an impact on debris accumulation. A solid-walled pier fairs much better when compared to an open pile bent structure as the chance for debris to be captured is lessened. Additionally, piers that are parallel to channel flow are likely to capture less debris as the pier area perpendicular to flow is minimized. Lastly, where possible the distance between piers should be maximized or at least spaced a distance apart that is greater than the anticipated design log length. This feature would avoid a single log being captured between two piers if travelling lengthwise perpendicular to flow.

Where heavy debris flows and overtopping of the bridge are anticipated in large flood events, in addition to designing the bridge to withstand hydrostatic forces in submerged state, one can reduce the potential for accumulation by minimizing the profile and number of openings of the superstructure, i.e., solid barrier walls.

Lastly, regardless of the measures one takes to mitigate debris accumulation, at least some debris will likely be captured by a bridge structure. Providing access to the bridge to remove debris for either annual maintenance or emergency situations can prove beneficial. The effort required to remove debris can be costly, thus improving access may return the initial cost over time.

Debris Mitigation Method Selection

Prior to conducting any design or implementation of debris mitigation methods, a field investigation should be completed with the purpose of understanding the debris problem at the bridge. When available, the most useful source of information is from past flood events. Unfortunately, this type of information rarely exists, thus requiring a thorough field investigation to reveal the types of debris transported and better clarify the required analyses for estimation of debris quantities. Information to assist the engineer may include soil, land use, and topographic mapping; aerial photographs; observations of the flow characteristics near the site and any direct and indirect evidence of high delivery potential for floating debris upstream of the site; sediment and discharge data; and future changes in watershed (Bradley et al. 2005).

Each of the mitigation methods has certain advantages, disadvantages, and associated costs. Determining which is best for any one bridge becomes an exercise in balancing those options. Table 2 and Table 3, adapted from previously conducted research, each provide direction for determining the appropriate method at a specific bridge.

Table 2 was developed to identify the abilities and best area of application for each countermeasure, provide information for anticipated maintenance costs, and indicate aesthetic and environmental impacts. The following types of debris used within this table are defined previously in this report: light flowing debris, medium flowing debris, large flowing debris, flowing debris, fine detritus, coarse detritus, and boulders.

Table 2. Debris-control countermeasures matrix adapted from Bradley et al. 2005

Countermeasure	Countermeasure Characteristics									
	Debris Classification						Maintenance	Aesthetics	Environmental Impact	
	Floating Debris			Flowing Debris	Bed Material					Estimated Allocation of Resources
	Light	Medium	Large		Fine Detritus	Coarse Detritus	Boulders	H=High M=Moderate L=Low	U=Undesirable A=Acceptable D=Desirable	H=High M=Moderate L=Low
Deflectors		x	x				x	H-M	U	L
Fins		x	x					M	A	L
Crib Structure		x	x						U	L
RTS - Iowa Vanes					x			M	A	M
RTS - Permeable Spurs				x	x	x		M	A	M
RTS - Impermeable Spurs				x	x	x		H	A	H
In-Channel Debris Basins				x	x	x		H	A	H
Flood Relief Sections		x	x					L	A	L
Debris Sweeper		x	x					L	A	L
Booms	x	x						L	U	M
DF - Freeboard		x	x					L	D	L
DF - Pier Type, Location, and Spacing		x	x					L	D	L
DF - Special Superstructure		x	x					L	D	L

RTS=River Training Structures

Table 3. Debris mitigation options and review adapted from Sheeder and Johnson 2008

Option	Benefits	Disadvantages	Annual Cost over 10 Year Period
Maintenance Removal of Debris	Simple Operation	Required over life of bridge; disruptive of aquatic ecosystem; accumulation during flood events may jeopardize bridge, cause scour and flooding	Low to Moderate (over longer term)
Vanes/weirs employed to direct debris flow through bridge opening	Following installation, may alleviate or reduce additional maintenance requirements	Will lead to alteration of sediment transport processes; if not designed correctly, can cause aggradation or erosion in the vicinity of the bridge. Debris may tend to hang up on structure	Low
Debris Deflectors	Simple design and construction	May trap debris upstream of bridge requiring maintenance removal; known to fail under high lateral forces of trapped debris; failure of piles may jeopardize bridge	Low
Debris Basin	Simple design, construction, and operation; potential to sell collected timber and sediment	May need to purchase land if not located in right-of-way; requires periodic removal of collected sediment and debris; lack of sediment transmission may lead to erosion downstream; may adversely affect migratory species	Moderate to High
Debris Sweepers	Active system; following installation, may alleviate additional maintenance requirements; requires little disturbance of the stream channel	Failure of system can increase potential for debris accumulation; not appropriate for certain bridge configurations (if span is less than maximum length of debris)	Low to Moderate
Crib walls, debris fins	May not require stream modification or continuing maintenance	Low reliability; problem may continue; maintenance required	Moderate
Reconfiguration of riprap at piers	Provides more effective scour protection as well as debris alleviation; can create system that alleviates both debris and scour	None	Moderate
Channelization or reconfiguring the channel	Prevent debris and sediment accumulation by increasing rate of flow through steepened reach	Higher velocity could cause scour at bridge; may cause erosion of bed and banks upstream; potential maintenance costs associated with erosion; not sustainable if river system is unstable	High
Removal of unneeded upstream infrastructure or other obstructions	Eliminates obstructions that may be causing sediment and/or debris-related problems in the vicinity of the bridge; no maintenance required following removal	Removal of obstructions may create new flow patterns, which may lead to additional sediment and/or debris related problems	Moderate to High

Maintenance costs indicated by high, medium, or low are a subjective estimation and are compared relative to the other countermeasures within the table. A low rating indicates that the countermeasure is relatively maintenance free; a moderate rating indicates that some maintenance is required; and a high rating indicates that the countermeasure requires more maintenance than most of the countermeasures in the matrix.

Aesthetically, the countermeasures have varying degrees of desirability. Like the maintenance costs, and rated by a U-undesirable, A-acceptable, or D-desirable, the aesthetics of each countermeasure is compared subjectively and relative to the other countermeasures within the table. A U rating indicates a noticeably unpleasing sight, an A rating indicates that the countermeasure is unobtrusive for the most part, and a D rating indicates the countermeasure is pleasing to the sight (Bradley et al. 2005).

Lastly, the environmental impact rating indicates the anticipated level of effect each countermeasure would have with respect to the other countermeasures. The ratings (low, medium, or high) are subjectively assigned and indicate minimal effect, mild adverse effect, or adverse effect on the environment, respectively.

Table 3 presents specific advantages and disadvantages for many of the debris mitigation methods. In addition, the anticipated cost over a 10 year period is given in comparison to the other methods.

NATIONAL SURVEY

To best determine the current state of the practice regarding debris deflection at bridges, a survey was developed and sent out nationally to state departments of transportation. Thirty-four responses from 31 different states were received. The questions and summary are provided herein.

Survey Questions and Answers

Question 1: What methods of debris deflection have been used in your state?

Methods of Debris Deflection	
Debris Fins	Crib Structures
Debris Deflectors	In-Channel Debris Basins
Debris Sweepers	River Training Structures
Debris Racks	None
Booms	Other

Answer 1

Methods of Debris Deflection Responses			
Debris Fins	2	Crib Structures	2
Debris Deflectors	11	In-Channel Debris Basins	1
Debris Sweepers	3	River Training Structures	4
Debris Racks	4	None	20
Booms	0	Other	5

Response Comments

1. For the in-channel debris basins, we have used this approach in channels with extreme sediment accumulation, not as a wood debris provision. (Alaska)
2. During design, we try to adhere to some common practices that enhance our structure's potential for collecting debris. These practices include refraining from using short spans and avoid skewed bents when significant debris is expected. Occasionally we may shape the nose of our piers such that it helps with the deflection of the debris. (Louisiana)
3. Sloped/battered upstream pile/pier, solid pier wall/encased pile bents. (Nebraska)
4. Rounded pier ends on the upstream side. (District of Columbia)
5. Sweepers proposed but not used. (New York)

Question 2: Please rate the overall performance of each method you selected as Poor, Satisfactory, Good, or Excellent

Answer 2

Overall Performance Rating				
Deflection Method	Poor	Satisfactory	Good	Excellent
Debris Fins	0	2	0	0
Debris Deflectors	2	8	1	0
Debris Sweepers	2	0	1	0
Debris Racks	1	3	0	0
Booms	0	0	0	0
Crib Structures	0	2	0	0
In-channel Debris Basins	0	1	0	0
River Training Structures	0	4	0	0
Other	0	1	1	0

Response Comments

1. The debris deflectors have only been installed on a very limited number of structures. Estimate installation occurred approximately 4 years ago, so no extensive data on performance has been developed. (Nevada – Regarding debris deflectors)
2. We have used the indicated devices once or twice. They perform OK but we don't have a lot of experience with them. (Georgia – Regarding debris deflectors and river training structures)
3. IDOT's 10 - 15 sweepers are the Debris Free bridge sharks or MOABS. Very scattered performance. Various failure modes- ice is most common. Debris racks are very few in number. (Illinois – Regarding debris sweepers and debris racks)
4. In cold climates, debris racks (particularly at culvert inlets) can promote frazil ice accumulation, potentially leading to a blockage. (Alaska – Regarding debris racks)
5. One installation in FDOT District 3 on SR4 over Escambia River did not perform well. Low flow conditions during drought probably made things worse. (Florida – Regarding debris deflectors)
6. The sloped upstream end of the pier/bent/pile helps to keep any debris at or above the water surface. (Nebraska – Regarding other methods)
7. In Minnesota District 7 Mankato we used two different debris removal devices made by Debris Free from California. The smaller device the shark could not stand up to the large trees that flowed past our bridges on the Minnesota River. I would call the smaller device the bridge sharks a sweeper and it had a poor performance. The larger device, the MOAB (Mother Of All Bridge sharks), I believe could have had a better performance had it not been for the piling installation. The smaller shark was mounted on a stainless steel rail system. The MOAB was designed to be mounted on a pile system. Both systems were designed to allow the device to rise and lower according to the water level. Because of poor welds on piles our MOAB's were mounted they failed. Before the large debris pile caused the failure, the MOAB system was deflecting timber debris. (Minnesota – Regarding debris deflectors)
8. There were some issues with maintenance. (Florida – Regarding debris deflectors)
9. No survey was conducted to rate the performance of the practice. (District of Columbia – Regarding rounded pier noses on upstream side)

Question 3: Please rate the overall cost effectiveness of each method you selected as Poor, Satisfactory, Good, or Excellent

Answer 3

Overall Cost Effectiveness Rating				
Deflection Method	Poor	Satisfactory	Good	Excellent
Debris Fins	0	1	1	0
Debris Deflectors	2	7	0	0
Debris Sweepers	3	0	0	0
Debris Racks	1	3	0	0
Booms	0	0	0	0
Crib Structures	0	2	0	0
In-channel Debris Basins	0	0	1	0
River Training Structures	0	3	1	0
Other	0	1	1	0

Response Comments

1. Long-term maintenance burdens and costs should be considered. (Alaska – Regarding general debris mitigation)
2. Appears to minimize accumulation of debris (Nebraska – Regarding sloped upstream and of piers, bents, and piles)
3. Could have been better for the MOAB if it wasn't for pile failure (Minnesota – Regarding debris sweepers)

Question 4: Have pier design methods been used in your state specifically to mitigate debris accumulation at bridges?

Answer 4

Pier Design Methods Specifically Used to Mitigate Debris Accumulation		
	No	Yes
Pier Design Methods Have Been Used	23	13

Response Comments

1. Vermont does not use multi-column piers in stream. The piers are either solid wall piers aligned with the flow of the stream or single circular column piers. (Vermont)
2. Rounded pier noses. Use of wall-type piers when feasible. (Utah)
3. Older bridges often feature concrete infill walls, which can help reduce wood debris accumulation. Newer bridges tend to have the (open) multi-pile bents or drilled shafts. (Alaska)
4. Attempts are made not to locate piers within the main channel, to use longer spans in the channel area, and to use single column bents in the channel area. (Arkansas)

5. Not in ordinary situations however in some special bridges. Not practiced frequently. (Louisiana)
6. Just the normal design measures...pier orientation in the waterway and geometry (rounded or angled ends). (Wisconsin)
7. Pier walls have used sloping extensions upstream of the bridge to divert debris. (California)
8. The main thing we try to avoid is placing piles or piers in the stream channel. If this cannot be avoided we try to use a singular circular pier to limit debris accumulation. (South Carolina)
9. Nebraska Hydraulic Guidelines recommend battering the upstream end of the Pier/Bent/Pile a minimum of 1H:8V. (Nebraska)
10. Avoid trestle pile bents where heavy debris is expected. (Missouri)
11. Various designs have been used to try to mitigate the debris accumulation. Rounded, pointed, tapered, pier designs. I worked on a bridge maintenance crew as a worker and supervisor for 30 years and have not seen a pier design yet that can prevent timber debris accumulation from our bridges! (Minnesota)
12. Typically if debris and ice are concerns for a stream crossing the substructure in the waterway is designed to incorporate web walls between the individual bent columns or designed as solid wall type piers. If possible/feasible, a single clear span structure is utilized. (South Dakota)
13. Our current design policy does not allow two column piers located within a channel. While this does not mitigate the accumulation of debris, it does provide structural redundancy to reduce the potential for a bridge collapse as a result of debris impact or scour on an individual column. (Texas)
14. We try to reduce number of piers in the stream. (Michigan)

Question 5: For which state or U.S. territory are you completing this survey?

Answer 5

Respondent Locations		
Alaska	Maryland	Pennsylvania
Arizona	Massachusetts	South Carolina
Arkansas	Michigan	South Dakota
California	Minnesota	Texas (2)
District of Columbia	Missouri	Utah
Florida (3)	Montana	Vermont
Georgia	Nebraska	Virginia
Hawaii	Nevada	Wisconsin
Illinois	New Jersey	Wyoming
Kansas	New York	
Louisiana	North Dakota	

* A single response was received from each state unless noted otherwise.

Table 4. Survey results summary

Location	Debris Fins			Debris Deflectors			Debris Sweepers			Debris Racks			Crib Structures			In-Channel Debris Basins			River Training Structures			Other			None		
	Method Used	Performance	Cost Effectiveness	Method Used	Performance	Cost Effectiveness	Method Used	Performance	Cost Effectiveness	Method Used	Performance	Cost Effectiveness	Method Used	Performance	Cost Effectiveness	Method Used	Performance	Cost Effectiveness	Method Used	Performance	Cost Effectiveness	Method Used	Performance	Cost Effectiveness	Method Used	Performance	Cost Effectiveness
Alaska							X	S	S	X	S	S	X	S	G	X	S	S									
Arizona																											X
Arkansas																											X
California				X	G	S	X	G	P	X	S	S															
DC																						X	S	S			
Florida				X	P/S	S																					
Georgia				X	S	S										X	S	S									
Hawaii																											X
Illinois							X	P	P	X	S	S															
Kansas	X	S	G													X	S	S									
Louisiana																											X
Maryland																											X
Massachusetts																											X
Michigan																											X
Minnesota				X	S	P	X	P	P																		
Missouri				X	P	P							X	S	S												
Montana																											X
Nebraska	X																										
Nevada				X	S																						
New Jersey																											X
New York																											X
North Dakota																											X
Pennsylvania																											X
South Carolina																						X					
South Dakota																						X					
Texas																						X					
Utah	X	S	S	X	S	S				X	P	P															
Vermont																						X					
Virginia																											X
Wisconsin				X	S	S																					
Wyoming				X	S	S										X	S	G									
Unknown				X	S	S																					

X = Used, S = Satisfactory, G = Good, P = Poor

Survey Observations

By the survey responses received, evidence is provided that only a fraction of the states have attempted some method of debris mitigation. The apparent need for mitigation is clear for some states, yet others may have minimal or no need at all. Overall, the entirety of the United States was fairly well represented as there was no region where at least one response was not received.

Of all the methods listed, debris deflectors were most commonly implemented and with varying success. The states that have used this method rated the performance as satisfactory, aside from California and Missouri, which rated the performance as good and poor, respectively. It should be noted that the cost effectiveness of debris deflectors was never rated higher than satisfactory in all cases.

Alaska has attempted more of the listed methods of mitigation than any other state; debris racks, crib structures, in-channel debris basins, and river training structures have been used. In each case, the performance and cost effectiveness was rated as satisfactory, excluding in-channel debris basins where the cost effectiveness was rated as good.

The performance of any one debris method was never rated higher than good. Those receiving a performance rating of good were debris deflectors and debris sweepers in California.

Likewise, the cost effectiveness of any one debris mitigation method was never rated higher than good. Those receiving a rating of good were in-channel debris basins in Alaska, debris fins in Kansas, and river training structures in Wyoming.

Four states implemented mitigation techniques that were rated as poor for both performance and cost effectiveness. Illinois, Minnesota, Missouri, and Utah rated debris sweepers, debris sweepers, debris deflectors, and debris racks as poor, respectively.

Only one state rated the performance of one method as good and the cost effectiveness of that same method as poor. California rated debris sweepers in this way.

Five locations indicated that other methods of debris mitigation were implemented. These methods included rounded pier nose at upstream side (District of Columbia), singular circular piers (South Carolina and Vermont), and solid wall type piers (South Dakota and Vermont). Texas did not indicate what other method of debris mitigation was used.

CONCLUSION

The apparent effects of debris accumulation on bridge structures have made it clear that a need for debris mitigation exists. Without mitigation, bridge structures are susceptible to scour, overloading, or even collapse. The objective of this report has been to present methods used currently or in the past to prevent debris-inflicted damage.

Many options exist and have been tried with varying degrees of success. Be that as it may, there is no apparent “best” option, as site-specific conditions often determine the performance of any one system. For this reason, it would be wise for any engineer to first study the debris source, transport characteristics, and accumulation tendencies at a single bridge location. Other factors including maintenance costs, aesthetics, and environmental impacts must also be considered.

With this knowledge and consideration, along with the previous accounts of successes and failures, a mitigation option can be selected that best addresses the situation and need.

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