# Alaa Abbas

# An innovative method for the construction of a separate sewer system in narrow streets in UK and EU cities

**(Oral)**

**Alaa Abbas [1], Felicite Ruddock[2], Rafid Alkhaddar[3], Glynn Rothwell[4] and Robert Andoh[5]**

[1] Postgraduate Research Student, Liverpool John Moores University, Department of Civil Engineering, Henry Cotton Building, 15-21 Webster Street, Liverpool, L3 2ET, UK, A.H.Abbas@2015.ljmu.ac.uk

[2] Programme Leader, Department of Civil Engineering, Liverpool John Moores University, Peter Jost Centre, Byrom Street, Liverpool L3 3AF, UK, F.M.Ruddock@ljmu.ac.uk.

[3]Professor of Water and Environmental Engineering and Head of the Department of Civil Engineering , Liverpool John Moores University, The Peter Jost Centre, Byrom Street, Liverpool, L3 3AF, UK, R.M.Alkhaddar@ljmu.ac.uk

[4]Dr.Glynn Rothwell, Department of Maritime and Mechanical Engineering, Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF, UK,G.Rothwell@ljmu.ac.uk

[5]Professor Robert Andoh, CEO and President of AWD Consult Inc. 32 Vista Drive, South Portland, ME 04106, USA, bandoh@awdconsult.com

**Abstract**

Sewer systems that convey both sanitary sewage and stormwater through a single pipe are referred to as combined sewer systems. This system diverts all flows exceeding the design capacity to the receiving watercourses in heavy rain events. Therefore, environmental regulations limit the use of this system and separate sewer systems are currently used in all new developments. However, the UK, most other European, and other countries usually have narrow streets occupied by a complex network of infrastructure services. About 70% of sewer systems in the UK and Europe are combined systems. Finding a space in which to place another two sets of pipes (in a separate sewer system) is therefore challenging. This research investigates a design which is capable of overcoming this challenge by a modified system for the sewer networks. The system includes a proposed new design for the manhole shape, which will allow the storm flow and the foul flow to pass through the same manhole without mixing and allows using one trench to set two pipelines. This will bring economic advantages by decreasing construction cost by about 30% plus extra protection for the environment by separating sewage from stormwater, decrease footprint by 16% and construction time by 18%.

**Keywords:** Combined, design, separate sewer system, storm, urban drainage.

## 1. Introduction

The sewer system is the networks of pipes used to drain the stormwater caused by wet weather and the sewage from urban areas. Two systems are mainly used; the old one is the combined sewer, which uses a single pipe to convey both sanitary sewage and stormwater through a single pipe. The newer one is a separate sewer system, in which two sets of pipes are used, one just to drain the cleaner stormwater runoff to the nearest watercourse (river, lake, etc.) while the second set of pipes collects and conveys the sewage water to a Waste Water Treatment Plant (WWTP).

The combined sewer system has been used widely and efficiently in the past because it is a simple system, as one pipe is designed to carry the sewage water flow through dry weather in addition to stormwater following wet weather. For that reason, the diameter of the pipe is designed to be able carry both sewage and stormwater flows and the WWTP is designed to have a capacity about three times the dry weather sewage flow. This system makes up about 70% of the sewer system in the UK and in many EU countries such as Germany, France, and Belgium(Read and Vickridge 1997). The large size of pipe with little flow through dry season causes that suspended solid settles as sediment at the bottom of the pipe and in wet weather, the storm flows help to remove these sedimentations from the pipes, many hydraulic and pollution problems associated with this phenomena. Expansion of urban areas and the increase of impermeable areas have put more pressure on the sewer system by increasing the quantity of stormwater flow, making the combined sewer system unable to convey all the flow to the WWTP in a short period to avoid flooding. The combined sewage system is designed to release untreated overflows to watercourses through a Combined Sewer Overflow (CSO) to keep the hydraulic load at a manageable level (Brombach 2005).

The separate sewer systems have been designed to address the harmful environmental impact of combined sewer system and avoiding flooding by increasing the capability of the stormwater drainage system to convey runoff caused by heavy rain to nearest watercourses, via separate pipelines (Butler and Davis 2011). The advantage of this system over the combined sewer system is regarding environmental protection as it does not discharge wastewater directly into the watercourse Table 1 (Eriksson et al. 2007). However, a separate sewer system occupies more space and is more expensive than the combined system and its use is dependant on environmental regulation to overcome the pollution challenges that caused by CSO. This resulted in limitation of the use of combined sewer systems, except as limited extensions or replacements for existing combined systems (Bizier 2007).

**Table 1.** Advantages of Combined and Separate Sewer Systems

| Separate System | Combined System |
|---|---|
| ➢ Expensive<br>➢ Less pollution effects on watercourse<br>➢ Additional space is required to accommodate both pipes | ➢ Lower costs for pipe construction<br>➢ High pollution level through heavy rain time on watercourses<br>➢ The space occupied by the single pipe is smaller |

## 2. Innovation in sewer system design

The new technologies available today for the design, manufacture, maintenance and inspection of sewer systems have urged designers to revisit traditional urban drainage management with an innovative outlook. The EPA implemented a project, which has provided an overview of many recent works on sewer systems. Innovative system designs identified in the EPA study include using Real-Time Control, Vacuum sewer technology and retrofit such as a sustainable drainage system (SUDS) or Best Management Practice (BMP) (United States Environmental Protection Agency 2007). The American Society of Civil Engineers (ASCE) conducted a study to separate the combined sewers in three cities in the US by using pressure tubing to pump the sewage from houses and suspend it in the existing combined sewer system, which has been used to convey stormwater only. A Feasiblity study of this project showed that the cost of the separation work is expensive compared with the traditional separate system because the high initial cost of integrating house units with a new pressure separate system (Jones 2006).

Cembrano (2004) and Polaskova et al. (2006) have presented attempts to decrease the discharge from

CSOs to the receiving watercourses by optimising the sewerage systems through a complex system that includes pressure pipes and additional storage tanks fitted with controller systems. This solution increased the storage capacity of the sewer system but it is still an expensive solution. (Wang et al. 2013) found that retrofitting into the urban environment by intercepting runoff through green areas is economical and protects the environment. They used three green infrastructure models: bioretention basins (vegetated basins), green roofs, and permeable pavement); their studies showed that employing green infrastructure will reduce runoff quantity, minimise peak stormwater flows, and improve runoff quality., However, this solution needs larger open areas for it to work. Andoh et al. (2005) found that it is better to find solutions in the upstream parts of the system rather than the downstream portions. His research focuses on installing inlet flow restrictors in catchment basins and using these to limit inflow to the hydraulic capacity of the existing combined sewer system.

This research proposes an innovative method for laying a separate sewer system using one trench to set up the storm pipe and sanitary pipe, one on top of the other. It is intended that this will bring economic advantages plus extra protection for the environment, decrease the footprint and construction time, and make it possible to lay this separate sewer system even in the narrow streets that most of the UK and European cities have.

## 3. Innovative design of sewer system

The UK and most other European countries usually have narrow streets, occupied by a complex network of infrastructure services such as potable water, electricity, communication and gas lines. Finding a space in which to place another two sets of pipes (in a typical separate sewer system) is a challenge, but this proposed design is capable of overcoming this problem.

The manhole is the main element of a sewer network; it is a structure used to gain access to the sewer for inspection and maintenance. Manholes have witnessed improvement over time in the materials used; old manholes were built of brick, and then significant developments were made by using concrete and using precast materials. However, corrosion of concrete by $H_2S$ means that the industry has to coat the inner surface of the manhole or use newly developed materials such as fiberglass and polyethylene instead (Hughes 2009). The manhole's location should provide easy access, and they should be sited at every change of alignment or gradient and wherever there is a change in the size of a sewer, and in addition at reasonable intervals for inspection and maintenance normally between (50 -100) meters. The typical design of a manhole is circular with a range of diameters between 1 to 1.8 m

Figure 1 shows a typical manhole design.

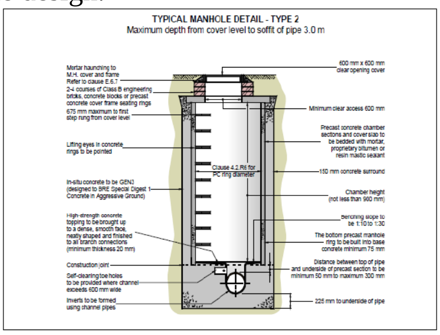
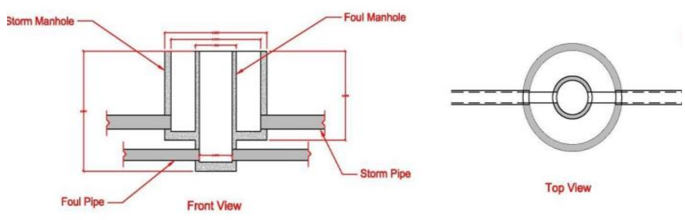



**Figure 1.** Typical design of a sanitary manhole (Defra 2011)

This research presents a new design for geometry of manhole integrating a storm and sanitary system in one combined structure and keeping the separate function. The system is designed to ensure that no mixing of stormwater and sewage will take place Figure 2a&b provides details for the separation technique. The sewerage pipe extends below the external manhole and ends at the internal manhole, while the storm pipe ends at the external manhole and then the flow makes a half circle around the inner foul manhole.




(a) (b)

**Figure 2 a & b**. New shape for storm/sanitary manhole

This design allows the use of one trench to accommodate the two separate pipes one over the other (storm on the top and sanitary pipe at the bottom) Figure 3 demonstrates the new method of laying pipes.

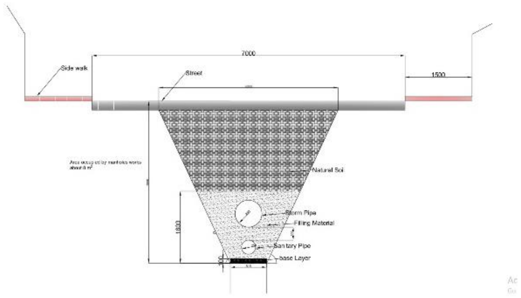



**Figure 3.** A new method for laying a separate pipeline system.

## 4. Feasibility Analysis

In order to evaluate the economic advantages of the new sewer system, one case study has been selected to apply the traditional separate sewer system in one case and the innovative separate sewer system in other. The following hypothesis and assumptions were created, based on industry standards and literature review as shown in Table 2.

**Table 2.** Design parameters proposed to calculate initial cost and construction time

| | **Traditional Separate Sewer System** | **Innovative Separate sewer system** |
|---|---|---|
| Initial cover depth | 1 meter | 1 meter |
| Pipes diameters | Storm water pipe of 250 mm<br>foul water pipe of 150 mm | Storm water pipe of 250 mm<br>foul water pipe of 150 mm |
| Slope of pipe | 1/pipe diameter | 1/pipe diameter |
| Trench’s side slope angle | 45º | 45º |
| Trench’s width (w) and depth (d) relationship | W=1.33d+200 (in mm) | W=1.33d+200 (in mm) |
| Rate of excavating production | 120 cubic metres per day | 120 cubic metres per day |
| Estimate cost of excavation and laying | 100 US$ per meter | 85 US$ per meter |

The cost of pipe laying includes excavation cost and excludes pipe material. The cost model proposed by (Maurer et al. 2010) is depended in design 200 meters length sewer line using both methods to compare the cost, time and occupied area. Figure 4. shows there is a 30% cost reduction for digging and laying the new design due to the narrower trenches required compared to the traditional method and Figure 5 demonstrates the new method uses 16% less road surface. The time factor is important when constructing a sewer network as it is related with the nuisance that infrastructure construction causes to local businesses and community, the new system reduces the total installation time by 18% as shown in Figure 6.

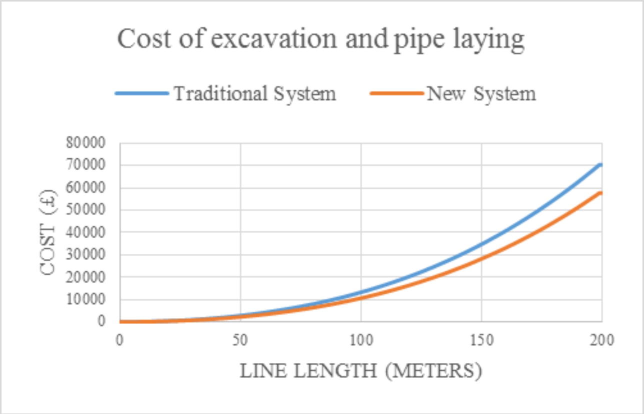



**Figure 4.** Comparison of the Digging and Laying Costs

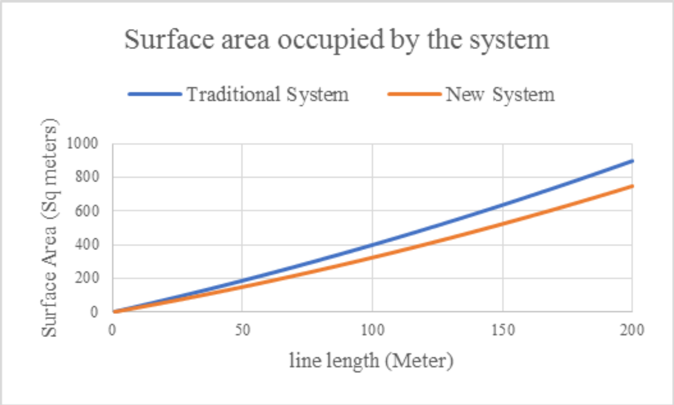



**Figure 5.** Comparison of the surface area occupied by each system

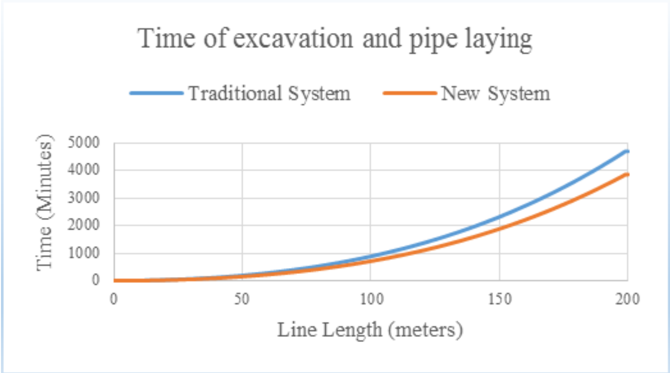



**Figure 6.** Comparison of the Construction Times

**CONCLUSION**

Due to the rapid expansion of urban cities and developments during the industrial era, communities have become more conscious of the necessity of disposing of the sewage generated by human activities and draining the storm water resulting from rainfall outside cities to avoid flooding and hygienic effects. It is clear that the traditional combined sewer system is no longer used in a development area, and the traditional separate sewer system has high initial cost makes it not attractive to authorities and has a limited use in narrow streets which is prevalent in the UK and EU cities. The innovative separate system proposed in this research merges the advantages of combined and separate sewer systems into one modified system, which complies with the regulatory requirements of the 21st century, decreases the initial cost and protects the environment. The new design makes it possible to install separate sewer systems even in narrow streets which is very challenging when using the traditional system.

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