Stulling of Large Diameter Steel Water Pipe—What It Is and What It Is Not

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Abstract

Large diameter steel water pipe is typically supplied with temporary internal bracing or "stulls" that have been shown to prevent damage to the pipe, particularly rigid lining and coating systems such as cement mortar lining and coating, during transportation and handling. They are also provided to assist with maintaining the shape of pipe ends to within AWWA C200 requirements for field jointing. Stulls are typically manufactured from rough cut lumber and on occasion, steel angle or poles. Stull sets are typically placed at pipe ends and at mid points, depending on diameter and thickness of the pipe. Stull sets typically consist of a minimum of one to three sets of stulls with various stiffeners, and may include shoes and blocks to assure the internal bracing will retain functionality during the handling process. Manufacturers may have variations in their stulling means and methods but all have the same goal of providing pipe integrity during handling and transport, and pipe-end roundness at the ditch, ready for joint assembly, installation and backfilling. Stulls may assist holding the pipe shape until side fill support is developed during backfill placement. Loads on top of the pipe, including construction loads, are distributed to the soil envelope around and adjacent to the pipe. The assumption that pipe stulls will limit or eliminate deflection has lead to misunderstandings, false expectations and even improper pipe installation due to over reliance on a stulling system's ability to limit deflection of the pipe. Pipe stulls are not in themselves designed to withstand the unknown loadings generated by depth of soil cover or various construction equipment and vehicles during installation. This paper will illustrate the installation of stull sets at the factory, review their intended function, discuss flexible pipe deflection control methods and review installation requirements of the AWWA C604 buried steel pipe installation standard.

INTRODUCTION

The purpose of a stull is to maintain the integrity of the pipe cylinder, lining and coating during handling and transport. Manufacturers use the inherent pipe stiffness, Diameter-to-Thickness ratio (D/t), combined with the lining and coating requirements and their knowledge of the equipment that will be handling the pipe to determine the need, configuration and location of stulls. Pipe stulls are not in themselves designed to withstand the unknown loadings generated by various construction equipment and vehicles during installation.

The basis of stull layouts and configurations are empirical. They are not typically based on a pure mathematical design, but rather the successful historical use and experience of the steel pipe industry. There is not one set method that can account for the various handling and transportation means that may be found in different manufacturing facilities.

Guidance has been provided in the Steel Penstock Manual (ASCE 2012), Chapter 13, which includes a table that establishes criteria for wood stulling of pipe with nominal diameter up to 120-in, Table 1. This table may be modified by the manufacturer to facilitate the proper protection of the pipe and its linings and coatings for handling and transportation.

Table 1: Wood Stull Criteria

	Pipe diameter/Stull size					
	D = <24 in.	D = 24 in. to <30 in.	D = 30 to <48 in.	D = 48 in. to <60 in.	D = 60 in. to <84 in.	D = 84 in. to 120 in. Cement-mortar lined pipe only
Diameter to thickness ratio (D/t)	2 in. × 6 in.	3 in. × 3 in.	3 in. × 3 in. for 30 in. and 4 in. × 4 in. for larger diameters	4 in. × 4 in.	4 in. × 4 in.	4 in. × 4 in.
$D/t \leq 120$	No stulls	No stulls	No stulls	No stulls	No stulls	No stulls
$120 < D/t \leq 160$	Brace between bunks	2 stulls vertical	2 stulls crossed	2 stulls crossed	2 stulls, 3 legs	2 stulls, 3 legs
$160 < D/t \leq 200$	Brace between bunks	2 stulls vertical	2 stulls crossed	2 stulls, 3 legs	3 stulls, 3 legs	3 stulls, 3 legs
$200 < D/t \leq 230$	—	2 stulls vertical	2 stulls crossed	3 stulls, 3 legs	3 stulls, 3 legs	3 stulls, 3 legs
$230 < D/t \leq 288$	—	—	2 stulls, 3 legs	3 stulls, 3 legs	3 stulls, 3 legs	3 stulls, 3 legs

Notes: D = nominal pipe diameter; t = pipe wall thickness; stulls should be placed 15 to 20% of the total pipe length from each end, but no less than 4 ft in from end; and shipping bunks are to be located near stulls.

Table reproduced from ASCE (2012), Chapter 13

TYPES OF STULLS

Once the determination is made to include stulls, or stull sets inside the finished pipe cylinder, the next step is to determine the configuration. Often only one stull is required, and as such, the single stull is placed vertically, Figures 1a and 1b.

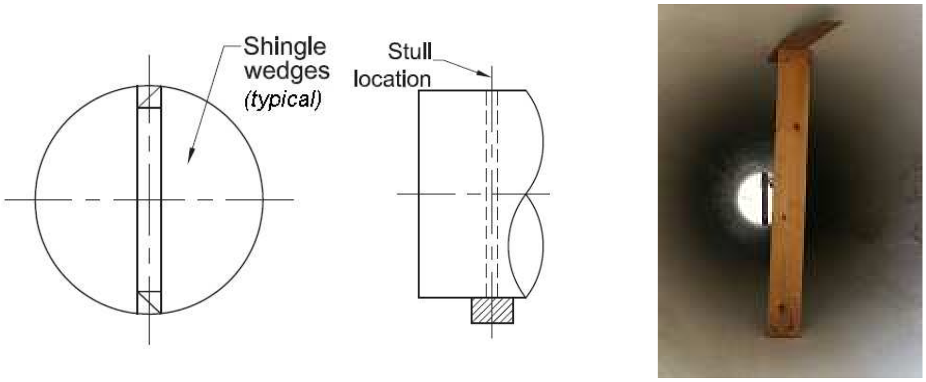

Figure 1a, b: Single Vertical Stull

If a 2-stull set is required based on the D/t ratio, a cross configuration is used to provide support in both vertical and horizontal axes. In the 2-stull configuration, one stull is vertical and the other is horizontal, Figures 2a and 2b.

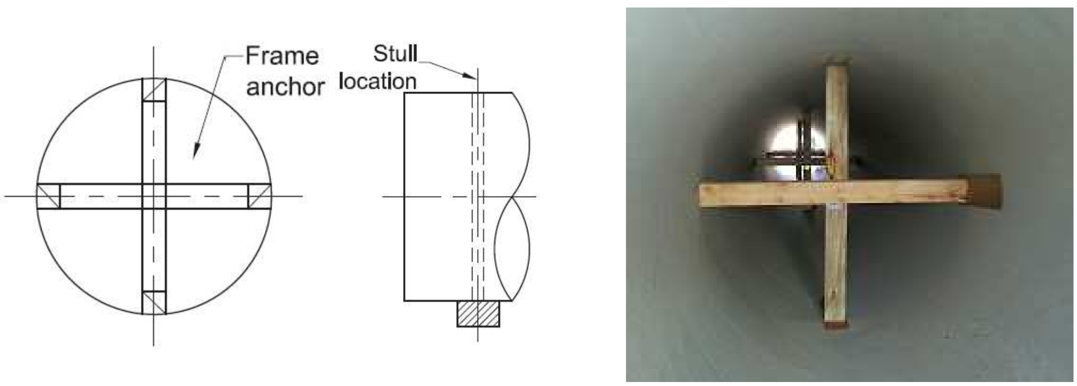

Figure 2a, b: 2-Stull Cross

For pipe cylinders with lower stiffness or a high D/t ratio, 3-stull sets oriented in a 60° configuration, commonly called a spider, are often used. In some cases, the vertical stull may be larger than the other 2 stulls in the set, Figures 3a and 3b.

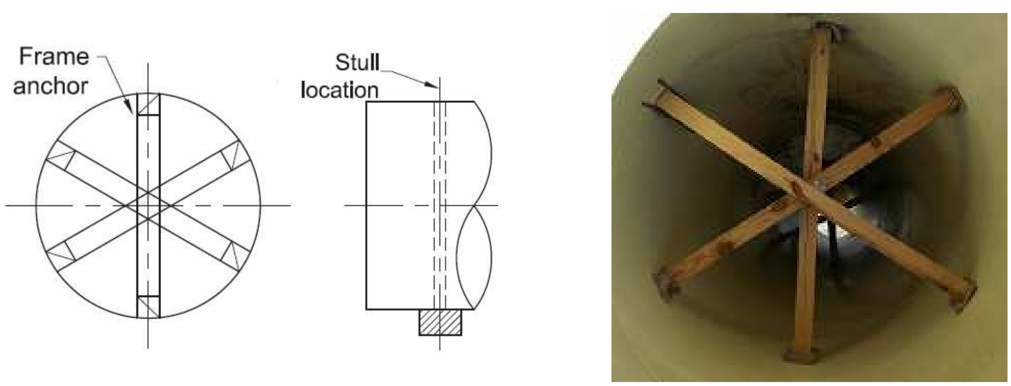

Figure 3a, b: 3-Stull 60° Spider

In rare circumstances small diameter steel tubing or a steel stull assembly, designed specifically for the application, is used to mitigate the possibility of excessive deflections during transportation and handling. This practice is typically limited to very large diameter, unlined pipe. The steel stull is often small diameter tubing that is inserted into a larger diameter "sleeve" welded to the inside of the cylinder. This type of stull set would need to be removed prior to the in situ lining operation. Additional guidance for steel stulls is available in the Steel Penstock Manual (ASCE (2012), Chapter 13

STULL LOCATIONS

To be effective, the proper number and location of stull sets should be used. The stull is the piece or pieces of material shown above (either single, double, 60° spider or special steel assembly) and the number of stulls is how the quantity and placement of the stull assembly is defined. At a minimum a stull set should align with storage and transportation bunks, and depending on the pipe stiffness and diameter, stulls will be placed in the center of the cylinder and near the pipe ends. Figure 4 shows 66-in pipe with 3 sets of stulls in a 3-stull 60° spider. In this case the pipe would be loaded for shipment with the bunks under the 2 outer stull sets.

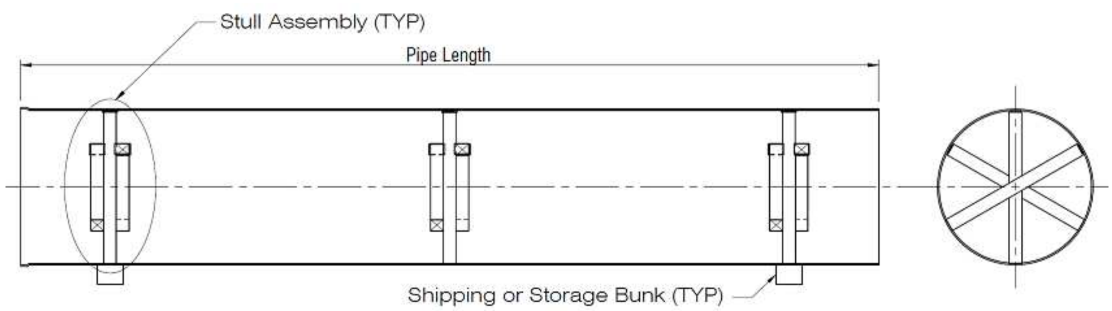

Figure 4: Completed Stull Set

STULL INSTALLATION

The placement of stulls is a relatively simple process. Figures 5 thru 14 show the installation of a stull set for a 66-in ID steel pipe with polyurethane lining and coating. This particular joint, when complete, will have 4 sets of stulls with 3 legs each. The lumber is first cut to length, Figure 5, typically just shorter than the inside diameter of the finished cylinder with the lining in place. Once the location is identified on the inside of the pipe, Figure 6, the vertical stull is fitted into place, often with a rubber mallet or small sledgehammer to ensure the lining is not damaged, Figure 7. Sometimes wood wedges or shims are used to adjust the length of the stull and to ensure the stull leg is firmly in place and will not fall out on its own if the pipe were to flex upon movement. For polyurethane or epoxy lined pipe, carpet is used on the ends of the stulls to protect the lining during shipping.

The subsequent legs are then fitted into place, Figures 8 and 9, again with firm contact to the inside of the pipe but not so roughly placed as to adversely affect the shape of the cylinder or to damage the lining in any way. In some cases, these stulls are then connected at their centers with wood screws or using a piece of angle iron and nails, Figure 12. Subsequent stull sets would then be placed inside the pipe in the same manner, keeping the vertical and horizontal orientation consistent throughout, Figures 11 and 13.

Figure 5: A pallet of stulls ready for use

Figure 6: The location of the inside stull is determined

Figure 7: The Vertical stull is fit into place

Figure 8: 2nd Leg is placed 60° from vertical

Figure 9: The final leg is placed, supporting the full circumference of the cylinder

Figure 10: Two inside stull sets are visible

Figure 11: All four sets, with consistent orientation throughout the cylinder

Figure 12: Angle and nails to connect the stull legs

Figure 13: Completed assembly down the length of the cylinder

DESIGN LIMITATIONS

Some have assumed that the standard stulling provided is there to limit any possible pipe deflection that can occur during backfilling. AWWA C604 – *Installation of Buried Steel Water Pipe* (AWWA 2011) details the fact that internal bracing (stulls) are provided for shipping and handling purposes "if required." C604 also states "This bracing may or may not be adequate to limit pipe deflection during backfilling operations." The reason for this caveat is that contractors have different means and methods regarding backfilling of pipe. The project specification may dictate type of material and/or level of compaction, but experienced contractors may have different approaches to satisfy these requirements. These subtle differences may have dramatic effects on the external loading of the cylinder during installation, thereby making it extremely difficult to design a stull set to account for these variations. Pipe stulling systems are not in themselves typically *designed* to withstand the unknown loadings generated by various types of construction equipment and vehicles during installation. This again stresses the importance of proper side soil support, and taking advantage of the pipe-soil interaction to maintain pipe shape during installation, backfill, construction and completion of the pipeline. A detailed discussion on the topic of pipe-soil interaction for buried flexible steel pipe can be found in Watkins et al. (2010).

In flexible pipe design, soil stiffness, not pipe stiffness, is the driving design consideration as the stiffness and strength of the compacted trench fill material essentially carries the live and dead loads of the pipe and prevents the flexible pipe from excessive deflection. Typically, the relative contribution of the soil stiffness to the resistance to allowable vertical deflection in buried flexible pipe is 97% while the pipe stiffness is only 3% (ASCE 2009). Stulls are provided to protect the integrity of the linings and coatings by limiting the flexibility of the cylinder during handling, transportation and pipe jointing.

Assuming that stulls will add significant pipe stiffness that will offset dead or live loads is problematic. As long as proper backfill techniques are followed per the AWWA C604 (2011) standard, the need for stulls to properly backfill flexible pipe is most often not warranted. The over reliance or misunderstandings on stulls "to keep the pipe round during backfill" can contribute to improperly installed flexible pipe. Key to proper installation of flexible pipes includes controlled lift techniques, proper compaction methods, balanced loading of backfill, and even monitoring of the horizontal and vertical movement of the pipe during the backfill process.

With proper dimensional monitoring, flexible pipe is good at telling an installer if the process being used is adequate. Deflection limits are defined by AWWA Manual M11 (2004) and/or project specifications and should be the guide to installation.

SUCCESSES

Proper placement of stull type, configuration, quantity and location can mitigate damage to the lining, coating and/or finished cylinder, thereby reducing costly and time consuming field repairs. They are also a useful aid in keeping the pipe joints within acceptable tolerance for joining adjacent cylinders in the trench, again saving installation time and costly fit-up expenses.

Figure 14 shows 108-in pipe being transported on padded forks. Figure 15 shows the inside of that same pipe joint, just prior to the end cap being installed. Bolts are used in this particular set but simply nailing the centers together has also proven effective. Figure 16 is a close up of the feet used for this particular stull configuration. The stull feet aren't always necessary but they do help ensure proper sizing of the stulls and create a larger bearing surface on the inside of the pipe joint for increased stability.

Figure 14: 108" pipe on padded forks in manufacturing facility

Figure 15: 5 sets of a 3-stull spider configuration

Figure 16: Support feet at the end of each stull

Figure 17 shows a 66-in pipe joint as it is being placed in the trench. In this photo the stull can be seen near the end of the pipe, used to keep the joint within applicable tolerances.

Figure 17: 66-in pipe joint being placed in the trench

CONCLUSION

Regardless of the type of external loading, stulling is successfully used to prevent excessive cylinder deflection and particularly to prevent rigid lining or coating damage during transportation and handling. Pipe stulling systems are not in themselves designed to withstand the unknown loadings generated by depth of soil cover or various construction equipment and vehicles during installation. Properly installed flexible pipe relies on the pipe-soil interaction to maintain its shape prior to the completion of backfill operations. With adequate side soil support provided by proper backfill, this pipe-soil interaction allows for transfer of the load, preventing excessive pipe deflection. Once backfill is placed and compacted to a level to provide side support, some stulling may be removed to facilitate access for inspection and/or joint completion.

REFERENCES

American Water Works Association (AWWA). (2011). "Installation of Buried Steel Water Pipe – 4in (100mm) and Larger." AWWA C604-11, Denver, CO.

American Water Works Association (AWWA). (2004). "Steel Pipe - A Guide for Design and Installation," Fourth Edition, Manual of Water Supply Practices - M11, Denver, CO.

American Society of Civil Engineers (ASCE). (2012). "Steel Penstocks," Second Edition, ASCE Manuals and Reports on Engineering Practice No. 79, Reston, VA.

American Society of Civil Engineers (ASCE). (2009). "Buried Flexible Steel Pipe: Design and Structural Analysis," ASCE Manual and Reports on Engineering Practice No. 119, Reston, VA.

Watkins, R., Keil, B., Mielke, R., and S. Rahman. (2010). "Pipe Zone Bedding and Backfill: A Flexible Pipe Perspective," *ASCE Pipelines 2010: Climbing New Peaks to Infrastructure Reliability*, Tom Roode and George Ruchti, eds., American Society of Civil Engineers, Reston, VA.