STUDY ON THE RELATIONSHIP BETWEEN HEAD LOSS AND THE CHARACTERISTICS OF PIPING SYSTEM

KOH TZE MIAN

Report submitted in partial fulfilment of the requirements

for the award of the degree of

B.Eng (Hons.) Civil Engineering

Faculty of Civil Engineering and Earth Resources

UNIVERSITI MALAYSIA PAHANG

JUNE 2014

ABSTRACT

The improper design of water supply system due to the improper consideration to the losses will cause a water shortage at certain area. Hence, it will cause the water supply does not archive the demand in that area. This research is about the determination of the relationship between head loss and the characteristic of piping system. The first objective in this research is to determine the total head loss by using the Darcy-Weisbach equation and Hazen-Williams equation. Through this research, it shows that the head loss calculated by Darcy-Weisbach equation have higher accuracy than using the Hazen-Williams equation. The loss due to the each component of the piping system also is ones of the objectives in this research and it were determined and compared with the theoretical methods. From this research, it shows the minor head loss is increases when the flow rate increases for every component in piping system and the least percentage of difference for minor head loss is around 6.45 % for globe valve. The total head losses due to various temperatures also were determined and compared by using Hazen-Williams equation and Darcy-Weisbach equation. The head loss given by the Darcy-Weisbach equation is closer to the experimental head loss compared to Hazen-Williams equation. The relationship between head loss and flow rate in piping system also were determined in this research. The finding in this research shows that the total head loss is increases when the flow rate also increases. In a nutshell, this research is important to provide more information regarding to the head loss for the future researches also can minimize the error during design the water supply system.

ABSTRAK

Reka bentuk yang tidak tepat dalam sistem bekalan air disebabkan oleh kurang pertimbangan kerana kehilangan tenaga akan menyebabkan kekurangan air di kawasan tertentu. Oleh itu, ia akan menyebabkan bekalan air tidak memenuhi permintaan di kawasan itu. Kajian ini adalah untuk menentukan hubungan antara kehilangan tenaga dengan ciri-ciri bagi sistem paip. Objektif pertama dalam kajian ini adalah untuk menentukan jumlah kehilangan tenaga dengan menggunakan persamaan Darcy-Weisbach dan persamaan Hazen-Williams. Melalui kajian ini, ia menunjukkan bahawa kehilangan tenaga dikira dengan persamaan Darcy-Weisbach mempunyai ketepatan yang lebih tinggi daripada menggunakan persamaan Hazen-Williams. Menentukan kehilangan tenaga di setiap komponen dalam sistem paip adalah salah satu objektif dalam kajian ini dan ia telah ditentukan dan dibandingkan dengan kaedah teori. Dari kajian ini, ia menunjukkan kehilangan kecil tenaga akan bertambah apabila kadar aliran menaik untuk setiap komponen dalam sistem paip dan minimal perbezaan bagi kehilangan kecil tenaga adalah 6.45 % untuk suis injab. Jumlah kehilangan tenaga disebabkan oleh pebagai suhu juga ditentukan dan dibandingkan dengan persamaan Darcy-Weisbach dan persamaan Hazen-Williams. Kehilangan tenaga dikira dengan menggunakan persamaan Darcy-Weisbach lebih hampir kepada kehilangan tenaga eksperimen dibandingkan dengan persamaan Hazen-Williams. Hubungan antara kehilangan tenaga dengan kadar aliran di dalam sistem paip juga telah ditentukan dalam kajian ini. Dengan dapatan kajian ini, ia menunjukkan bahawa jumlah kehilangan tenaga akan bertambah semasa kadar aliran meningkat. Secara ringkasnya, kajian ini adalah penting untuk memberikan maklumat lanjut yang mengenai kehilangan tenaga untuk penyelidik dan ini juga boleh mengurangkan kesilapan ketika membuat rekabentuk sistem bekalan air.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF SYMBOLS

f	Darcy resistance factor
L	Total length of pipe
v	Mean velocity
D	Diameter of pipe
g	Acceleration of gravity
Re	Reynold number
ρ	Density of water
μ	Dynamic viscosity of water
Q	Flow rate
C	Coefficient of Hazen- Williams
K_L	Loss coefficient
ϵ	Roughness of pipe

LIST OF ABBREVIATIONS

DW	Darcy-Weisbach equation
HW	Hazen-Williams equation

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

According to the Dusan (2000), due to the rapid development of water supply system in the water industry, some problems of regarding to the improper design of the water distribution network are still unresolved, for example the relationship between the water supply, water demand and the losses. In addition, the losses must also be taken into account when designing the water supply system (Dusan, 2000). Hence, the losses in the water supply system must be consider to ensure the water supply by the authority can fulfill the demand of the people after the water supply experience a losses in the water supply system.

The losses in a water supply system can be divides into two categories which are the major loss and the minor loss (Gerald, 2007). The major loss is the losses due to the friction and the minor loss is the losses due to the fitting, elbow, valves and others. According to the Tefaruk and Mehmet (2004), the major loss in the piping system can be determined by using the Darcy–Weisbach equation and Hazen–Williams equation. The major losses are very significant in a piping system however when the water passes through a pipe system that contains many components and a relatively short length of pipe, the minor loss will be larger than the major loss. Hence, the total losses due the various characteristics of piping system will be study to provide more information for the future.

1.2 PROBLEM STATEMENT

The problem of shortage of water of a certain area normally occurs due to the improper design of the water supply system. This is because the engineer may do not consider the losses in the piping system properly. Hence, it will cause the water which supplied by the water supply system does not archive the demand by a certain area. Although the losses due to the fittings, elbow, valves, expansion and contraction of pipe is consider as a minor losses in a piping system, however when the water is pass through the piping system which contains many components the minor loss also will be consider as very significant. Furthermore, the weather in a country also will affect the head loss in a piping system. Hence, it is important to determine the most suitable method for calculate the total head loss when the temperature is deviated. In a nutshell, the shortage of water due to the improper design of water supply system will affect the daily life of the human.

1.3 OBJECTIVES

The objectives of this study are:

i. To determine the total head loss of piping system by using Darcy-Weisbach equation and Hazen-Williams equation.
ii. To determine the relationship between total head loss and flow rate in piping system.
iii. To compare the loss coefficient, k for minor head loss between the experimental and theoretical.
iv. To study the relationship between the temperature of the water and the head loss by using the Darcy-Weisbach equation and Hazen-Williams equation.

1.4 SCOPE OF STUDY

The research will be carried out by using the piping system in the laboratory to determine the total head loss by using Darcy-Weisbach equation and Hazen-Williams equation. Furthermore, the head loss caused by the sudden expansion, sudden contraction, globe valve, and smooth 90 degree bend with 50.8 mm, 100 mm, and 152 mm radius also

will be determined in this research. Hence, the coefficient for minor head loss, k gained from the experiment will be compared to the head loss calculated by the theory. For this research, the $\frac{1}{2}$ inches of copper tube pipe and 1 inches of copper tube pipe are used. Besides that, the head loss due to the different velocity of flow also will be determined through this research. The different velocity will be tested based on the time needed for the flow of water. In addition, the total head loss at different temperature also will be tested and calculated by using the Darcy-Weisbach equation and Hazen-Williams equation.

1.5 SIGNIFICANT OF STUDY

The study will be a significance endeavor in provided the information for the future researches and students in University Malaysia Pahang, UMP. From this study, the future researches and students in UMP can more understand about the differences to determine the head loss in piping system by using the Darcy-Weisbach equation and Hazen-Williams equation. Furthermore, this research also helps the engineer to minimize the head loss due to the fittings, bends, and valves can be minimizing when they are designing the piping system. In a nutshell, this study is very significant to the community and field of civil engineering in Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the literature review will be divided into three parts, which are the losses in pipe, characteristics of the pipes, and properties of water. For the first part, the advantages and the limitations for the Hazen-Williams equation and Darcy-Weisbach equation are clearly explained. In the second part, the characteristics of the pipes will be discussed. In addition, the properties of water are divided into two parts which are the velocity and temperature of water will be clearly discussed in third part. Lastly, a conclusion will be made and a clear understanding regarding to the losses in the piping system will be obtained to run the research further.

2.2 LOSSES IN PIPE

Head loss in a piping system is referring to the total amount of the pressure drop when fluids flow through a piping system. Furthermore, the head loss also can be represent the total pressure will be reduced due to the orientation in piping system and it can be used to determine the efficiency of a piping system. The head loss in a piping system can be classified into two categories which are the major loss and minor loss. The major loss is denoted for the loss due to the viscous effect in piping system. On the other hand, the loss due to the pipe components for example expansion, contraction, fittings, bends, and valves are called as the minor loss.

2.2.1 Major loss

There are two types of method to determine the major loss which are the Hazen-Williams equation and Darcy-Weisbach equation. Each method has their advantages and limitations. As mentioned by the Allen (1996), there are many engineer predict the losses due to the friction in piping system by using the Hazen-Williams equation because of the simplicity of this equation. This statement also supported by the Gurol and Mehmet (2009) by saying the Hazen-Williams equation is popular used in current engineering application when determine the losses due to the friction in piping system. Furthermore, the Alazba and Einesr (2011) also agree with this point by saying that the Hazen-Williams equation is widely used in the irrigation system due to its simplicity.

However, there are some limitation of the Hazen-William equation when compare to the Darcy-Weisbach equation. The Darcy-Weisbach is more accurate compare to the other equation when predict the friction losses in piping system because the friction factor is considered in determined the relative roughness of pipe and the Reynolds number for the flow (Tefaruk& Mehmet, 2004). Furthermore, Tefaruk and Mehmet (2004) also mentioned that the Hazen-Williams equation, Scobey equation and Manning equation assume the flow is in rough pipe and the effect of Reynolds number is neglected. Alazba and Einesr (2011) also agrees with statement by saying that the accuracy of the Darcy-Weisbach is based on the friction coefficient, which depends on the characteristics of pipe and flow. In contrast, the Hazen-Williams only based on the material and age of pipe (Alazba& Einesr, 2011). In addition, Gurol and Mehmet (2008) also stated that the Hazen-Williams equation may cause around ±40 error when applied at outside limit of the Reynolds number, and diameter of pipe. Besides that, Allen (1996) also agreed with this statement by saying the Darcy-Weisbach equation can obtain more accurate result compared to the Hazen-Williams when the temperature of flow is deviate and at a high degree of turbulence. Furthermore, Martonaro (2006) also agrees with this view by saying that the Darcy-Weisbach equation is more applicable than the Hazen-Williams equation in sprinkler system when the velocity of water exceed 40 ft/sec and the temperature is very low.

In a nutshell, the Darcy-Weisbach equation can obtain more accurate result compared to the Hazen-Williams equation when the flow is under various conditions.

2.2.2 Minor loss

Minor loss is the losses due to the pipe components in a piping system. According to the Singh et al. (2013), the pipe components are including the bend, valves, expansion, and contraction. The designation of the major and minor loss does not reflect the importance of the losses. This is because the piping system which contains many pipe component and relatively short pipe, the minor loss will be larger than the major loss (Kudela, nd). According to the Gontsov, Marinova and Tananaew (1984), the most common elements of hydraulic system is elbow and it is importance to study the efficient calculation method to determine the loss of elbow. Hence, the minor loss due to the elbow, fitting, valves, expansion and contraction is considered significant in a piping system.

2.3 CHARACTERISTICS OF PIPES

The characteristics of pipes will affect the amount of losses in piping system. The losses of piping system are based on the types of material and size of the pipes. The more rougher the material used for the pipe, the more amounts of losses will be produced. Hence, the relationship between the material and sizes of pipe with the losses in a piping system will be explained as below.

2.3.1 Material and size of pipes

Many factors will affect the losses in piping for example the viscosity of the fluid, the size of the pipes, the relative roughness of the internal surface of the pipes, and also velocity of the fluids. The physical properties of the pipe which are the material and size of the pipes will cause a significant effect in losses in piping system. In addition, the fluid will flow over a smooth surface will be relative easier than the rough surface. This is because various pipe materials have their own relative roughness and this will affect the amount of

losses in pipes. According to the "Hydraulics of PVC pipe", the losses due to the friction for Hazen-Williams equation is based on the roughness of the internal pipe material when determine the Hazen-Williams flow coefficient, C. The relative roughness also will affect the major loss due to the friction when to determine the friction factor, f in Darcy-Weisbach equation. For the Darcy Weisbach equation, the roughness of a pipe to the internal diameter of a pipe will affect the friction factor in the turbulent flow. However, when the flow is laminar the relative roughness is not presented. Hence, the relative roughness and size of pipe will influences the losses in the piping system.

2.4 PROPERTIES OF WATER

Besides the properties of the pipes, the properties of the water also are a main factor to affect the losses in a piping system. The properties of water which will affect the losses in piping system are the temperature, velocity and viscosity of water. The detail explanation of the temperature and velocity of water affect the head loss will be explain as below.

2.4.1 Velocity

The properties of the water are ones of the factors which affect the head loss in a piping system. The velocity of the water has a significant effect of the losses in the piping system. According to the Lewis and Princeton (1944), the velocity of the water is directly proportional to the head loss due to the friction. This means the higher the velocity, the higher the losses due to the friction in a piping system. However, there are some recommendations for the velocity of water in piping system according to the size of piping system. The recommendation for the velocity of water in piping system according to the various size of piping system is shown as Figure 2.1. For the pipes which having 1 inches of diameter, the velocity of 1 m/s is suggested to the system. Hence, the various velocities will be tested to determine the most suitable velocity which can obtain the least loss.

Pipe Dimension		Water	
inches	*mm*	*m/s*	*ft/s*
1	25	1	3.5
2	50	1.1	3.6
3	75	1.15	3.8
4	100	1.25	4
6	150	1.5	4.7
8	200	1.75	5.5
10	250	2	6.5
12	300	2.65	8.5

Figure 2.1: A rule of thumb the following velocities can be used in design of piping and pumping systems for water

Source: http://www.engineeringtoolbox.com/pump-delivery-flow-velocity-water d_232.html

2.4.2 Temperature

Temperature of the water is ones of the major factors which will also affect the losses in piping system. According to the Allen (1996), the Hazen-Williams equation assumes the temperature is constant at 20 °C along the piping system. However, the temperature cannot be assumed as constant because the temperature will be deviate from 20 °C in actual application for example trickle irrigation system (Allen, 1996). Hence, it represents the temperature will having a significant effect when calculating the losses by using various formulae in piping system. Besides that, the Tefaruk and Mehmet (2004) also agree with this point by saying that the Hazen-Williams equation, Manning equation and Scobey only applicable when the water is at normal temperatures. In a nutshell, the temperature of water must be consider when determine the losses of piping system by using various formulae.

2.5 CONCLUSION

Based on the literature review, the Hazen-Williams equation and Darcy-Weisbach equation can be used to determine the losses in piping system. The advantages and limitations of the Hazen-Williams equation and Darcy equation is clearly explained in the literature review. Furthermore, the characteristic of the pipes and properties of water also will affect the amount of the losses in piping system. In conclusion, the factors which will affect the losses in piping system are clearly explained in this chapter.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter is to describe the flow and details of research methodology. Furthermore, this chapter is divided into four sections which are the research design, layout plan, laboratory work, and data analysis. The procedure and the method to obtain the data will also be described.

3.2 RESEARCH DESIGN

The methodology which used to carry out in this research is by using the piping system with changing various variables in laboratory. It is an experiment which is economical and effective to compare the relationship between the characteristics of piping system with the head loss in the piping system. The flow chart of methodology for this research is shown as below.

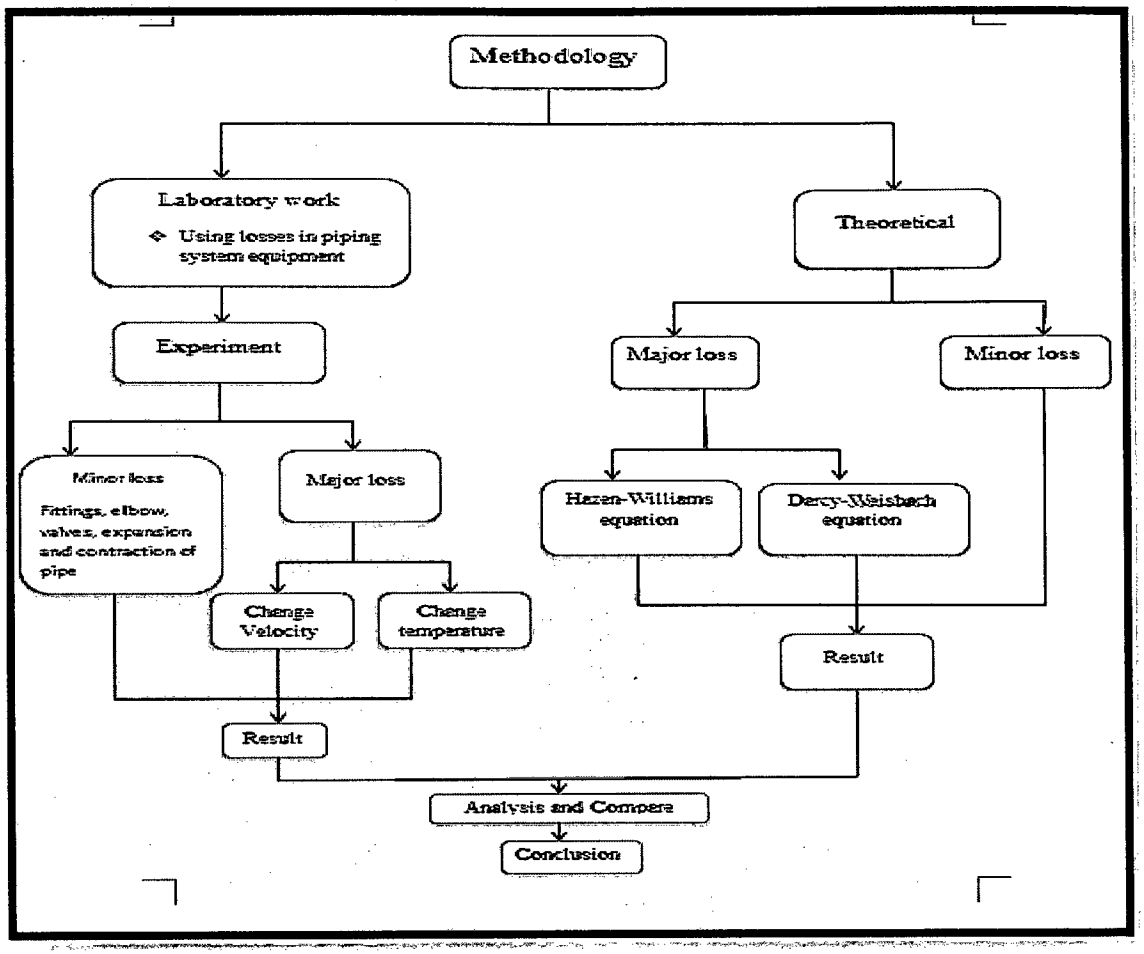

Figure 3.1: Flow chart of methodology

3.3 LAYOUT PLAN

The Figure 3.2 below shows the layout plan of the piping system used for the research. The light blue circuit of the piping system was used to determine the head loss due to the friction and pipe components. The head loss at the point E, F, G, H, J, and K are recorded. Each of the points is represent the types of pipe components in the piping system. The detailed will be representing in Table 3.1.