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SPSP foundation in the construction of Kanchpur (Shitalakhya), Meghna and Gumti bridges

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The Kanchpur, Meghna and Gumti 2nd Bridges Construction and Existing Bridges Rehabilitation Project, RHD

ABSTRACT: In this paper, the foundation technology of SPSP (Steel Pipe Sheet Pile) in the construction of Kanchpur (Shitalakhya), Meghna and Gumti 2nd Bridges have been introduced. The SPSP is an advanced Japanese technology, used first ever in Bangladesh through this project. SPSP system fulfils two purposes: i) works as a lateral earth retention system for constructing pier base (top slab) ii) plays its role as deep foundation as it takes lateral and vertical loads coming from pile base and super-structure. SPSP is used in 6 Piers (P1 to P6) at Kanchpur, 9 Piers (P2 to P10) at Meghna and 6 Piers (P2 to P7) at Gumti bridges. Based on the construction progress two types of SPSP driving methods-1) Vibro-Hammer and Hydraulic Hammer Method and 2) by Press-in Method (using Silent Piler) have been applied. Stud welding on steel pipe inside SPSP cofferdam is executed to integrate SPSP with the Top Slab and thus exhibits strong lateral resistance. Using SPSP, foundation of existing bridge is joined with the new bridge's sub-structure in this project. Thus, combined foundation of existing and new bridge acts as a monolithic foundation unit.

1 INTRODUCTION

SPSP is composed of a steel pipe and couplings welded on the side/sides of the steel pipe. The interlocking of the coupling of the steel pipe sheet pile links SPSP to construct SPSP foundation and the interlocked couplings form the joints (Joint Pipe) of SPSP structure. Joint Pipes are grouted with filling mortar for water tightness and structural bonding (Figure1 & 2). With strong stiffness, large bearing capacity and trustworthy construction, SPSP structures have been widely used as the foundations of large scaled bridges, especially in cases that the bridge spans a river or a bay where the surface ground is very weak and/or the water is very deep. The salient features are:

- Lateral bearing capacity of reinforced foundation system is increased.
- Strong shear resistance in pipe joints and behaves an intermediate structure between steel pipe and caisson foundation.
- Act itself as a cofferdam during construction as well as main body of the structure. This leads in reduction of construction time and construction work volume.

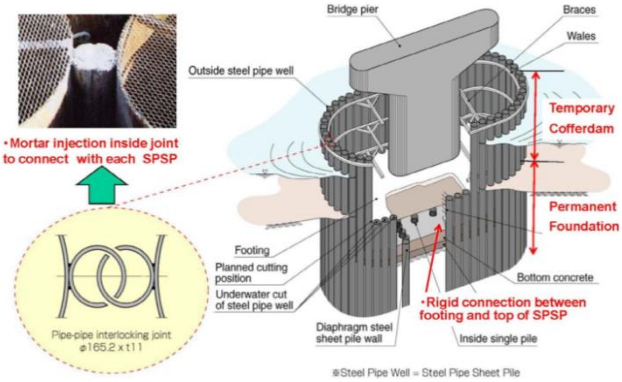


Figure 1. General structure of SPSP.

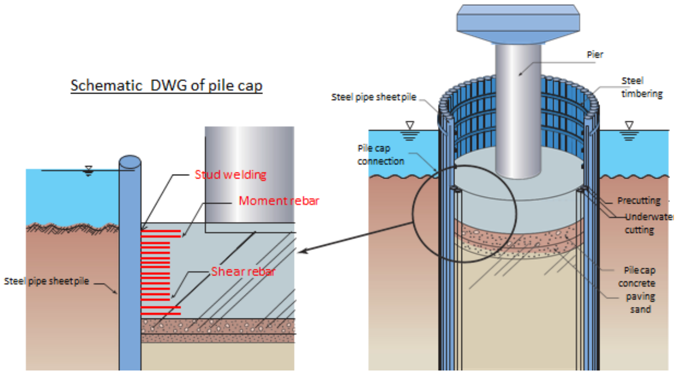


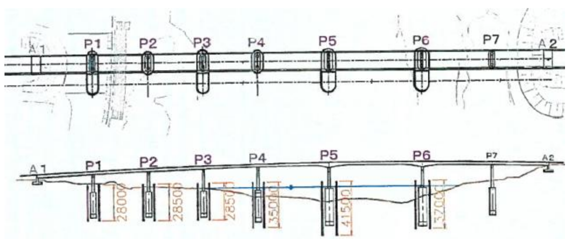
Figure 2. Top slab connection to SPSP.

– Proven structural advantages of higher earthquake resistance and riverbed scouring countermeasures.
– Suitable for reinforcing existing bridge foundation in water.

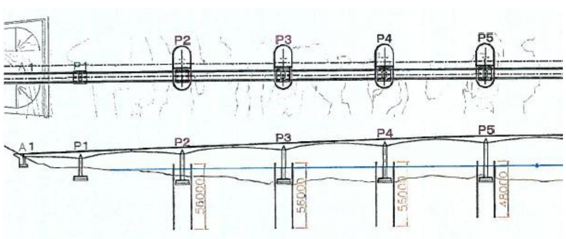
Table 1. SPSP material used in KMG project.

Item	Quantity	Material	Weight of SPSP & Joint Pipe
Kanchpur Bridge:			
SPSP	352 nos	SKY490 ϕ1000mm,t=14mm	4,907 tons
Joint Pipe	712 nos	STK400 ϕ165.2mm,t=11mm	
Meghna Bridge:			
SPSP	765 nos	SKY490 ϕ1000mm,t=14mm	16,640 tons
Joint Pipe	1550 nos	STK400 ϕ165.2mm,t=11mm	
Gumti Bridge:			
SPSP	510 nos	SKY490 ϕ1000mm,t=14mm	11,367 tons
Joint Pipe	1032 nos	STK400 ϕ165.2mm,t=11mm	
Welding Material	All Bridges	OW-SH50H OW-56A	Joint Welding
Total	1627 nos		32,923 tons

The general layouts of SPSP foundation for three bridges are shown below:



(a)



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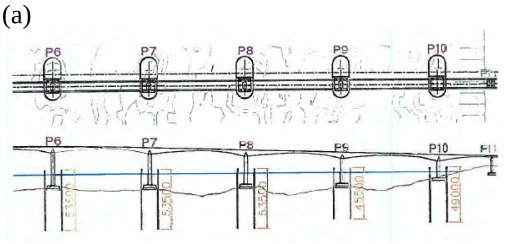
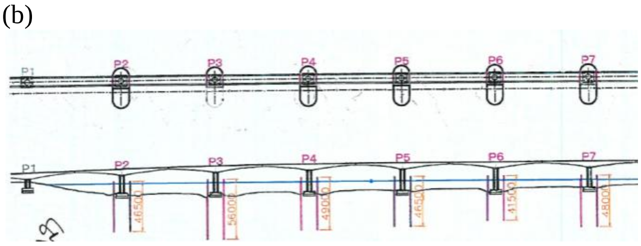


(c)



(d)

Figure 3. General layout of SPSP foundation in bridges: (a) Kanchpur (b) Meghna (c) Gumti.

There are 7 Piers in Kanchpur Bridge and SPSP has been used in 6 Piers (Pier1 to Pier6) depending on the soil and river water condition. Similar is the case for both Meghna and Gumti bridges where 9 Piers (Pier2 to Pier10) and 6 Piers (Pier2 to Pier7) respectively, are constructed by SPSP. The details of SPSP material used for foundation works of Kanchpur, Meghna and Gumti is shown in Table1. In this project, diameters of SPSP are 1m and length varies from 26m to 78m long as summarized in Table 2.

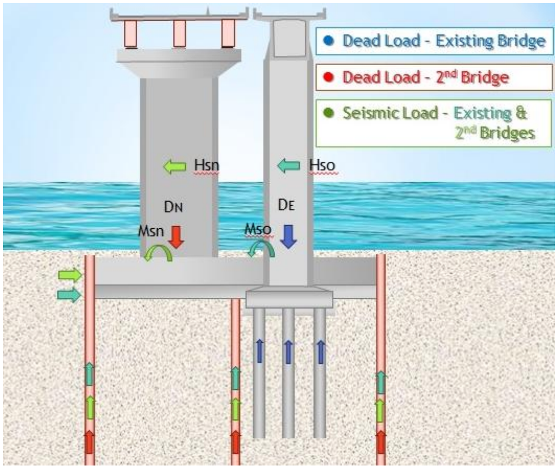


Figure 4. Load distribution assumption for SPSP in KMG Project.

2 METHODOLOGY

The stepwise procedure for construction of SPSP foundation system of Kanchpur, Meghna and Gumti bridges is shown in a flowchart below (Figure5) and depicted by an illustration (Figure 6):

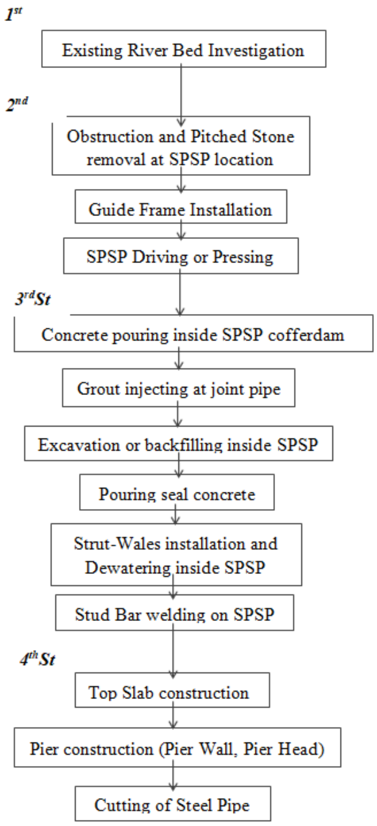
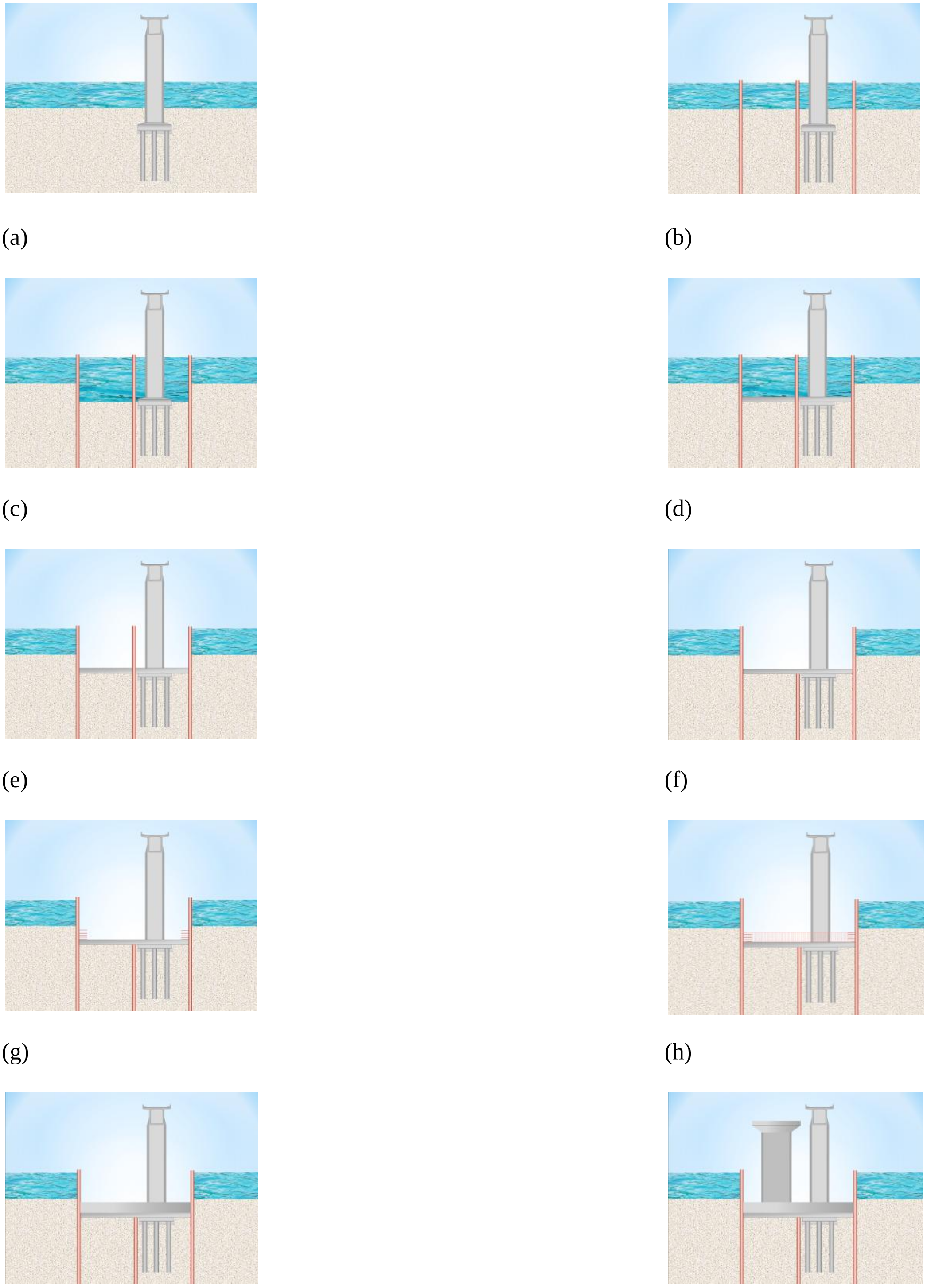


Figure 5. Flowchart of construction procedure of SPSP foundation system.



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j)

Figure 6. Illustrative diagram of development of SPSP foundation (sectional views): (a) Existing bridge (b) Completion SPSP driving (c) Excavation/ backfilling inside SPSP cofferdam (d) Pouring seal concrete inside SPSP cofferdam (e) Dewatering (f) Cutting bulkhead (g) Stud bar fixation (h) Top slab rebar placing (i) Top slab concreting and (j) Pier wall/column and pier head structural works.

3 CONSTRUCTION WORK

Step 1: Existing River bed Investigation: After river bed investigation of existing bridges, obstructions (Pitched stone, geobags, debris etc.) have been identified.

Step 2: Obstruction and Pitched Stone Removal at SPSP location: Obstructions have been removed before the commencement of foundation works to avoid impeding the driving of SPSP and Bored Piles. Removal of pitched stone and geo-bags are done by Clam shell and Orange Peel Bucket whereas U.G. obstacles are conducted by All Casing Cutting Method (advanced Japanese technology).

(a)

(b)

(c)

(d)

Figure 7. Investigation by 3D scan (b) Pitched stone in water (c) Concrete debris in water (d) Geobags in water.

Figure 8. Removal by orange peel.

Figure 9. Removal by all casing machine.

Installation of Guide Frame:

Figure 10. Installation of guide frame.

SPSP Driving or Pressing**:** Hammer method of driving applied to SPSP at wall area, 2nd bridge area, closing area (outside the influence of the existing bridges)(Figure11 to 13) and Press-in Method used to drive SPSP under the influence of the existing bridges to allow driving under the existing girder (Figure 14, 15).

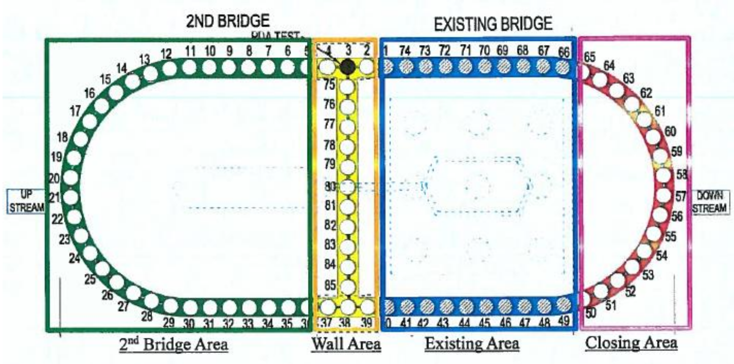


Figure 11. General installation sequences of SPSP.

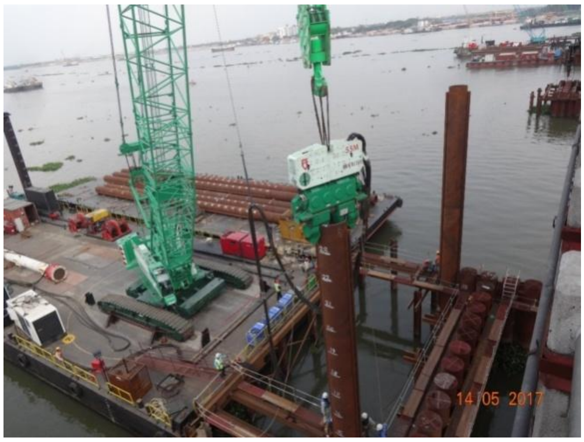


Figure 12. SPSP hammering (200t Crane with vibro-hammer 600 kW-1000kW).

Figure 13. SPSP hammering (200t crane with hydro-hammer 150 kJ-280kJ).

Figure 14. SPSP pressing (silent pilar pressing force max 200t – 300t).

Dynamic Load Testing (PDA Test) on SPSP: PDA (Pile Dynamic Analyzer) test are done to check the vertical bearing capacity of the test pile and to ensure the designed allowable bearing capacity of each pile mentioned in Table2.PDA tests (Figure16) are carried out on first installed permanent pile at each pier. This test has been performed twice for each test pile when the driven pile reaches the target depth (1st PDA test) and at a time after more than 5 days from 1st PDA test (2nd PDA test).

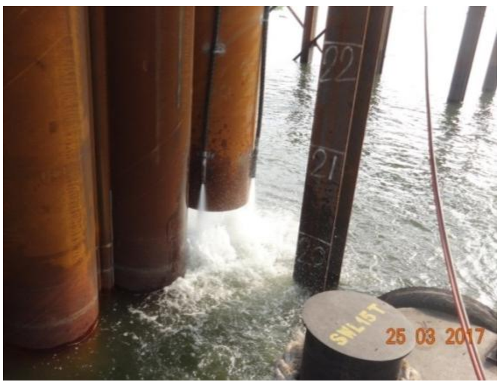


Figure 15. SPSP pressing (water jet- max. water pressure 15MPa).

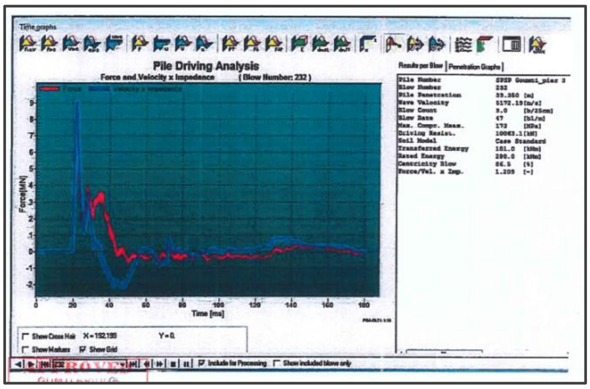


Figure 16. Pile driving typical analysis/result by PDA test (Pier-3 at Gumti).

Table 2. List of designed bearing capacity of piles at Kanchpur, Meghna and Gumti Bridges (Ref. 2).

Pile ID	Pile Diameter (mm)	Quantity	Pile Length (m)	Level of SPSP (m)		Designed allowable bearing capacity (kN)
				Top	Bottom	
Kanchpur:						
P1	1000	1	28	6	-22	3,339
P2		1	28.5	6	-22.5	2,731
P3		1	28.5	6	-22.5	3,179
P4		1	35	6	-29	4,165
P5		1	41.5	6	-35.5	2,911
P6		1	37	6	-31	3,245
Meghna:						
P2	1000	1	56	6.04	-49.96	2,648
P3		1	56	6.04	-49.96	3,913
P4		1	55	6.04	-48.96	2,181
P5		1	48	6.04	-41.96	2,185
P6		1	53.5	6.04	-47.46	2,784
P7		1	53.5	6.04	-47.46	4,240
P8		1	53.5	6.04	-47.46	2,954
P9		1	45.5	6.04	-39.46	4,052
P10		1	49	6.04	-42.96	2,300
Gumti:						
P1	1000	1	46.5	6.04	-40.46	2,159
P2		1	56	6.04	-49.96	2,593
P3		1	49	6.04	-42.96	3,217
P4		1	46.5	6.04	-40.46	2,062
P5		1	41.5	6.04	-35.46	3,786
P6		1	48	6.04	-41.96	2,363

Step 3: Concrete pouring inside SPSP:

Figure 17. Filling concrete inside SPSP.

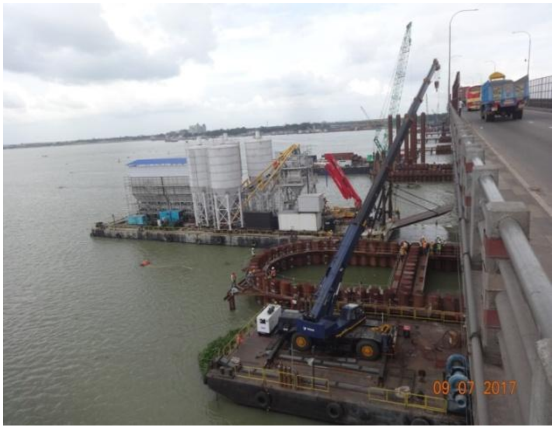


Figure 18. Concrete batching plant 50t rough terrain crane.

Figure 19. Cement milk (Grout) injection inside joint pipe of SPSP.

Figure 20. Backfilling (sand filling) inside SPSP cofferdam.

Figure 21. Pour seal concrete.

Figure 22. Curing of sealed concrete.

(a)

(b)

Figure 23. (a) Struts and wales installation and (b) Dewatering operation.

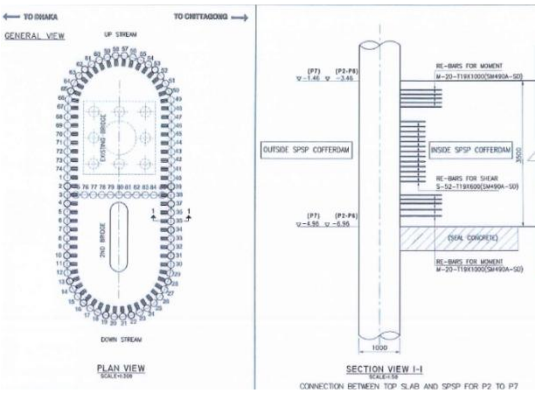
Lean Concrete: A thin concreting work (50 to 100mm) is done for base preparation of Top Slab sub-structure. Gravel is laid and concrete is poured as per the approved mix design by the Engineer of the project (Figure 24).

(a)

(b)

Figure 24. Lean concrete work at KMG bridges (a) Gravel laying for lean concrete and (b) Lean concreting operation.

Stud Bar welding on SPSP: To join in the top slab with permanent SPSP as an integrated foundation, the stud welding (Figure 25) is executed for the installation of steel reinforcement and following concrete casting.
Top Slab construction: After dewatering and lean concrete preparation, Top Slab structural works starts (Figures 26, 27).

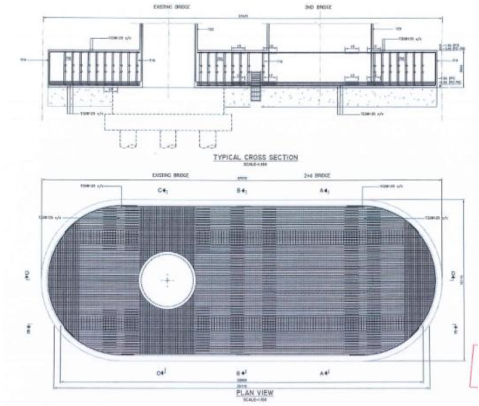


(a)

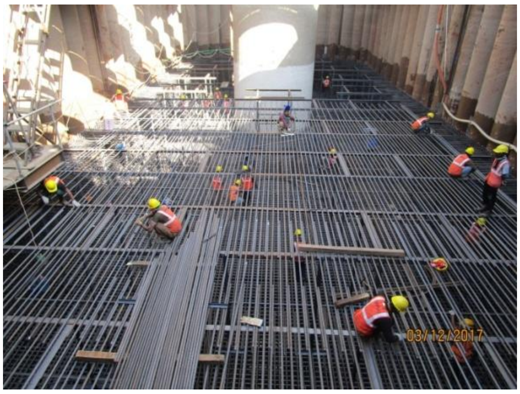
(b)

(c)
Figure 25. Stud Bars: (a) Typical drawing for Pier-2 to Pier-7 at Gumti Bridge (b) stud welding operation on marked surface of SPSP and (c) existing bridge pier surface chipping.

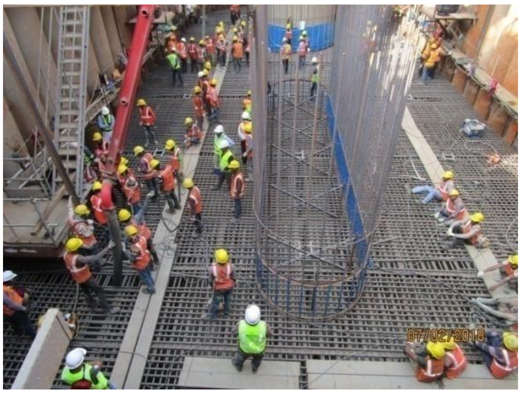
(a)



(b)



(c)
Figure 26. Top slab rebar installation: (a) typical drawing of rebar arrangement (b) bottom layer rebar placing (c) top layer rebar placing.



(a)

(b)
Figure 27. Top slab (a) concrete pouring and (b) curing operation.

Figure 28. Pier wall rebar (new bridge).

Figure 29. Pier wall layer-wise concreting work (new bridge).

(a)

(b)

Figure 30. Pier head (a) Rebar setting and (b) Concrete pouring.

Figure 31. Completion of pier head work.

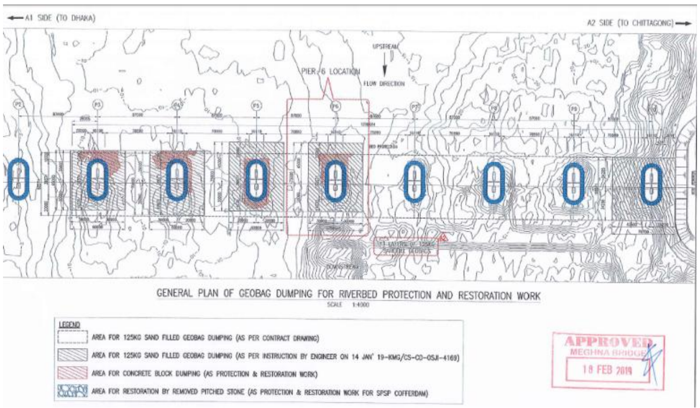


Figure 32. Layout plan of Geobag dumping for riverbed protection and restoration work for SPSP at Meghna bridge piers.

Cutting of Steel Pipe**:** After Pier construction work has been completed the SPSP have been cut at designated top elevation using gas cutter and the cut edge of SPSP was ground to be smooth in compliance with the method statement approved by the Engineer.

4 CONSTRUCTION PROBLEMS

GEOBAG Dumping (River Training), Protection and Restoration Work: 125 Kg Sand Filled GEOBAG dumping have been done for protection and restoration work for SPSP foundation at Pier-3, 4, 5, 6 & 10 of Meghna 2nd Bridge (Figure 32).

Water Leakage from SPSP Joint Pipe: A water leakage has been observed from the joint pipe location of the installed SPSP (between SPSP and Top Slab) at Pier 4 and Pier 7 at Meghna 2nd Bridges. After observation an immediate action has been taken as a remedy. A steel plate was installed by welding at the water leakage locations for the purpose of diverting the water in order not to let the leaked water contaminate the slab concrete. Thus the water –leaked area has been separately boxed out to purposefully create a gap. After the structural works i.e., top slab, pier wall and pier head are completed, the boxed-out gap (i.e. gap for water leakage diversion between SPSP and Top Slab) has been filled with concrete (Figure 33 and 34).

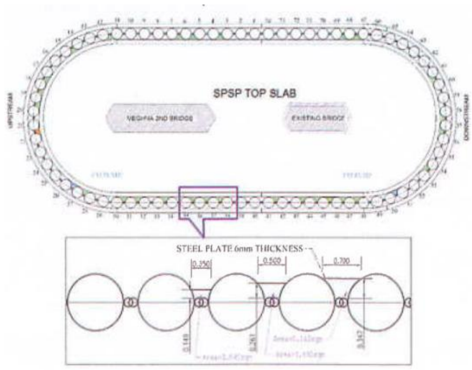


Figure 33. Plan (drawing) showing the concreting location inside the gap for Meghna Bridge.

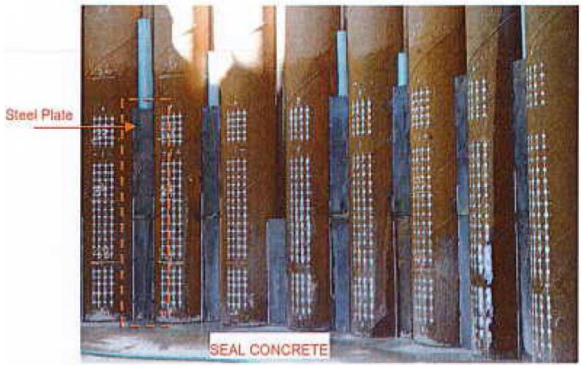


Figure 34. Typical elevation of gap at Meghna Bridge site.

5 CONCLUSIONS

SPSP system is a very worthy system for its dwell role playing performance (initial role is lateral earth retention during base construction and finally works as service pile for foundation), time saving, economic and as a whole optimized system which is very suitable for turbulent rivers that has been proven in this project. This system can be widely used in Bangladesh in future for the similar type of bridge projects more effectively. SPSP system will remain as a remarkable foot-step being a new construction system of foundation in our country as like "The Kanchpur, Meghna and Gumti 2nd Bridges Construction and Existing Bridges Rehabilitation Project" will also be remarked in the bridge construction history of Bangladesh for long days.

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