Pipeline installation using horizontal directional drilling method (HDD)

Putri Arumsari*, Elisa Tanuwijaya
Civil Engineering Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480

Corresponding author: putri.arumsari@binus.ac.id

Abstract. Pipelines crossing rivers, highways, and railways require special consideration that includes details in both design planning and the field installation. One of the methods used for pipelines crossing is the horizontal directional drilling method (HDD). Risks are associated with the HDD installation such as the failure of the pilot boring and reaming, the ground collapsing, and the failure of the pullback process. Construction method based on these risks will be analysed in this paper. Based on the construction method proposed, the quantity of materials, heavy equipment, and workers, and the cost and time are analysed.

Keyword: construction method, horizontal directional method, pipeline, risks

1. Introduction

River crossing pipelines, highways or rail crossing require special considerations both in design planning and installation method in the field. There are 2 main construction methods that are commonly used in the installation of river crossing pipelines, the open trenching method such as the open excavation method and the trenchless methodsuch as the Horizontal Directional Drilling (HDD) method. Consideration of construction method need to be analysed during pre-construction to analyse the suitable method based on the crossing location, geographical challenges, standard regulation, and cost and time limitation[1]. The HDD method is usually used to avoid dense areas or wide rivers. There are some risks associated in the HDD construction method such as failure in the pilot boring and reaming[2], the ground collapsing [3] and the risk of failure in the pullback process[4].

In considering a construction method, several factors need to be analysed such as the labour, the material and the equipment needed, the site characteristic, the management of the owner, the financial and other factors [5]. Water Intake Karawang New Industry City project has a pipeline track approximately 7 kilometres from the river to the water processing site. The 7 km track has different challenges, and one of them is a river crossing challenge. This paper will be analysing one of the construction methods, which is the HDD regarding the labour, material, and the equipment needed, and the cost and duration involved.
2. Horizontal Directional Drilling

Horizontal Directional Drilling (HDD) is a construction method used to make crossings under rivers, roads, and existing structures. This method is also commonly used in pipe installation / deploying, where there are no other possible options [6] such as pipe installation under rivers, highways, railroad tracks and other environmentally sensitive areas, including steep cliffs in where changes in altitude over short distances endanger conventional cutting and cover installations [7].

Pipe installation by HDD is generally carried out in 3 stages. The first stage consists of drilling a small diameter pilot hole along the designed direction path. The second stage involves enlarging the pilot hole to the appropriate diameter for pipe installation. The third stage consists of pulling the pipe back into the enlarged hole [7]. These are the illustration of stages involve in the HDD method:

2.1. Pilot Boring

Pilot boring is the first step in the HDD process. The test hole was drilled along a predetermined alignment where the entry and exit points were located using traditional survey methods. Control of the drill bit is achieved by using a non-rotating drill strap with an asymmetrical front end. The process of pilot boring is shown in Figure 1.

![Figure 1. Pilot Boring](image.png)

2.2. Hole Opening (Reaming)

The second step consists of one or more opening holes. There are two types of tools that enlarge the pilot hole, they are: fly cutters, used for most earth formations, and rock opening tools, used for very dense earth and rock formations. Typically, a hole opening tool is attached to the same drill pipe rope which drills the pilot hole and then is rotated and pulled back towards the drilling rig from the exit point. The process of reaming is shown in Figure 2.

![Figure 2. Reaming Process](image.png)

2.3. Pull Back

After the hole is enlarged, the product pipe can be pulled through a pullback. A reamer is attached to the drill string and then connected to the drill head to pull the pipe through a rotary motion. The process of reaming is shown in Figure 3.
3. Risks in Horizontal Directional Drilling (HDD)

Three dominant risks are associated with the Horizontal Directional Drilling (HDD) construction method such as the failure in pilot boring and reaming, the ground collapsing, and the risk of failure in the pullback process. Interviews were done to 3 respondents to find out the highest risk out of the 3 risks identified based on the frequency and impact of each risk. The impact considered were the environmental impact, the cost, and the duration. Based on the interviews, the failure in the pullback process is considered as the highest risk associated in the HDD construction method. Therefore, some mitigations are proposed, such as:

a. Prevention / reduce the risk of pullback failure by boring the ground with a borehole diameter that exceeds the outer diameter of the pipe / 1.5 times the outer diameter of the pipe.

b. Increase the number of slurry pumps with the aim that the mud can be sucked up quickly before the mud returns to fill the drill hole and disrupt the course of the pullback process.

c. If a failure in the pullback process has occurred, then the pipe must be pulled back towards the inlet using an excavator heavy equipment.

4. Horizontal Directional Drilling (HDD) Method Analysis

4.1. Location

The location of the pipeline track is in the Water Intake Karawang New Industry City project. The total length of the pipeline is approximately 7 km and 160 m of the pipeline crosses a river, which is analysed using the HDD construction method. In Figure 4 is the designed route of the water intake pipeline using the HDD and in Figure 5 is the cross section of the designed work specification of the HDD. Based on these specifications, the material, the heavy equipment and the workers needed, and the cost and duration associated in the HDD construction method are then analysed.

Figure 3. PullBack

Figure 4. Water Intake Route using the Horizontal Directional Drilling Method
4.2. Material Analysis

The material needed for the drilling process of the HDD method are solar as the fuel for the heavy equipment, and water, bentonite, and polymer are used as the drilling slurry. Paitan grass and the topsoil is used to level up the ground after the drilling process is finished. The detailed list of the material analysis can be seen in Table 1.

Table 1. List of Material Analysis of the Horizontal Directional Drilling Method

| No | Material                     | Quantity | Unit       |
|----|------------------------------|----------|------------|
| 1  | Solar                        | 9936     | liter      |
| 2  | Water                        | 2484     | m³         |
| 3  | Bentonite + Polymer          | 2070     | kg         |
| 4  | HDPE Pipe PN 12,5            | 207      | m          |
| 5  | Paitan Grass                 | 9        | m²         |
| 6  | Topsoil                      | 9        | m²         |

4.3. Heavy Equipment Analysis

Theodolite is needed during the pre-construction of the HDD to locate and place benchmark of the drilling position based on the design. The heavy equipment used during the drilling process are the HDD machine, water tank, water suction tank, mixing pump, generator, and the submersible pump. The truck crane and the butt fusion welding machine is used during the welding of the HDPE pipe. The detailed list of the heavy equipment analysis can be seen in Table 2.

Table 2. List of Heavy Equipment Analysis of the Horizontal Directional Drilling Method

| No | Heavy Equipment       | Quantity | Unit           |
|----|-----------------------|----------|----------------|
| 1  | Theodolite            | 1        | Unit/rent per day |
|    | HDD Machine type GBS-28L |         |                |
|    | Drag Bit              |          |                |
|    | 200mm                 |          |                |
|    | 300mm                 |          |                |
|    | 400mm                 |          |                |
|    | 500mm                 |          |                |
|    | 600mm                 |          |                |
|    | 700mm                 |          |                |
|    | Drill Rod             |          |                |
|    | 200mm                 |          |                |
|    | 300mm                 |          |                |
|    | 400mm                 |          |                |
|    | 500mm                 |          |                |
|    | 600mm                 |          |                |

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| No. | Heavy Equipment     | Quantity | Unit                  |
|-----|---------------------|----------|-----------------------|
| 1   | 700mm Reamer        |          |                       |
| 2   | 200mm               |          |                       |
| 3   | 300mm               |          |                       |
| 4   | 400mm               |          |                       |
| 5   | 500mm               |          |                       |
| 6   | 600mm               |          |                       |
| 7   | 700mm               |          |                       |
| 8   | Water Tank          | 1        | Unit/rent per day     |
| 9   | Mixing Pump         | 1        | Unit/rent per day     |
| 10  | Generator           | 1        | Unit/rent per day     |
| 11  | Truck Crane         | 1        | Unit/rent per day     |
| 12  | But Fusion Welding Machine | 1 | Unit/rent per day |
| 13  | Water Suction Tank  | 1        | Unit/rent per day     |
| 14  | Excavator PC75      | 1        | Unit/rent per day     |
| 15  | Submersible Pump    | 2        | Unit/rent per day     |

4.4. Workers Analysis

There are 6 types of workers that are needed in the HDD construction method, there are the worker, foreman, plumber, truck driver, drag bit expert and the tracking operator. The detailed list of the workers analysis can be seen in Table 3.

| No. | Workers            | Quantity |
|-----|--------------------|----------|
| 1   | Workers            | 14       |
| 2   | Foreman            | 1        |
| 3   | Plumbers           | 2        |
| 4   | Truck Driver       | 2        |
| 5   | Drag Bit Expert    | 1        |
| 6   | Tracking Operator  | 1        |

4.5. Cost Analysis

The breakdown job description of the HDD construction method consists of 4 works, such as the preliminary work, the standard work, the HDD work, and the finishing work. The detailed cost analysis of each work can be seen in Table 4. The total cost of the HDD work based on the design on Figure 4 and Figure 5 is Rp2.786.713.646,78.
Table 4. Cost Analysis of the Horizontal Directional Drilling Method

| No | Work Description                      | Volume | Unit | Unit Price   | Total         |
|----|---------------------------------------|--------|------|--------------|---------------|
| A  | Preliminary Work                      |        |      |              |               |
| 1  | Land clearing                         | 59     | m²   | Rp33.465.00  | Rp1.974.435.00|
|    | Benchmark surveying and marking,      |        |      |              |               |
|    | driving, and receiving pit            | 59     | m²   | Rp4.725.93   | Rp278.829.58  |
|    | Procurement, transportation and       | 207    | m    | Rp150.418.51 | Rp31.136.630.54|
|    | unloading of HDPE pipe                |        |      |              |               |
|    | Welding of HDPE pipe                  | 52,595 | m    | Rp1.098.417.90 | Rp57.771.289.45|
|    | Trace dismantling for driving and     | 9      | m²   | Rp33.465.00  | Rp301.185.00  |
|    | receiving                              |        |      |              |               |
|    | Heavy equipment mobilization          | 2      | Ls   | Rp5.000.000.00 | Rp10.000.000.00|
| B  | Standard Work                         |        |      |              |               |
|    | Excavation work, driving and          | 6.3    | m³   | Rp139.790.93 | Rp880.682.88  |
|    | receiving                              |        |      |              |               |
|    | HDD Work                              |        |      |              |               |
|    | Pilots Boring                         | 207    | m    | Rp5.520.517.50 | Rp1.142.747.122.50|
|    | Reaming                               | 1242   | m    | Rp363.436.96 | Rp451.388.709.64|
|    | 200, 300, 400, 500, 600, 700mm        |        |      |              |               |
|    | Pullback                              | 207    | m    | Rp5.262.055.00 | Rp1.089.245.385.00|
| C  | HDD Work                              |        |      |              |               |
| D  | Finishing Work                        |        |      |              |               |
|    | Fill work                             | 5.4    | m³   | Rp104.765.00 | Rp565.731.00  |
|    | Grass planting                        | 9      | m²   | Rp47.071.80  | Rp423.646.20  |
|    | Subtotal                              |        |      |              | Rp2.786.713.646.78 |

4.6. Time Analysis

The time analysis of the HDD method is based on the experiences of contractors that have been installing the HDD on site. Based on that experiences the duration of each work in the HDD construction method can be seen in Table 5. The time analysis is analyse using the precedence diagram method (PDM) which can be seen in Figure 6. Based on Figure 6, the total duration needed for the HDD method is 21 working days.
Table 5: Time Analysis of the Horizontal Directional Drilling Method

| No | Work Description                              | Volume | Unit  | Duration (day) |
|----|-----------------------------------------------|--------|-------|----------------|
| A  | Preliminary Work                              |        |       |                |
| 1  | Land clearing                                 | 59     | m²    | 1              |
|    | Benchmark surveying and marking, driving,     |        |       |                |
|    | and receiving pit                             | 59     | m²    | 1              |
| 2  | Procurement, transportation and unloading of  | 207    | m     | 3              |
|    | HDPE pipe                                     |        |       |                |
| 3  | Welding of HDPE pipe                          | 52,595 | m     | 8              |
| 4  | Trace dismantling for driving and receiving   | 9      | m²    | 1              |
| 5  | Heavy equipment mobilization                  | 2      | Ls    | 1              |
| B  | Standard Work                                 |        |       |                |
| 1  | Excavation work, driving and receiving        | 6,3    | m³    | 1              |
| C  | HDD Work                                      |        |       |                |
| 1  | Pilot Boring                                  | 207    | m     | 3              |
|    | Reaming diameter 200, 300, 400, 500, 600,     |        |       |                |
|    | 700mm                                         | 1242   | m     | 9              |
| 2  | Pullback                                      | 207    | m     | 3              |
| D  | Finishing Work                                |        |       |                |
| 1  | Fill work                                     | 5,4    | m³    | 1              |
| 2  | Grass planting                                | 9      | m²    | 1              |

Figure 6. Precedence Diagram Method (PDM) Diagram of the Horizontal Directional Drilling Method

5. Conclusion

Based on the analysis done on the Horizontal Directional Drilling (HDD) construction method on the Water Intake Karawang New Industry City project these are the results:

a. Material analysis: 6 types of material needed
b. Heavy equipment analysis: 10 types of heavy equipment needed
c. Worker analysis: 6 types of workers needed
d. Cost analysis: the total cost is Rp2,786,713.646,78
e. Time analysis: the total duration is 21 working days.

These results will then be used on the later research in comparing with other construction methods on river crossing which can be a possible option.
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