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Case Study: Stormwater network construction

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Abstract

This paper briefly reviews the practical side of the construction of a stormwater network. The construction of a stormwater network is a necessity to efficiently drain the rain and prevent the adverse impact on infrastructure and the inhabitants of a specific area. Building an efficient stormwater network must incorporate appropriate design and construction of the network. The construction of a stormwater network is significantly important, and a poor construction process can severely reduce the efficiency of a stormwater network. This paper will focus on the various construction stages of a stormwater network.

The purpose of this paper is to provide a comprehensive understanding of stormwater network components and methods of construction. Despite the variance in methods of construction of a stormwater network in different countries, this paper will include rich information about the practical side of stormwater network construction. The investigated case study in this paper will be a stormwater network constructed in the UAE with a length of 22 km and a maximum pipe diameter of 1200 mm.

1. Introduction

The draining of heavy rains poses a critical problem for many countries. A heavy storm can cause severe damage to infrastructure and personal properties. The impact of heavy storms can be reduced by improving the infrastructure and providing a stormwater network that can efficiently drain the rain. The presence of a stormwater network will reduce the impact of heavy storms and save human lives. Moreover, it will prevent the disruption of infrastructure and daily life for country citizens. The performance of a stormwater network will depend on appropriate design, proper construction, and maintenance of the network.

This paper will discuss various topics related to stormwater network construction. This paper will study the following points:

- Importance of a stormwater network.
- components of a stormwater network: inlets, catch basins, lagoons, etc.
- The construction procedure for a stormwater network
- Obstacles faced during construction
- Tests conducted at the field, such as leak tests and deflection tests.

2. Importance of stormwater network

The absence of an appropriate stormwater network during a storm of heavy rain may result in fatalities and severe damage to infrastructure. The presence of a well-maintained and efficient drainage system can reduce the negative impact of a storm. Recently, we've seen a considerable number of heavy storms hit the Middle East and different spots around the world. Despite the presence of drainage systems in some countries, these storms cause huge damage to infrastructure, economic, and a number of fatalities.

The building of a drainage network is important to prevent negative impact, such as:

- Accumulation of water on roads results in obstructing vehicle movement, which can negatively impact economic.
- Flooding stores and homes, which can damage personal belongings such as goods, cars, farms, etc.
- Damaging existing roads and existing infrastructure.
- The loss of human lives.

3. Component of a stormwater network

A natural catchment will have a natural system of draining water. The urban development of a natural catchment will replace the natural drain system with an artificial drain system. The structure of the constructed drain system will be similar to that of the natural system.

A stormwater network will consist of various elements such as gullies, catch basins, manholes, pumping stations, etc. The construction of an efficient drainage network requires adequate knowledge of future urbanization, such as road levels, for the preparation of stormwater network layout and the placement of inlets and pipes efficiently. Also, the designer should have the rainfall data and the run-off coefficient to estimate the flow precisely. The estimation of flow will impact the pipe and inlet size. Also, it will play an important role in determining the spacing between the inlets and gullies.

3.1 Inlet and gullies

The accumulation of water in urban areas can be a serious hazard for road commuters and residents of the area. Water pooling on roads jeopardizes the lives of drivers and pedestrians. Therefore, inlets or gullies should be provided at roads if there is a possibility of water ponding during a storm. Figure 1 presents different types of stormwater inlets. The upper portion of inlet/gully is only shown in figure 1. Under the cover lies the remaining inlet, where the pipe is connected to the inlet or gully. The structure, size, and typical arrangement of inlets and gullies may vary for different countries.

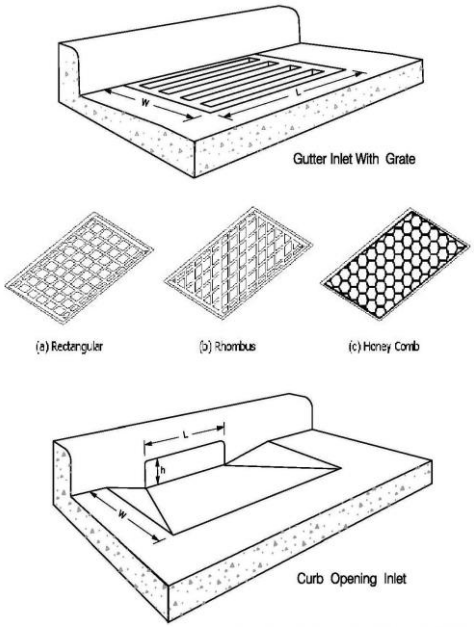

Figure 1

Figure No. 02 shows a stormwater inlet during the construction stage of a drainage network. The correct location of inlets will facilitate the drainage of water and reduce the hazards associated with water ponding. The inlet should be placed at the lowest point of a road. The location of inlets is controlled by the road profile and cross-slope. Along the road profile, the inlets should be placed at the low points of the road profile, known as sag points. Furthermore, inlets should be placed at the low point of the road cross-section.

Figure 2

3.2 Catch-basin

The catch basin's main function is to sediment the sand and debris, which prevents the clogging of the network. Catch basin constructed with a sump below the drain pipe to instigate the sedimentation process of sand and debris. Clearly, catch basins have a bigger size compared to inlets, as shown in figure 3. A larger size will ensure an efficient sedimentation process for debris and sand. In addition to collecting sand and debris, the catch basin can be fitted with a grated cover and function similarly to an inlet to collect runoff water.

Figure 3

A catch basin can be used as a junction of pipes similar to manholes. In general, the catch basin will collect the runoff water from the inlets and convey it

to a manhole, which will prevent the clogging of main pipe lines.

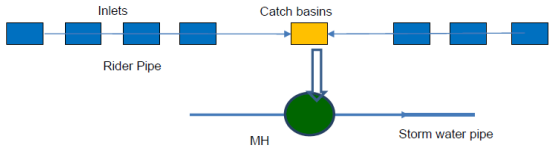

Figure 4

3.3 Manhole

The collected runoff water from inlets and catch basin flowed to a manhole. The shape and details of manholes are not the same everywhere, and they may vary. In general, the manhole shape will be circular, as exhibited in Figure 5. The manhole will receive water from a number of inlets, as per the design. Therefore, the manhole will collect a large amount of water. Therefore, the size and depth of manholes are usually bigger. It is necessary to provide safe access to facilitate the maintenance process of the network.

Figure 5

As a general rule, manholes are constructed at various locations, such as:

- The junction of stormwater pipes
- At the point where pipe size changes
- At the point of pipe gradient or direction change

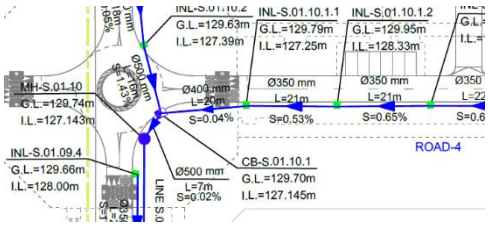

Figure 6

3.4 Tanks or lagoons

Tanks or lagoons may be used in a stormwater network as storage units to prevent overflow downstream during heavy rain. Furthermore, in the case of hydraulic constraints for the existing stormwater network, it can be used to reduce the peak flow of the new network to fit the capacity of the existing network. This process is known as flow attenuation.

4. Construction of a stormwater network

The construction of a stormwater network will include the laying of pipes, the installation of inlets and manholes, the connection of pipes to manholes, etc. The construction process shall be monitored by a competent engineer and supervisor to build an efficient drainage network. Moreover, competent land surveyors are very important to verify the level of pipes and the location of inlets and manholes.

A clear layout of a stormwater network must be provided to the construction team. The layout shall include the details of a stormwater network, such as inlet and manhole coordinates, invert level of pipes, pipe diameter, pipe slop, etc. Also, the construction details of manholes shall be furnished to the construction team. The construction details will illustrate the dimensions, reinforcement, connection details, opening details, etc.

4.1 Survey works

Sufficient numbers of competent surveyors equipped with calibrated machines are necessary for the construction of a stormwater network. The surveyor should be equipped with level machines, total station or GBS. The surveyors must be provided with shop drawings that contain sufficient data to complete their job. Shop drawings should clearly provide data such as coordinates of inlet/manhole, invert level of pipes,

slope of pipes, diameter of pipes and other necessary information.

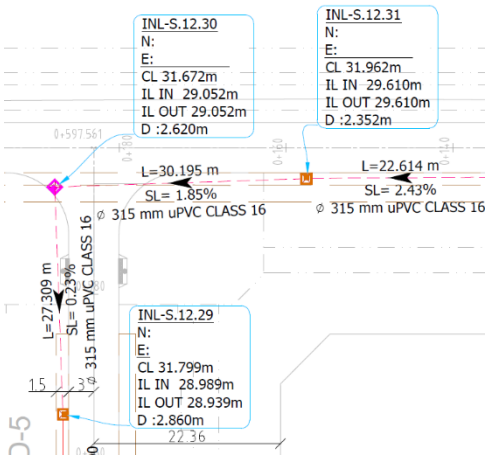

Figure 7

Surveyor should rely on verified survey bench marks and calibrated survey instruments to prevent any deviation in readings. Furthermore, it is important to verify the existing bench mark with responsible authority.

4.2 Trench construction

Drainage pipes are enclosed inside special trenches at the specified depth. Excavators are used to dig trenches to the required depth and size. The size and all the details of a trench are usually specified in the contract drawings or project specifications.

Figure 8

Before excavating, the surveyor will provide the engineer and site team with the trench layout and mark it as a guide. And during the excavation, the surveyor will verify the level and size of the excavation of a trench to ensure it is within tolerance. The bed of the trench should be prepared, leveled, and compacted with suitable equipment.

4.3 Pipe laying and aggregate surround

Pipes must be laid at the correct alignment and levels. The tolerance in alignment should not exceed 20 mm and 6 mm in levels. The type of pipes joints may vary depending on the pipe material and manufacturer. Pipes may be connected directly through a socket and spigot at the pipe ends, or a coupler used to connect pipes together. It is important to ensure that the rubber gasket is placed properly at the joint to prevent pipe leakage in the future. Furthermore, a gap of 10 mm, or as per manufacturer recommendation, should be left between the connected pipe ends to allow for thermal expansion of the pipes.

Aggregates may be used as a surround for pipelines. The appropriate placement and compaction of aggregate below and surrounding the pipes will reduce the settlement and prevent unwanted deflection of the laid pipes. Excessive deflection of pipes may lead to pipe damage or breakage. The spreading and compaction of aggregates are critical for improving the bearing capacity of the trench bed and reducing pipe deflection.

Figure 9

4.4 concrete surround

Extra protection could be used for pipes where the soil cover is not sufficient. Usually, it is used where the cover above the pipe is less than one meter. The concrete is used to prevent pipe damage due to vehicle or equipment loads. Alternatively, concrete protection slabs or tiles can be used to protect pipes at shallow depths.

4.5 Installation of inlet/Catch-basin

Frequently, inlet/catch- basins are cast in a precast yard, then shifted and installed on site. All the required details for producing inlets, such as reinforcement, dimension, and opening location, should be available in shop drawings. During site installation, the engineer should verify some important points, such as the location and orientation of the inlet, the blinding concrete level, and the pipe opening location.

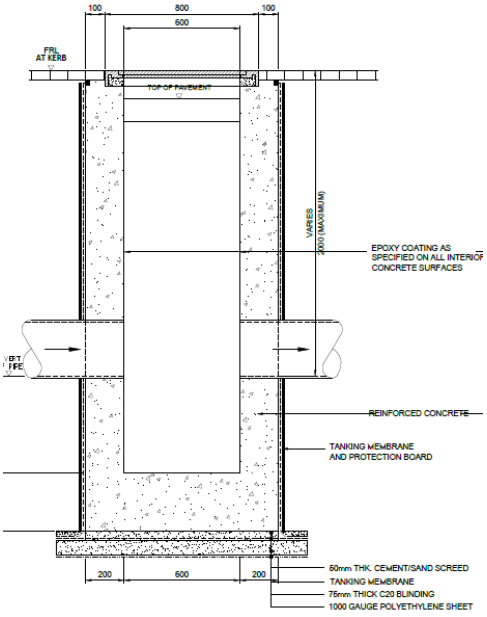

Figure 10

Figure 11 shows a stormwater inlet. The area around the inlet will be cleaned and backfilled. The backfilling should be layer-wise with appropriate compaction to prevent settlement around the inlet. The grated cover of the inlet is installed at later stages. The cover will be installed when the backfilling is completed. The late installation of cover will prevent the damage to the cover during construction and will allow a precise determination of the cover level. The inlet cover should be flush with the pavement level for the top entry inlet or curb stone level for the side entry inlet.

Figure 11

4.6 Installation of manholes

A manhole will usually have a circular shape, as presented in figure 12. The manhole will collect runoff water from a variety of inlets. The size of manholes is larger than the inlet, and they should be suitable to provide access for maintenance. Moreover, the manholes are usually located at pipe junctions. Therefore, the circular shape of manholes allows the connection of pipes from different directions and angles.

Figure 12

The size and weight of a stormwater manhole will determine whether it can be pre-casted and then installed in the field. In some cases, the manhole base is pre-casted and the remaining part of the manhole

casted at the field due to weight restrictions. Pre-casting of inlets and manholes will save construction time by simply installing the inlet and manhole in the field. Each and every type of manhole should have a typical detail that shows the dimension and reinforcement details, similar to figure 13.

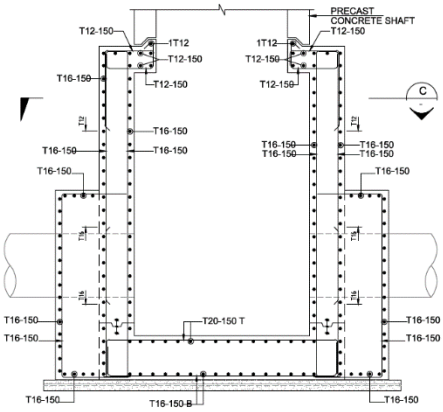

Figure 13

4.7 waterproofing and epoxy coating

The waterproofing of the external surface of inlets and manholes protects the concrete and reinforcement from the surrounding environment. Different types of waterproofing systems can serve the same purpose and provide protection. A common system is a waterproof membrane. In this system, the concrete is painted with bitumen, and then the membrane is applied to the painted surface. It is very important to read the manufacturer's instructions to obtain the best results. A protection board can be provided to prevent damages to the waterproofing membrane during the construction process and to keep the membrane in good condition. It is important to ensure proper bonding between the membrane and the painted concrete surface without any bubbles or loose areas. Moreover, the overlapping between membranes should be as per the recommendation of the manufacturer. Furthermore, epoxy coating is used to protect the concrete surface inside inlets. The concrete surface inside the inlet can be coated with two or more layers of epoxy coating. Epoxy coating will protect the concrete surface from the harmful chemicals in runoff water.

Figure 14

4.8 Access to inlets/manholes

Safe access, such as ladders, should be provided for deep inlets and manholes. Access is important for the maintenance work of the network. Furthermore, cleaning inlets and pipes is crucial. The accumulation of sand and dirt inside the inlets and manholes is inevitable. Therefore, periodic cleaning is necessary to facilitate the drainage of runoff water during the storm. Ladders can be made from various materials, such as steel, GRP, etc. It is important for the installed ladder to be capable of supporting worker weight without excessive deflection or failure. Figure 15 shows an example of an access ladder to an inlet. The type of ladder used and the arrangement can be different for deeper manholes. A circular hoop may be added to the upper portion of the ladder for safer access to inlets.

Figure 15

4.9 Pipe jointing and Connection to inlets/manhole

4.9.1 Pipe joining

Various types of joints are available in market. Any type of joint can be used as long as it is suitable for the field conditions and will not leak in the future. Pipe couplers are used to connect pipes together. In this type of joint, the rubber gasket will be placed inside the coumpler at the specified location. And the pipe will be pushed inside the coupler with the assistance of lubricating soap.

Figure 16

Socket and spigot are common pipe joining methods. In this method, the pipe will have an enlarged end on one side, known as a socket. The socket will be fitted with the rubber gasket, and the spigot (normal pipe end) will be pushed into the socket. These are examples of pipe joining methods. Different manufacturers may have their own special joining methods, such as mechanical joints, joint lamination, etc.

Figure 17

4.9.2 Connecting pipe to inlet/manhole

The pipeline will be connected to the inlet port pipe. Inlet port pipe can be fixed during the construction of the inlet wall, or an opening is left at the inlet or manhole, and then the pipe is fixed during the construction stage. Advance fixing of port pipe can result in difficulties during the connection of the pipeline to the inlet due to inevitable changes that may arise during the laying of the pipe as per site requirements. Therefore, most contractors prefer to fix the port pipe during the pipeline laying stage. Port pipe will have a small length, and usually it will protrude 30 to 60 cm beyond the inlet or manhole wall.

A rocker or short pipe is sometimes used to provide flexibility. The short piece is fixed between the port pipe and the pipeline. The presence of the rocker pipe will increase the pipe flexibility and reduce the negative impact that may occur due to manhole or inlet settlement. Manholes and inlets are susceptible to settlement due to traffic loads. Therefore, providing rocker pieces is recommended to provide flexibility and reduce the impact of traffic loads. Figure 16 presents the pipeline connection arrangement to a stormwater manhole.

5. Obstacles faced during construction

Various obstacles can be faced during the construction of a drainage network. Existing services burred inside

the ground pose a serious obstacle during construction. Therefore, a detailed investigation with trial trenches should be conducted to locate all the services. Existing services may clash with pipelines or inlets. Therefore, a clash analysis should be performed to clear any clashing between existing utilities and the proposed drainage network. Figure 18 shows a clash between the existing service crossings and the pipelines. The solution for such a case could be raising the clashing services or changing the pipeline profile if possible.

Figure 18

Groundwater can be considered an obstacle as well. Groundwater should be drained to proceed with activities such as excavation, the laying of aggregate surrounds, and pipelines. The dewatering of groundwater for each trench is a difficult and exhausting process for large networks.

Deep excavation for laying pipelines poses a serious safety issue, particularly for loose soil and in the vicinity of live roads. Proper measures should be taken to reduce the risks related to excavation. For loose soil, sheet piles can be used to prevent trench collapse. Moreover, trenches should be barricaded to prevent the access of unauthorized persons.

Excessive rain can seriously impact construction projects. Rain poses a serious challenge for the drainage network under construction. Excessive rain will flood the excavated trench and may cause soil collapse. Furthermore, soil can accumulate inside pipes, as shown in figure 19. Great effort is required to drain the trench of accumulated water and clean the pipes.

Figure 19

6. Field testing: leak test, deflection test

Field testing is performed to verify the quality of executed works and the compliance of finished works with standards and client requirements. Commonly, water leak tests and deflection tests are conducted for completed pipelines. A leak test can be conducted either by filling the pipe with water or air. The air leak test is more prevalent and comm than the water test. Air tests are easier and quicker to conduct. The test is performed by fixing stoppers at pipe ends and then blowing air into the pipe. A manometer will be connected to the stopper, and the water head in manometer will be observed. The test will be considered successful if the water level didn't fall below 75 mm for a period of 5 minutes.

Figure 20

A deflection test is also conducted at the field to verify the amount of deflection the pipe undergoes after installation and backfilling. If the pipe deflection exceeds the allowable limit (usually 5%), it indicates that the pipe may potentially fail under the loading and undergo excessive deformation. Excessive deflection can impact pipe integrity with joints, reduce hydraulic capacity, and affect the flow characteristics of the pipe. A deflection test is performed with the use of a deflectometer instrument or a mandrel ball.

7. Conclusion

A strong storm can severely damage infrastructure and cause fatalities. Therefore, the construction of a drainage network is crucial to reducing the impact of storms. Building an efficient drainage network is associated with appropriate design and execution of the design on the field. This paper discusses many aspects of a drainage network. In this paper, I focus on the particular parts of building a drainage network, such as the as the construction procedure, components of the network, challenges faced during construction, and field testing.

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