H3) Design and construction of the vacuum sewerage system

E. Petrešin(1)
eugen.petresin@uni-mb.si
University of Maribor, Faculty of Civil Engineering, Slovenia

M. P. Nekrep(2)
matjaz.nekrep@uni-mb.si
University of Maribor, Faculty of Civil Engineering, Slovenia

Abstract

In our work we will present reasons for the application of special drainage techniques as the vacuum sewerage system in large scale buildings. We will explain theoretical base, components of the vacuum sewerage system and function of the vacuum sewerage system .

Keywords

Drainage for buildings/ Civil engineering / Building technology/ Computer model

1. Introduction

Vacuum sewerage, as an alternative to conventional systems, is reasonably well known, and most civil engineers are aware that there can be significant capital savings on construction costs. There are several reasons for the application of special drainage techniques. Reasons are mainly though the reason of cost reduction.

Compared to conventional sewer systems, vacuum sewer technology provides major advantages in the following circumstances:

- The topography is flat
- Groundwater table is high
- Sewer system is located near a lake, river, coastline or floodplain
- Ground has an adverse gradient
- Wastewater flows are highly variable, e.g. holiday establishments or local recreational facilities

- Difficult ground conditions, e.g. rock, running sands, peat, swamps etc.
- Refurbishment of sewer systems
- Rural area where houses and buildings are not close to each other
- Crossing rivers, streams, railwaylines, major road etc
- Groundwater protection areas

We can expect highest economy in flat areas with high ground water level and poor soil conditions. The world most famous vacuum sewer project is currently the Palm Island in Dubai.

2. History

The vacuum sewerage system exists now for nearly 150 years. Pneumatic and mechanical operating vacuum sewage collection systems were firstly introduced in the second half of the 19th century. In 1866 the Dutch engineer and former Captain in the US army, Captain Liernur (1828-1893) introduced at a Congress in the city of Haarlem, The Netherlands, his vacuum operating sewage collection system for toilet waste. He introduced the definition of the so called "black water" for toilet waste. The philosophy was based on the re-use of treated toilet waste for agriculture. In the same year (1866) the Liernur technology was registered as a patent in England and The Netherlands.

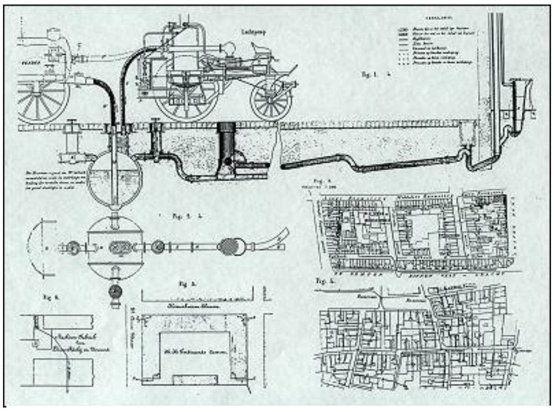

Figure 1 – Liernur/s patent

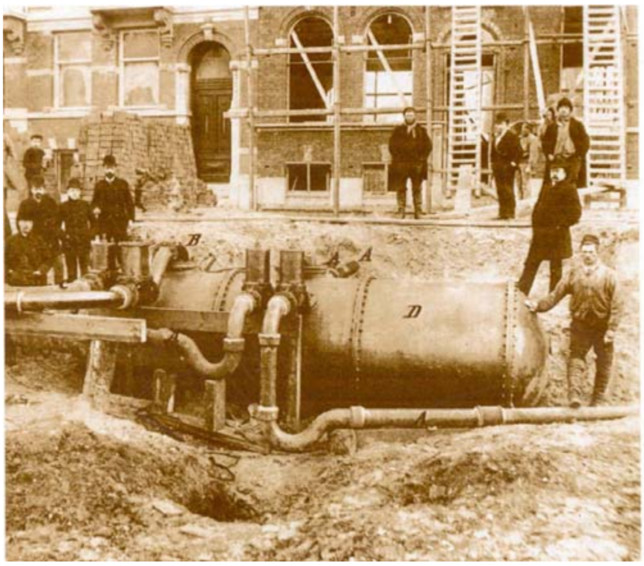

Figure 2 – First vacuum sewage system in Amsterdam in the 1873

In the year 1892 already, 500 properties with 15.000 inhabitants of the northwestern suburb of Paris, Levallois-Perret have been connected to the vacuum sewerage system.

Although the experience had been excellent the system fell into oblivion in the course of the decades.

It was not until the year 1959 the Swede Joel Liljendahl continued to develop the vacuum sewerage system and tested it in the in a residential district in the north of Stockholm. Also in Germany several communities have been installed a vacuum sewerage systems. But soon after their putting to work the system proved to be very instable. This was mainly based upon the house connections being controlled by a vacuum.

3. Principe and components of the modern vacuum sewerage system

A vacuum sewer system uses the differential pressure between atmospheric pressure and a partial vacuum maintained in the piping network and vacuum station collection vessel. This differential pressure allows a central vacuum station to collect the wastewater of several thousand individual homes, depending on terrain and the local situation. Homes are equipped with a gravity system and connected with domestic shafts.

- Domestic shaft: in which the sewage is submitted to the pipe network in measured amounts

Figure 3 – Domestic shaft and vacuum valve

- Pipe network for the transport of the sewage

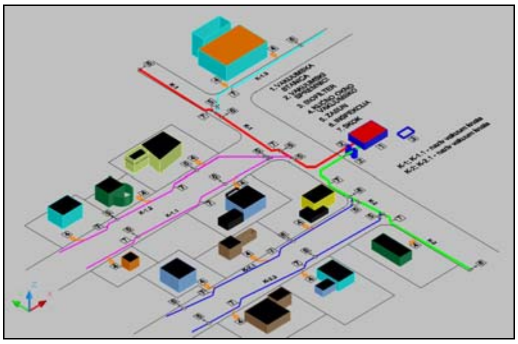

Figure 4 – Network scheme

- Pumping station in which the vacuum for the sewage conveyance is produced

Figure 5 – Pumping station in Slovenia

4. Applications

Vacuum fluid collection systems can be employed in a wide range of situations and typical applications of this versatile and environmentally attractive technology are indicated below :

- Rural community main sewerage
- Roof drainage
- Camp and caravan sites
- New housing developments
- Old towns with narrow streets
- Hospital effluent collection
- Shopping centres with difficult or confined areas
- Replacement of conventional gravity systems
- Petro-chemical industry
- Factory sewerage
- Arctic communities
- Leachate from landfills
- Spillage around industrial storage tanks
- River, lakeside and coastal communities
- Quayside re-developments
- Ship to shore sewage collection

Figure 6 – Iseci vacuum fluid collection system of Tai Wai and Tai Po in the New Territories of Hong Kong

5. Our measurements

We have made comparable test of different types of vacuum valves to compare membrane and piston technology. We have tested valves from several producers: Roediger (Roevac) – membrane type and Iseki(Redivac), Airvac, Quavac – all pistone type valves. All valves where 2” of size at different vacuum and time of open valve 10 seconds. We have measured flow through the valve in that time,

Table 1 – Flow through measured valves in litres (t = 10 sec)

	vacuum 0.6 bar	vacuum 0.2 bar	vacuum 0.15 bar
Roediger(Roevac)	**86**	**45**	**25**
Iseki (Redivac)	**80**	**41**	**22**
Airvac	**78**	**40**	**20**
Flovac	**75**	**38**	**21**
Quavac	**50**	**31**	**23**

We can see that membrane technology give us best result. Membrane technology vacuum valves are also significaly smaler. As result also domestic shalfs can be smaller.

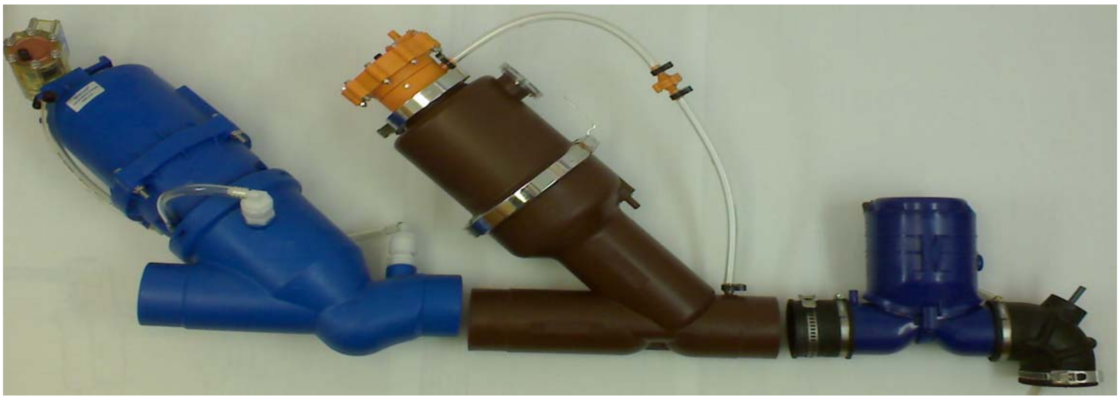

Figure 7 – Diferent types of valves

6. Dimensioning methods

Wery important question I show to properly plan vacuum sewage network. Most common planning and construction method in our area is to use tables and equations from ATW-DVWK-A 116 work sheet.

Table 2 – Example of table from ATW-116

Medium air-water-ratio upstream	Nominal width of the trunk						
	DN 65	DN 80	DN 100	DN 125	DN 150	DN 200	DN 250*
Number of inhabitants connected upstream							
2	0-110	0-350	250-600	350-900	500-1400	750-2100	(1100-3000)
4	0-65	0-200	135-340	200-500	300-800	400-1200	(600-1650)
6	0-45	0-140	95-240	140-350	200-550	300-820	(400-1150)
8	0-35	0-105	75-185	105-270	150-425	220-625	(300-850)
10	0-30	0-85	60-150	85-220	120-340	175-500	(250-700)
12	0-25	0-75	50-125	75-180	100-290	150-425	(200-600)

But some authors propose more exact numeric methods for calculation and modeling evacuation process in the pipe networks of vacuum sewerage systems.
One of possible methods is use of method of characteristics.

We can simulate the evacuation process with a model of divided parameters that assumes not only time, but location dependency as well. We assume that the gas flow in the pipe of a constant diameter is one-dimensional and non-adiabatic, there is no friction between the molecules, but the pipe is hydraulically rough, the friction coefficient of the flow is known and constant.

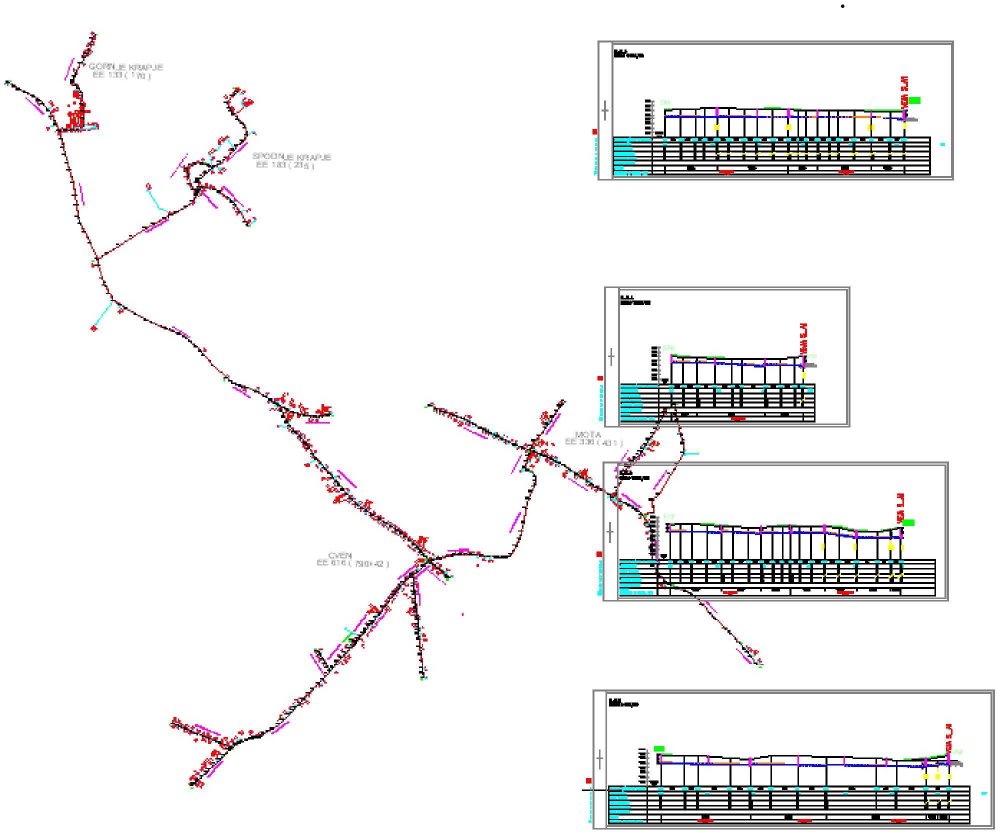

Figure 8 – Plan of vacuum sewerage network where we have tested dimensioning techniques

7. Conclusion

Our work is now oriented into development of more exact methods, tools and models for planning and dimensioning of vacuum sewerage networks.

Acknowledgments

We would like to express our gratitude to the experts of "TIBORA International" which serve as with all necessary data about their systems.

8. References

1. Schluff, Design and construction of the vacuum sewerage system, University of Stuttgart, Stuttgart 1999
2. ATV-DVWK-A 116, Special drainage procedures/systems, Hennef 2004
3. G. Fábry, A possible numeric method for calculating the evacuation process of a pipe-network – the method of characteristics, Vrnjačka Banja 2007
4. D. Pavor, Vakuumska kanalizacijska tehnologija u odvodnji, Zagreb 2007
5. E. Petrešin, M.P.Nekrep, Hidravlični preračun vakuumske kanalizacije - praktične izkušnje in priporočila, Vodni dnevi 2007, Portorož 2007
6. E. Petrešin, Uporaba membranskih in batnih ventilov v vakuumskem sistemu kanalizacije
7. 1.Fachhochschule Muenster, Prof. Dr. Ing. Hartmut Hepcke: Pruefungszeugnis Nr. 980815-1 nach DIN EN 1091, Ausgabe Februar 1997.
8. 2.Fachhochschule Muenster, Pruefungszeugnis Nr. 20040115-01, Unterdruck-Kanalisations system ausserhalb von Gebaeuden, DIN EN 1091, Ausgabe Februar 1997, 15.01.2004
9. Fachhochschule Muenster, Pruefungszeugnis Nr. 20040116-01, Unterdruck-Kanalisations system ausserhalb von Gebaeuden, DIN EN 1091, Ausgabe 1997, 16 .01.2004
10. CEN-Europaeisches Komitee fuer Normung:B-1050 Bruessel:EN1091: Unterdruckentwaesserungssysteme ausserhalb von Gebaeude, Dezember 1996.
11. Arbeitsblatt ATV-DVWK-A 142, Abwasserkanaele und –leitungen in Wassergewinnungsgebieten, Entwurf, August 2000
12. .Bojan Kalchbrenner, Volker Zang,Vakuumska kanalizacija-suvremeni sustav odvodnje odpadnih voda., Hrvatski savez građevinskih inženjera, Cavtat 22-24 travnja,2004, UDK 628.21001
13. Franc Maleiner: Prvo vakuumsko kanalizacijsko omrežje v Sloveniji. Gradbeni vestnik, Ljubljana, letnik 54, februar 2005
14. Australian standard AS 4310-2004, DN 80 piston type vacuum interface valves for municipal sewer systems, (this standard was published on 1. November 2004)
15. http://www.vacuumsewage.com/, web page
16. ROEDIGER, tehnical papers
17. DIN EN 1124/4, PART 4: Components for vacuum drainage systems

9. Presentation of Author(s)

Dr. Eugen Petrešin is a Professor and Head of Chair for Hydraulics at the Faculty for Civil Engineering

Matjaž Nekrep Perc, B.SC. Civil. Eng. is a Senior Lecturer at the Faculty for Civil Engineering and author of many working solutions of CAM in civil engineering.