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JOURNAL`S UNIVERSITY OF BABYLON FOR ENGINEERING SCIENCES (JUBES)

مـــجلـة جـــامعة بـــــابـل للعلـــــوم الهندسية

Vol. 32, No. 5. \ 2024 ISSN: 2616 - 9916

Review on the Collar Performance in Reduction Local Scour

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Received:	22/3/2024	Accepted:	15/10/2024	Published:	30/12/2024

Abstract

Local scour around the pier is one of the main reasons for bridge failures in the world. Many studies have been conducted to assess the hydraulic performance of different types of countermeasures designed against scouring. Generally, the countermeasures can be classified into two groups: flow-altering and bed-armoring techniques. Collar is the most commonly used countermeasure to change the flow around the pier, hence reducing local scour depth. This paper briefly reviews the most up-to-date studies regarding using the collar method as a protective technique for the pier. The reviewed studies indicated that the amount of scour reduction around the collar-protected pier is based on the size, shape, and position of the collar. The rectangular collar outperforms better than circular, trapezoidal, and triangular shapes under the same conditions. Additionally, combination the collar with other types of countermeasures can enhance the scour reduction process.

Keywords: Collar, Down flow, Flow-altering, Pier, Scour, Vortex

1. Introduction

"One who overlooks water under a bridge will find a bridge under water" [1]. This anonymous citation emphasizes the significant impact of flowing water on bridge safety, specifically on the piers supporting the bridge. Bridge failures have occurred since the beginning of construction thousands of years ago. Today, a considerable portion of technical understanding of bridge engineering is based on historical bridge hazards. The scour phenomenon around bridge piers is a major source of concern for bridge foundation stability[2] . Generally, scour is a natural phenomenon caused by the action of moving water that removes and erodes material from riverbanks or the area surrounding bridge piers. Scour can be classified into two types: general scour and localized scour. The first type is a lowering of the streambed across the stream due to natural stream changes or human activity[3]. General scour arises regardless of the existence of the bridge structure and is classified as short- or long-term scour. The combined effects of contraction and local scour caused by the presence of the bridge are referred to as localized scour [4], [5]. Contraction scour occurs when the river's cross-sectional area changes as a result of the installation of structures such as bridge abutments and piers. Local scour, on the other hand, is caused by a complex flow pattern around bridge piers, resulting in a decrease in bed elevation that gradually proceeds and eventually stabilizes at an equilibrium depth. The developed scour hole may cause the bridge to collapse, especially during river floods. Scour is further classified based on the ability of the approaching flow to transport bed material. Clear-water scour arises when bed sediment isn't moved by the approach flow due to the too low velocity of flow. In contrast, live-bed scour takes place when the approach flow transports the bed load [6]- [8].

Previous studies indicated that specific parameters effect on the occurrence of local scour, such as the materials of the river bed, fluid properties, the bed configuration, the geometry of the pier, and time[9]. The scouring issue is very harmful to the hydraulic structure, causing numerous hydraulic problems. Thus, researchers are constantly encouraged to develop scientific methods to reduce this scour and its catastrophic impact on water infrastructure. Several techniques have been developed to deal with scour problems at the bridge site and prevent its progress. These techniques are based on several concepts [10], including: preventing the formation of the horseshoe vortex or lessening its effectiveness; creating a circulatory flow adjacent to the bed that is in the opposite direction to reduce the impact of the horseshoe vortex; installing an apparatus on the upstream side of the pier to transport material to the scour hole; and using an armor layer with an appropriate size distribution and thickness to inhibit scouring.

The most challenging issue for hydraulic engineers is preventing the formation of scour holes around the bridge pier while ensuring cost-effectiveness and stability in design considerations. In general, engineering techniques for scour reduction can be classified into two classes: bed-armoring and flow-altering countermeasures. The first class of countermeasures acts as physical obstacle, resisting the shear stress that occurs around the pier. These barriers are often huge and heavy, making them difficult to remove by the action of flow, such as riprap stones, cable-tied blocks, reno mattresses, and gabions. The flow-altering countermeasures, on the other hand, reduce the horseshoe vortex strength by diverting the down flow. Flow-altering techniques include the use of slot and internal connecting tubes in the pier, collars, suction on the pier, and modifying pier geometry [11] [12]. In literature, many studies focused on the scour around piers protected with collars, and based on their findings, numerous collar designs have been proposed that can reduce the scour effect and hence prevent bridge failure. In this study, a detailed review of current studies on applying the collar as a countermeasure technique is presented, with a focus on recently proposed designs as well as revisiting some studies on previous designs.

2. Local Scour Mechanism

Down flow at the upstream face of the pier and the vortices creation at the base are the key mechanisms that cause local scour at bridge piers. The development of complex vortex systems, caused by flow separation, results in the formation of a scour hole [13]. As shown in Fig. 1, the flow declines as it approaches the pier and comes to a halt at its face. The velocity of approach flow decreases until it vanishes upstream of the pier, and hence the pressure increases. At the pier site, the pressure profile has the largest value at the water surface, and then it declines downward. Accordingly, the creation of the adverse pressure gradient results in a separation of the 3D boundary layer upstream the pier. This mechanism leads to a downward flow that impacts on the stream bed, initiating the scour hole in front of the pier, and then rolling up to form a complex vortex system [14]. This vortex system, shaped like a horseshoe, is known as the horseshoe vortex, and it drives the downward flow inside the scour hole closer to the pier. This

Vol. 32, No. 5. \ 2024 ISSN: 2616 - 9916

vortex then extends downstream along the sides of the pier. When the scour depth grows, the strength of the horseshoe vortex weakens, which consequently decreases the sediment transportation rate from the base of the pier [15]. Based on Melville's results [16], the downward flow behaves as a vertical jet that erodes the bed. This downward flow is the main cause of the scour, while the horseshoe vortex is an outcome of the scour and not the basis of it, where it is firstly weak and low. The separation of the flow downstream of the pier creates wake vortices that act as miniature tornados, removing particles from the river bed and forming a scour hole downstream of the pier [17]- [19]. However, both horseshoe and wake vortices remove bed material from the pier's base. The strength of the wake vortices decreases with distance downstream, resulting in the accumulation of sediment closely downstream of the pier.

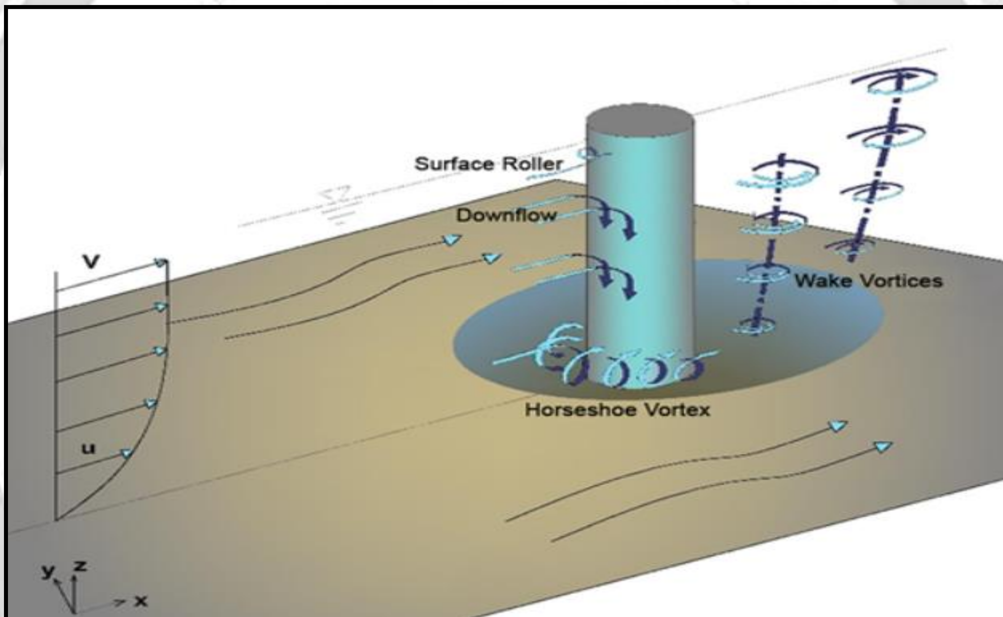

Fig. 1: Flow structure around a cylindrical bridge pier [13].

3. Collar as a Countermeasure Against Scouring

A Collar is a thin plate constructed from a strong material, such as steel or concrete, and attached to a pier at a specific elevation [11][20]. At any height above the bed, the collar separates the flow into two zones: the top and bottom of the collar [2]. The Collar is considered to be an efficient way of reducing the volume and depth of scour around bridge piers by decreasing the impact of the eroding agents and redirecting flow toward the collar sides. Figure 2 shows that, in the region above the collar, the strength of the down flow is reduced due to the collar's impact, which functions as an obstruction to the down flow. As a result, the horseshoe vortex in the zone below the collar decreases, reducing the possibility of sediment transport [21].

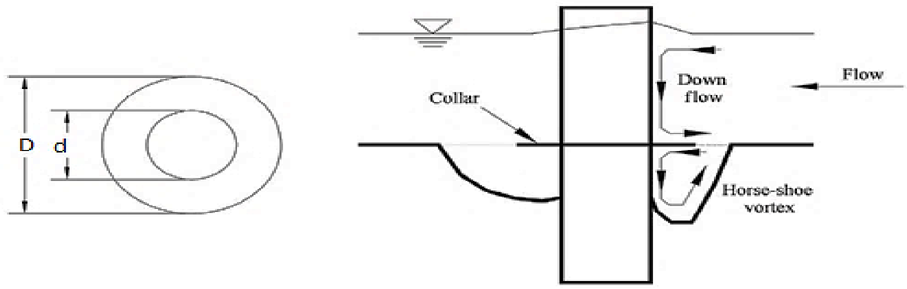

Fig. 2: The impact of collar on pier [2].

Compared to an unprotected pier, the scour reduction percentage can be calculated from the following relationship:

$$R = \frac{ds_1 - ds_2}{ds_1} \times 100 \quad (1)$$

R is the percentage reduction in local scour depth around the pier bridge.

d_{s1} is the non-collar scour depth

ds_2 is the scour depth in the presence of collar.

Collar effectiveness may improve when combined with additional countermeasures, such as slots, bed sill, vanes, and piles [22]. For example, Chiew [23] found that a collar and slot combination serves as a useful alternative to riprap protection for scour issues at bridge piers. They concluded that a collar with a diameter twice the pier diameter (2d) reduces scour depth by about 20% when there is no slot; however, when a (0.25 d) slot is combined with this collar, the scour depth is diminished to zero. A sleeve, which is a hollow cylinder of larger diameter surrounding the pier, can be used in conjunction with a collar as an effective protective device to decrease outside scour. Singh et al. discovered that pier scouring can be eliminated by combining a 1.5d sleeve with a 2d collar plate and sealing the sleeve 0.25d below the top of the sleeve [24]. According to Moncada et al., a slot-collar combination can achieve 100% efficiency when the collar size is twice the pier diameter and it is positioned at bed level, regardless of slot length [25]. For bridge pier groups with two piers in line, the utilization of continuous collars and riprap results in a significant scour reduction, which is about 50%. On the other hand, continuous and independent collars without riprap can decrease the scour depth by about 25 and 30%, respectively [26]. Additionally, combining riprap stones with a collar placed at the streambed bed and around a rectangular pier reduces the size and amount of stable riprap stones [27]. However, the effect of the collar decreases with increasing pier skew angle and aspect ratio. The series of small collars attached to a pier can work as roughness elements, reducing down flow strength and scour depth. However, the scour depth does not significantly decrease when the small collars are placed close together. On the other hand, if they are placed far apart, the scour depth decreases compared to the non-collar pier [28]. The problem of using collar around bridge pier has been extensively investigated by various researchers. Numerous studies have been conducted over time to evaluate collar performance, taking into account a variety of criteria such

Vol. 32, No. 5. \ 2024 ISSN: 2616 - 9916

as collar shape, collar size, collar position relative to the bed level, pier geometry, and flow conditions. The next section provides a brief overview of the most recent research on collar designs as pier protective equipment.

4. Literature Review

Singh et al. 2001studied experimentally the effect of various sizes of collar plates on maximum scour depth. They found that circular collars with sizes of (1.5, 2, and 2.5) times the pier diameter when positioned on the bed can reduce scour depth by 50%, 68%, and 100%, respectively, compared to an unprotected pier. That is because of the larger shielding effect of the larger collar. Additionally, a 2d collar plate placed at a distance 0.1d below the bed achieves a maximum efficiency of 91%. In contrast, a collar positioned at 0.5 d above the bed only reduces scour by 25% [24].

Zarrati et al. 2004 investigated the sediment motion thresholds around a rectangular pier that aligned to the flow and skewed at 5 and 10 degrees. Two rectangular collars of varying sizes were utilized, with effective widths equal to two and three times the pier width. It was discovered that the larger collar at lower levels is more efficient, and the collar efficiency decreases as the skewness of the pier increases. A larger collar when installed at streambed level can reduce scouring by 74%. On the other hand, larger collars that are skewed to the flow at 5 and 10 degrees can reduce scour depth by 56 and 35%, respectively, when installed at streambed. Additionally, when compared to earlier tests on circular piers, the larger collar aligned to the flow was found to be more efficient in reducing scour depth for rectangular piers. Due to the large stream-wise size of the rectangular pier, the expanse of the downstream scour hole can’t extend the upstream border of the collar. Because installing the collar at the streambed level in practice is challenging, the authors carried out an extra test to see if installing an additional collar at a higher level can enhance the scour protection. In this test, the larger and smaller collars were fixed at distances of 0.2d and 0.6d measured from the bed. Comparing the depth of the scour hole to the unprotected pier, it was discovered that the second collar, which was located higher, created a 50% reduction [29].

Garg et al. 2005 conducted an experimental study to investigate the impact of flow conditions, the pier situation, and the size of a single collar on scour reduction. The results indicated that, at a certain position, a collar of larger size performs better than the other small collars. When the diameter of the collar plate (D) increases from (1.5 to 3.0) d, where d is the pier diameter, the reduction in maximum scour depth increases from 37% to about 100%, respectively. However, collar efficiency is highly related to vertical distance from the stream bed. When a (2d) diameter collar, placed at the bed level, is shifted upward a distance (0.5d), the collar performance reduces from 66% to 16%, respectively. On the other hand, when collar plates of sizes equal to three times the pier diameter or larger are placed at the bed level, they can entirely protect against scour. The authors stated that a pier fitted with a collar plate of an appropriate dimension can eliminate the issue of local scour, but the collar will become useless if the general bed level lowers over time [30].

Based on the results of Mohamed et al. 2008, a triangular collar of width (B) fitted around a rectangular pier of width (b) can decrease scour depth by 84% and 22%, respectively, for relative width (B/b) of 5 and 1.5, when compared to an unprotected pier. Furthermore, when the relative width of a triangular collar is small, the main scour hole is developed upstream of the pier nose, whereas when the relative width is large, the main scour hole is developed around the collar's apex angle [31].

Negm et al. 2009 indicated that the rectangular collar shape possesses a larger protection expanse than trapezoidal, circular, and triangular collar shapes. This is due to its ability to absorb extra downward velocities generated at the upstream nose of the pier. Thus, compared to the non-collar pier, using a rectangular collar as an optimal shape highly minimizes the relative scour depth around the bridge pier by 90% for collar width equals five times the pier width. Furthermore, they found that the triangular collar is the worst one, and both the circular and trapezoidal collars give a mostly similar reduction. Additionally, as the relative width of the collar increases, the protected part on the movable bed expands. This reduces the contact area between the downward velocity and the bed, causing a significant reduction in the maximum relative scour depth [32].

According to the results of an experimental study conducted by Zarrati et al. 2010, piers protected with collars with diameters of 2d or 3d had scour depths that were approximately 20% and 26% less than the unprotected pier, respectively. It was also found that using the collar in conjunction with riprap reduced the riprap layer extension on the pier's front and sides. With a collar of diameter (D=2d), however, the riprap extent in front and sides of the pier was significantly reduced and it was completely eliminated at (D=3d). These findings show that, assuming constant thickness, the volumes of riprap with collars of D = 2d and D=3d are 31% and 57% less than for a pier without a collar, respectively [14].

Jahangirzadeh et al.2014 concluded that the rectangular collar outperforms the circular collar in terms of weakening and controlling both the horseshoe vortex and the rising flow. The existence of sharp corners in the rectangular collar provides a larger coverage for preventing the downward flow. Furthermore, they observed that the under bed collar performs better than the collars located close to the stream bed or higher. The best and most cost-effective collar dimensions for maximum scour reduction were discovered to be D = (3-3.5) d [13].

Chen et al. 2018 found that flat collars are usually larger in diameter, which make them more expensive to fabricate and difficult to install. Thus, they utilized experimental and numerical techniques to assess the performance of the hooked -collar with a width of 1.25 d and a height of 0.25 d. When compared to the bridge pier without a collar, it was revealed that a hooked collar placed 0.25d under the channel bed can decrease the scour depth by 24%. Furthermore, a single hooked collar installed at the bed level can reduce scour depth by 42%, while a double collar located at distances 0 and 0.25d from the bed level reduces the scour by about 50%. The hooked collar that is linked to a small ring outside the collar deflects the down flow away from the pier in an upward direction, causing a weak down flow [33].

Farooq et al. 2020 investigated the efficiency of an octagonal hooked collar placed at the streambed and attached to a pier of an octagonal cross-section of width (w). These collars with varying sidewall heights and widths were tested experimentally. It was found that an octagonal hooked collar with a (2.5w) width and a (0.45 w) side wall height performs better in terms of protecting the pier against local scouring. When compared to the octagonal pier without any protections and under the same flow conditions, the percentage reduction in the scour depth hole for the optimal hooked collar was 73.3% [34].

Bestawy et al. 2020 investigated the effectiveness of various shapes of collar around a circular pier, including: circular flat, circular with wings at 45° and 90° angles, and a conical-shaped collar. The collar diameter was three times the pier diameter. They concluded that flat and conical collars completely avoided scouring in front of the pier; the collar with 90° wings performed better than the collar with 45° wings in minimizing scour depth upstream of the pier, while the collar with 45° performed better than the collar with 90° at the rear of the pier. The flat and angled collars at 90°, on the other hand, have approximately the same effect on reduction scour downstream of the pier. The results indicated that the most effective shape for minimizing scour depth upstream and downstream of the pier is the conical collar, with reductions of 100% and 61.1%, respectively [35].

Valela et al. 2021 developed a new design for the collar around the cylindrical pier such that the collar serves as a solidified scour hole with outward slope sides. The new collar, with an outside diameter 3.3 times that of the pier, was level in all directions and flush with the surrounding bed. The horseshoe vortex was directed into a 3-D cavity inside the collar and below the bed level rather than on top of the bed surface, to reduce interference with the passing flow. This can keep the horseshoe vortex, and especially the scour hole, from developing or altering shape. When compared to a non-countermeasure pier, the highest scour depth reduction was 69.7% at a given flow condition. However, in the conditions studied, the new-collar shape was seen to lower scour depth more than the flat circular collar, unless the latter was undermined. When the flat collar was undermined, the scour volume was still high while the scour depth decreased as material coming from beneath the collar clogged the downstream scour holes. Despite the fact that the scour depth had been reduced, it migrated closer to the pier. Generally, the flat collar gave lower scour reduction at smaller Froude number (Fr) values and suffered undermining at higher values of (Fr). This makes a flat collar a less beneficial device. The new design of the collar has shown to be a better scour countermeasure and more predictable which, can be a useful alternative to other used collars [36].

Raeisia and Ghomeshi 2022 experimentally tested different shapes of asymmetric lattice collars by placing them at different levels on a cylindrical pier. The asymmetric collars had protrusions three times greater than the pier diameter towards the canal's downstream end, with 15, 30, and 40% lattice openings, as shown in Fig. 3. To reduce the downward currents around the pier, the collar's longitudinal length was 4 to 6 times greater than the diameter of the pier. The results showed that the collar model with a 15% lattice and a longer longitudinal length performed the best on the bed surface, with a 72% reduction in scour rate. The collar model, which has a 40% lattice and a shorter longitudinal length and is positioned at a distance of 0.5 d, has the lowest scour control performance, with a 26% reduction in scour rate. The investigated lattice collars reduced the scour depth by delaying the flow separation and altering the boundary layer flow [37].

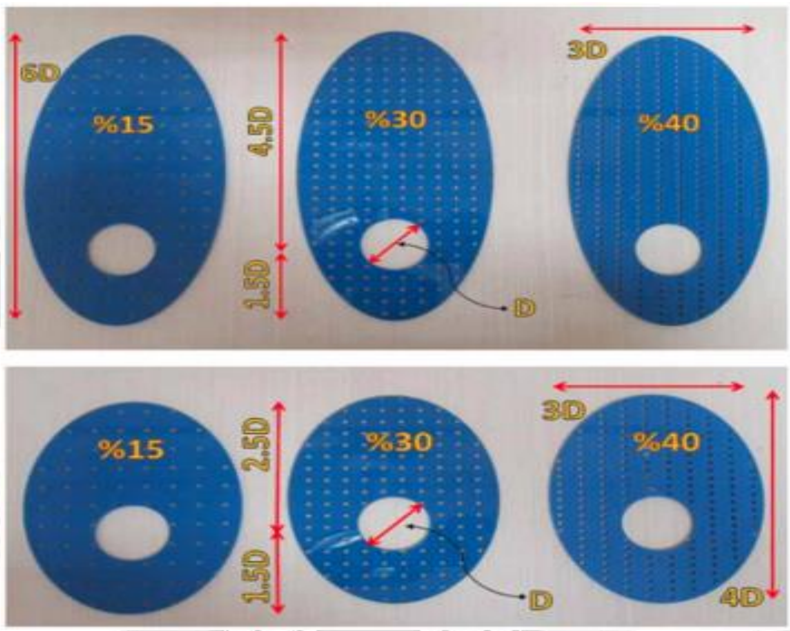

Fig. 3: Asymmetric lattice collars [37].

Kassem et al. 2023 investigated the performance of hexagonal collars in minimizing scour around a circular bridge pier. As shown in Fig. 4, the shapes of these collars include: sloped, sloped with openings, and sloped with ribs. The maximum scour depth was shifted downstream away from the pier when using hexagonal collars. The results showed that the sloped hexagonal collar with ribs is the most efficient geometry. Compared to the pier without collars, the sloped hexagonal collar with ribs decreases the depth, upstream length, downstream length, and width of the scour hole by 56%, 29%, 51%, and 19%, respectively [35].

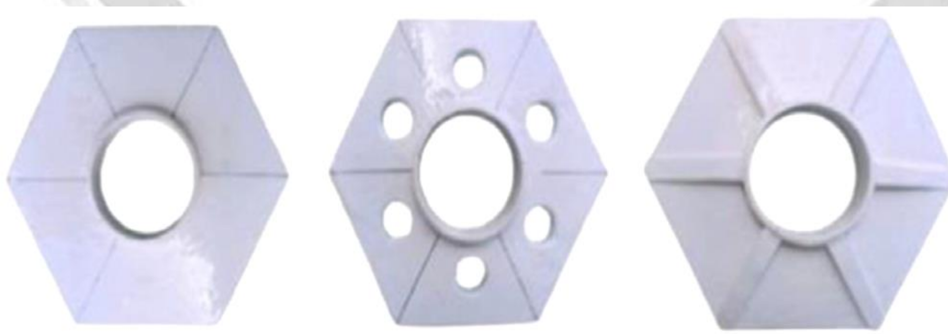

Fig. 4: The shapes of investigated hexagonal collars [35].

Gupta et al. 2023 studied the effect of an airfoil collar on scour reduction in clear water, as depicted in Fig. 5. Four collars, with diameters ranging from 1.5 to 3 times the pier diameter,

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Vol. 32, No. 5. \ 2024 ISSN: 2616 - 9916

were placed around a circular pier at varied heights above the sediment bed. It was found that the higher the collar, the lower the protection against scouring. The percentage decreasing in scour depths for the collar size (1.5-3) d were 65-100%, 40-53%, 23-38%, and 8-29% when the collar was elevated (0-0.75) times the water depth from the bed, respectively. These results demonstrated that a larger collar diameter produces more resistance to the flow around the pier, lowering flow velocity and the erosive forces, and preventing the scour hole from growing larger. Furthermore, it was revealed that the collar's effectiveness was initially reduced, but that due to the protection provided by the collar around the pier, it developed over time and became nearly constant in its final stages. Statistical sensitivity analysis revealed that the collar's distance from the water surface and dimensionless time are the most and least sensitive parameters, respectively [38].

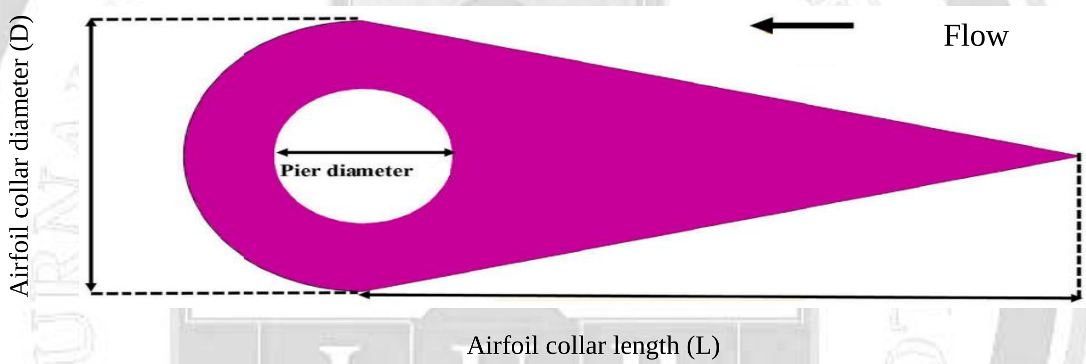

Fig. 5: Airfoil collar shaped [38].

Yuan et al. 2023 studied experimentally the effect of the porosity of the permeable collar around a circular pier under clear water conditions. The tests were conducted using collars of eight different porosities, ranging from 12.5 to 87.5, with constant size and thickness. The findings showed that the porosity of the collar has a significant effect on the scour depth reduction, where the reduction efficiency grows first and then reduces as the collar porosity increases. In the case of a 50% porosity, the collar functions best and its efficiency can reach up to 78.1%. It was observed that the permeable collar splits the flow into three portions: above, inside, and below the collar. The lower velocity flow inside the collar serves as a solid plane that can reduce the velocity and strength of the downward flow upstream of the pier and the flow around the collar, indicating the local scour at the collar edge is reduced effectively. However, increasing the porosity of the permeable collar gradually reduces its resisting effect on downward flow, resulting in a decrease in the permeable collar's reduction efficiency. On the other hand, the presence of the permeable collar alters the pattern of the wake flow. As porosity increases, the sedimentation behind the pier becomes more visible, and the sedimentation area grows larger. When the porosity of the permeable collar is ≤ 75%, its reduction effect is comparable to that of a solid collar. This means that the permeable collar, which requires less material, is capable of producing the same reduction effect as the solid collar under identical conditions [39].

Bagheri et al. 2024 investigated experimentally the scour depth around a circular pier with a perforated collar. Four types of perforated collars (triangular, circular, square, and rectangular) with three opening ratios (d_1/d = 0.1, 0.15, and 0.2) were tested. The results showed that the scour depth decreased when a perforated collar was placed on the pier, and scouring decreased considerably as the collar shape was changed from triangle to rectangle. Scouring, on the other hand, increased as the diameter of the opening in the perforated collar was increased. Rising opening ratios from 0.1 to 0.2 resulted in an average scour increase of 29.7% at all velocities. Additionally, increasing the flow intensity (v/vc) from 0.54 to 0.95 resulted in an increase in scour depth about 94.7% on average [40]. Table 1 provides a summary of the reviewed studies described above

Table 1 The summery of reviewed studied on the collar.

Authors	Flow Condition	Collar shape	Pier cross-section	Dimensions and position	Optimal case
Singh et al. 2001	------	Circular	Circular	D/d = (1.5-2.5) Z/d = (0 and -0.1)	D/d =2, Z/d = -0.1 R =91%
Zarrati et al. 2004	Q = 0.05 m3/s y=0.195 m	Rectangular	Rectangular	W/w= (2 and 3) Z/w= (-0.8 to 0.4)	W/w=3, Z=0, R=74%
Garg et al. 2005	v = (19.05-20.22) cm/s y = (15.63-16.8) cm	Circular	Circular	D/d = (1.5-3) Z/d = (-0.5 to 0.5)	D/d =3, Z=0, R=100%
Mohamed et al. 2008	Fr = 0.188 to 0.532	Triangular	Rectangular	B/w=1.5-5 Apex angle = 122° Z=0	B/w =5 R = 84 %
Negm et al. 2009	Fr=0.188 to 0.532	a. Rectangular b. Circular c. Trapezoidal d. Triangular	Rectangular	B/w=1.5-5 Z = 0	B/w =5: a. R= 90% b. R= 87 % c. R= 86% d. R= 84 %
Zarrati et al. 2010	Q= 25-65 l/sec y = (12-42) cm	Circular	Circular	D/d = (2-3) Z=0	D/d = 3 R= 26%
Jahangirzadeh et al. 2014	Q=12.2 l/s	a. Rectangular b. Circular	Circular	W/d= (2-3.5) D/d= (2-3.5) Z/d = (-0.5,0,0.5)	W/d= 3.5, Z/d = -0.5 a. R= 78% b. R = 70%
Chen et al., 2018	Q = 0.011 m^3/s	Hooked-collar	Circular	D/d=1.25 Z/d=-0.25 to 0.25	-Z/d=0, R=42% Double collar at

	y= 20 m				Z/d= 0and 0.25, R=50%
Farooq et al. 2020	Fr = 0.26	Octagonal hooked	Octagonal	W/w = (1.5 -3.5) H_{wh}/w=(0.15-0.6) Z = 0	W/w=2.5 Hwh/w = 0.45 R = 73.3%
Bestway et al. 2020	Fr=0.33	a. Flat circular b. Wing collar 90° c. Wing collar 45° d. Conical	Circular	D/d = 3 Z/d = 0	a. R_{us}=100%, R_{ds}= 33.3% b. R_{us}= 81.4%, R_{ds}= 33.3% c. R_{us}= 71.2%, R_{ds}= 50% d. R_{us}= 100%, R_{ds}= 61.1%
Valela et al. (2021)	Fr=0.21-0.34	Solidified hole with outward slope sides	Circular	D /d= 3.3 Z/d = 0	R= 69.7 %
Raeisia and Ghomeshi (2022)	Fr=0.26-0.37	Asymmetric lattice collar	Circular	D /d= 3 L/d=4 and 6 Z/d=0 to 0.5 Lattice= (15-40) %	L/d= 6 Z/d =0 Lattice = 15% R = 72 %
Kassem et al. 2023	Fr = (0.18-0.33)	Hexagonal: a) Sloped b) Sloped with, holes c) Sloped with ribs	Circular	D/d = 3 Z /d = 0	a) 48% b) 37% c) 56%
Gupta et al. 2023	V= (0.195 and 0.247) m/s y=0.1 m	Airfoil shaped	Circular	D/d= (1.5-3) L=2D Z/y= (0-0.75)	D/d= 2.5 and 3 Z/y = 0 R = 100%
Yuan et al. 2023	v = 0.325 m/s	Permeable Circular Collar	Circular	D/d =3 Z =0 Porosity = 12.5%-87.5%	Porosity = 50% R= 78.1%
Bagheri et al. 2024	v/vc= 0.54-0.95	Perforated collar: a) Triangular b) Circular c) Square d) Rectangular	Circular	d_1/d= 0.1, 0.15, 0.2 Z=0	Rectangular v/vc= 0.54 d_1/d= 0.1 R= 51%

5. Conclusion

A collar is a flow-altering device attached to a bridge pier to reduce the shear stresses via changing the flow pattern, hence reducing the scour depth. The present study provides an overview of scour reduction at piers protected with various types of collars. In general, utilizing a collar was shown to be an effective technique to reduce scour around bridge piers. Based on the previously mentioned review of recent studies on collar design, the following results can be obtained:

1. Scour reduction is a function of the collar size, the position relative to the river bed, and flow characteristics. The collar not only reduces the scouring depth but also causes the scouring hole to take a longer time to form. This influence becomes more noticeable as the collar size increases.
2. The most efficient and cost-effective collar size is within the range of 3-3.5 times the pier diameter. The scour reduction increases slightly when the collar size exceeds the upper limit of this range.
3. The collar that is installed at the streambed or below it can reduce the scour depth more than the collar placed above the streambed. Under the same flow conditions, collar performance decreases as its position related to the bed increases
4. The rectangular collar outperforms better than circular, trapezoidal, and triangular shapes under the same conditions.
5. Collar effectiveness improves when combined with bed-armoring or other flow-altering countermeasures.
6. A collar of an appropriate size and shape can eliminate the local scour, but it becomes useless if the general bed level lowers over time.

Notation

B: width of triangular collar

D: diameter of circular collar

d: pier diameter

d_1: The opening diameter of the perforated collar

d_{s1}: scour depth around the pier without collar

d_{s2}: scour depth around the pier with collar

H_{wh}: sidewall height of the Octagonal hooked collar above bed level

L: longitudinal length

R: percentage reduction in scour depth around the pier

R_{ds} : percentage reduction in scour depth downstream the pier

R_{us} : percentage reduction in scour depth upstream the pier v: approach velocity

vc: critical velocity

W: width of rectangular collar

w: the width of pier

y: the depth of flow

Z: the height of the collar above the bed

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ARTICLE
JOURNAL`S UNIVERSITY OF BABYLON FOR ENGINEERING SCIENCES (JUBES)
مـــجلـة جـــامعة بـــــابـل للعلــــوم الهندسية
Vol. 32, No. 5. \ 2024 ISSN: 2616 - 9916

مراجعة عن أداء الطوق في تقليل الانجراف الموقعي

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الخلاصة:

يعتبر الانجراف الموقعي حول الدعامات أحد الأسباب الرئيسية لانهيار الجسور في العالم. تم اجراء العديد من الدراسات لتقييم الأداء الهيدروليكي لأنواع مختلفة من التدابير المصممة ضد الانجراف. يمكن تصنيف التدابير المضادة على نطاق واسع إلى مجموعتين: التدابير المضادة لتغيير الجريان وأخرى لحماية القاع. الطوق هو الإجراء المضاد الأكثر استخدامًا لتغيير التدفق حول الدعامة، وبالتالي تقليل عمق الانجراف الموقعي. تستعرض هذه الورقة بإيجاز أحدث الدراسات المتعلقة باستخدام طريقة الطوق كتقنية وقائية للدعامة. أشارت الدراسات التي تمت مراجعتها إلى ان تقليل الانجراف حول الدعامة المزودة بطوق يعتمد على حجم الطوق، شكله، وموقعه. يتفوق الطوق المستطيل على الأشكال الدائرية والشبه المنحرفة والمثلثة تحت نفس الظروف. بالإضافة إلى ذلك، يمكن للطوق المدمج مع أنواع أخرى من التدابير المضادة ان يحسن من عملية تقليل الانجراف.

الكلمات الدالة: طوق، جريان سفلي، تغيير الجريان، دعامة، انجراف، دوامة.