UNIVERSITI PUTRA MALAYSIA

EXPERIMENTAL LEAKAGE ANALYSIS FOR PUSH FIT ELASTOMERIC STEEL PIPE SPIGOT AND SOCKET JOINT

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By

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Pipes have been used for many centuries for transporting fluids. Steel is one of the most versatile materials for pipe walls, as it is ductile yet has a high tensile strength. Steel pipes are made in lengths of up to 10 m and jointed on site. Several pipes need to be joined to form a piping system. The type of joint to use on a pipeline will depend on the type of pipe materials, strength and flexibility requirement, cost, water tightness and the facilities available on site. Currently used joints for large diameter steel pipes are welded sleeve (i.e. spigot and socket), mechanical, flanged and butt welded joints

This research is carried out to investigate the capability of the elastomeric ring as a seal for large diameter steel pipe joint. A pair of spigot and socket pipe with a mean outer diameter of 668 mm is being used in this project. A socket pipe which has groove for elastomer location has an inner diameter of 690.2 mm while spigot pipe which has tapered part having outer diameter of 654 mm at its end. An elastomeric lip seal of dual hardness which is having 702 mm outer diameter is also being used in this work. The technique of push-fit method has yet to be introduced as an alternative joining method for larger steel pipes to quicken and ease the process.

An experimental test rig is designed and fabricated to test the performance of the joint as in working environment. Two type of tests are conducted - pressure test and leakage test. The findings indicated that the water pressure inside the pipe is 0.625 MN/m^2, lower than the contact pressure exist at the top and bottom surfaces of elastomer that are 28.541 MN/m^2 and 23.758 MN/m^2 respectively. The results of pressure test shows that no leaking occurs along the test including the extension of 10 minutes after full pressure test has been attained. The leakage test is also success as no water is added/pumped to maintain the pressure of 4.17 bar for a period of 24 hours.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

ANALISIS KEBOCORAN SECARA UJIKAJI SAMBUNGAN BERELASTOMER PAIP SPIGOT DAN SOKET JENIS KELULI

Oleh

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Paip telah digunakan berabad lamanya sebagai saluran air. Keluli pula merupakan salah satu bahan serba boleh yang biasa digunakan di dalam industri pembuatan paip kerana kemulurannya dan kekuatan tegangan yang tinggi. Paip keluli kebiasaannya boleh dibuat sepanjang 10 m dan penyambungan dilakukan di tapak projek. Beberapa batang paip perlu disambungkan untuk membentuk satu sistem perpaipan. Jenis sambungan yang digunakan untuk sistem perpaipan bergantung kepada jenis bahan, keperluan kekuatan dan tahap kelenturan, kos, kekedapan air dan kemudahan yang terdapat di tapak projek. Kebanyakan sistem penyambungan untuk paip keluli berdiameter besar yang diaplikasikan pada masa kini adalah seperti spigot dan soket (secara kimpalan sarung), mekanikal, bebibir dan kimpal temu.

Penyelidikan yang dibuat ini mengkaji kebolehan elastomer sebagai bahan penyambungan bagi paip keluli berdiameter besar. Sepasang paip iaitu soket dan spigot yang mempunyai purata diameter luar 668 mm digunakan untuk projek ini. Paip soket yang mempunyai lurah untuk meletakkan elastomer mempunyai diameter dalam iaitu 690.2 mm manakala paip spigot yang mempunyai pengecilan saiz dihujungnya mempunyai diameter luar sebanyak 654 mm. Elastomer yang berbentuk bibir berdiameter luar 702 mm dan mempunyai dua kekerasan yang berbeza juga digunakan untuk projek ini. Teknik penyambungan berelastomer ini perlu diperkenalkan sebagai alternatif kepada kaedah sedia ada untuk paip keluli berdiameter besar bagi memudahkan dan mempercepatkan proses penyambungan.

Oleh yang demikian sebuah radas ujikaji direkabentuk dan dihasilkan untuk menguji kemampuan sambungan ini seperti di persekitaran kerja. Dua jenis ujian perlu dijalankan – ujian tekanan dan ujian kebocoran. Keputusan yang diperolehi menunjukkan tekanan air di dalam paip iaitu 0.625 MN/m^2, lebih rendah berbanding dengan permukaan tekanan yang wujud di bahagian atas dan bawah elastomer iaitu 28.541 MN/m^2 dan 23.758 MN/m^2 masing-masing. Keputusan ujian tekanan menunjukkan tiada kebocoran berlaku sepanjang ujian dijalankan termasuk waktu tambahan 10 minit selepas mencapai ujian tekanan maksima. Ujian kebocoran juga berjaya memandangkan tiada air yang ditambah/dipam untuk mengekalkan tekanan pada 4.17 bar untuk selama 24 jam.

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I certify that an Examination Committee met on 2nd January 2002 to conduct the final examination of Faieza Binti Haji Abdul Aziz on her Master of Science thesis entitled "Experimental Leakage Analysis for Push Fit Elastomeric Steel Pipe Spigot and Socket Joint" in accordance Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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LIST OF ABBREVIATIONS

A	area
b	contact width
d	diameter
d_{sp}	external diameter of pipe at spigot ends
d_{sc}	internal diameter of pipe at socket ends
F_x	pushing force
L	length
$\overline{P}$	average contact pressure
P_w	pressure due to water in pipe
P_{esp}	elastomer contact pressure at spigot
P_{esc}	elastomer contact pressure at socket
R_i	inner radius of pipe
R_o	outer radius of pipe
S_{max}	maximum permissible working stress
t	thickness
T	time
μ	coefficient of friction
σ	stress
τ	shear stress

GLOSSARY OF TERMS

AC	Asbestos Cement
BS	British Standard
CAD	Computer Aided Design
CI	Cast Iron
CMM	Coordinate Measuring Machine
DASYLab	Data Acquisition System Labaratory
DI	Ductile Iron
GRP	Glassfibre Reinforced Plastics
HDPE	High Density Polyethylene
IRHD	International Rubber Hardness Degrees
MDPE	Medium Density Polyethylene
MS	Malaysian Standard
SBR	Styrene Butadine Rubber
uPVC	unplasticised polyvinyl chloride

CHAPTER 1

INTRODUCTION

A pipe can be defined as a tube made from either homogeneous or composite materials. Pipes are used to transport liquids, gases, slurries and/or fine particles. Pipes joined to form networks have been in use since prehistoric times, originally for water distribution purposes. Pipes are usually available with different lengths, diameters, wall thickness and materials.

A piping system is generally considered to include the complete interconnection of pipes, including in-line components such as pipe fittings and flanges. Pumps, heat exchangers, valves and tanks are also considered part of the piping system. The contributions of piping system are essential in an industrialized society – they provide efficient transport of clean drinking water to cities, irrigation water to farms and cooling water to building and machinery. In terms of construction, several pipes need to be joined.

There are several types of pipe materials available such as Cast Iron, Ductile Iron, Asbestos Cement, Steel, High Density Polyethelene, Unplasticized Polyvinyl Chloride, Glassfibre Reinforced Plastic etc. The major factors to be considered when selecting the type of pipe are: -

(a) working and test pressure, including surge pressure

(b) strength of pipe to withstand designed internal and external load

(c) durability of the pipe

(d) suitability and workability for laying and operating requirements

(e) capital, operation and maintenance costs

(f) extent of possible leakage

A particular type of the pipe can be joined with one or more types of joints to suit the circumstances in which the pipeline is laid and has to operate. Some types of joints commonly used are flanged, welded (fillet and butt), gibault, flexible mechanical coupling, sleeve coupling, push-on spigot and socket, single gland – mechanical and stepped coupling. In the Malaysian water industry, butt welded joint, fillet welded, bolted flanged joint, flange adaptor joint and mechanical coupling joint are currently used for joining large diameter steel pipe.

1.1 Problem Statement

This project is carried out to study the push-fit techniques as a means of joining steel pipes. The use of push-fit method, which is fast and could be economical, has yet to be introduced as an alternative joining method for larger steel pipes. A pair of spigot and socket steel pipes with a diameter of 668 mm is being used for this experiment investigation. Currently this joining method is very common and widely used but only for small diameter pipes (maximum of 160 mm diameter only) and the materials are ductile iron, PVC and vitrified clay pipes. They also have been used for hydraulic and pneumatic purposes and only limited to where the working environment is not very severe.

Boon & Cheah Steel Pipes Sdn. Bhd supplies the specimen pipe and elastomeric seal used in this project. A test rig is to be designed and fabricated in the Mechanical Engineering, Universiti Putra Malaysia laboratory for the purpose of testing the performance of the joint as in working environment.

There are two types of test to be conducted. They include the pressure test and the leakage test. The pressure test is to be carried out by increasing the water pressure in the incremental of one bar and one minute pause until the pressure achieve 6.25 bars. The test shall be considered pass if no reduction occurs during the specify one minute pause between each increment and including the extension of 10 minutes after full pressure test has been attained. The leakage test will then be followed by reducing the pressure from 6.25 bars to 4.17 bars and it has been noticed that the pressure of 4.17 bars is maintained for 24 hours, thus satisfy the criteria.

1.2 Objectives

The objectives of the project are as follows: -

1. To determine the sealing mechanisms of integral spigot and socket joints when subjected to internal pressure.
2. To determine the force to assemble the pipes.
3. To determine the capability of the pipe on the pressure capacity.

1.3 Thesis Outline

This thesis has been organized to seven chapters. It starts with the introduction and followed by second chapter, which review the literature related to this project. Among the subjects discussed in chapter two are pipes, pipe joints, sealing properties and the software used in this study. Chapter 3 consists of materials and methods used in the experiment as well as the tests to be conducted to determine the capability of the joint. Chapter 4 concentrates on the design and fabricating the test rig. Chapter 5 presents the output and discussion on the tests conducted. The conclusion in Chapter 6 compare the results obtained by finite element analysis with the results in this investigation. Finally Chapter 7 recommends a few items to be done in getting better results in the experiment.

CHAPTER 2

LITERATURE REVIEW

In this chapter, literature related to pipe, its materials and joints, rubber, elastomer and sealing properties will be reviewed. At the beginning of the chapter, the review will be focused on pipes, pipe materials and joints currently in use. It will be then followed by the study of elastomer, the behaviour and its sealing component. An example of the existing elastomeric ring types and its failure causes were also covered. The effect of pressure on elastomer and leaking criteria would also be discussed.

2.1 Pipes

This section provides information on various types of pipe materials, their range of pipe sizes and the joints usually associated with these pipes. It also discusses the general specifications and performance of these pipes materials [1].

2.1.1 Pipe Materials

The selection of pipe materials for water distribution is discussed. It is very important to identify the most cost effective material option to suits the application. The following section also provides information and guidance which can be used to formulate an optimum pipe materials selection rules.

2.1.1.1 Asbestos Cement (AC) Pipes

AC pipes are commonly available in sizes of 80- to 600 mm nominal diameter and are manufactured in standard lengths of 4 metres. AC pipes commonly used are of Class 20 and Class 25 and can be used for maximum working pressure of 10 and 12.5 bar respectively (see Table 2.1). The principles advantages of AC pipe are its strength, rigidity and relatively good corrosion resistance [2].

2.1.1.2 Ductile Iron (DI) Pipes

DI pipes are available in a wide range of sizes, from 80 to 1600 mm diameter, and are available in length of 4 to 6 metres [1]. DI pipe is made from a ductile material more like steel than iron but with good resistance to external corrosion. The thickness and diameter of Class K9 [2] ductile iron pipes are as given in Table 2.2.

The mechanical strength and toughness of ductile iron pipe make it suitable for high stress application (e.g. very high pressure mains, pumping mains, under heavily trafficked roads, where there may be a high risk of interference and in areas subject to ground movement and subsidence), where other materials may be less satisfactory [2].

2.1.1.3 Unplasticised Polyvinyl Chloride (uPVC) Pipes

Unplasticised Polyvinyl Chloride (uPVC) pipes are semi rigid pipes. The standard length for uPVC is 6 metres [3]. Nominal diameter can range from 80 mm to 575 mm (Table 2.3). The main advantages of uPVC pipes are their relatively light weight, ease of handling and laying, simple jointing technique and corrosion resistance [2].

2.1.1.4 Glass Fibre Reinforced Plastic (GRP) Pipes

GRP Pipe is available in diameters ranging from 300 mm to 2500 mm, smaller sizes down to 200 mm nominal diameter can also be obtained. In addition, GRP pressure pipe provides for sizes up to 4000 mm nominal diameter (and down to 25 mm). All sizes manufactured, are supplied in standard for 6m lengths, although for convenience 2500 mm diameter pipes are usually produced in 3 m length for ease of site handling.

In Malaysia GRP pipes are relatively new and have not been widely used. The GRP pipe manufacturer shall design the pipe wall thickness based on various parameters in accordance with the British Standard, BS 5480 [3]. The principles advantages of GRP pipes are their corrosion resistance, and their relatively light weight. GRP pipes normally require no internal and external protection for water supply application.

2.1.1.5 Prestressed Concrete Pipes

Prestressed concrete pipes normally consists of an inner core pipe which is precompressed by means of a high tensile wire wound spirally around the core under a controlled tension. Two basic types of prestressed concrete pipes are "cylinder" (or "steel cylinder") and "non-cylinder" pipes. Prestressed concrete pipe is used at high pressure. Conceptually, it is similar to a ductile iron system, which is its natural competitor [4]. Prestressed concrete cylinder pipes are presently manufactured in sizes ranging from 600 mm to 1400 mm nominal internal diameter in 100 mm increments. These are normally supplied in lengths of 4 and 5 metres.

The advantageous of prestressed concrete pipes are their generally acceptable resistance to corrosion, high beam strength and, as rigid pipes, the lack of high compaction requirements during installation. One of the most disadvantageous is their weight, the lightest (600 mm nominal diameter) being 1.6 tonne. Heavy transportation and lifting equipment are required.

2.1.1.6 Polyethylene (PE) Pipes -MDPE / HDPE

All polyethylene (PE) pipes made from polymer having a density greater than 0.93 g/ml. The following density classification is applicable.

- MDPE (Medium Density Polyethylene Pipes) – 0.931 g/ml to 0.944 g/ml
- HDPE (High Density Polyethylene Pipes) – equal to or greater than 0.945 g/ml

The polymer is blended with additives (antioxidants, uv stabilizers and pigments) necessary for the manufacture of pipes according to specifications and for their end use including weldability. The thickness and diameter of polyethylene pipes are as given in Table 2.5. The main advantages of PE pipe are its light weight, corrosion resistance, weldability and its flexibility [2].

2.1.1.7 Steel Pipes

In this section, the details about steel pipes including their specifications, joints available and explanation of each joint, their advantages and limitations is discussed. It is vital to understand the nature of steel pipes thoroughly since the pipe used for this experiment is made of steel.

Steel pipes are widely used in the water industry. The term steel refers to alloys of iron and carbon. There are a large number of steels available and normally classified as carbon steel, alloy steel, stainless steel and structural steel. Steel pipes may be as large as 2 metres nominal diameter, but steel pipes used in mains water distribution in Malaysia usually range from 100 mm to 900 mm diameter [1]. The use of steel pipelines is concentrated in the larger sizes (particularly greater than 600 mm diameter) because this is the range in which the materials tend to become an economically attractive option [2].

Pipes having 450 mm diameter and above have a standard length of 9.0 metres while those of 450 mm diameter and below are 6.0 metres long. However, steel pipe manufacturers are able to produced pipes to various specified lengths [3]. All steel pipes used in Malaysia are manufactured according to BS 534 [5]. The standard thickness and diameters are as given in Table 2.6 [1].

2.1.2 Pipe Joints

There are several types of joints available for different pipe materials. This section explain various types of joints currently used for each pipe materials and joints for steel pipe will be discussed in more details.

a) Asbestos Cement (AC)

In most cases, AC sleeve joints are used for pipe-to-pipe jointing. Gibault joint and flexible mechanical couplings may also be used (Figure 2.1).

b) Ductile Iron (DI)

Standard DI pipes are provided with spigot and socket ends [6]. The spigot and socket joint, and flanged joint are commonly used. Figure 2.2 shows various joints of DI pipes.

c) UPVC

The push-fit joint with an integral (or “locked-in”) elastomeric jointing ring (or sometimes called Bell mouthed joint) is recommended for uPVC pressure pipelines (Figure 2.3(a)). Flanged pipe mechanical coupling and solvent-welded joint may also be used for uPVC pipes (Figure 2.3).

d) Glass Fibre Reinforced Plastic (GRP) Pipes

There are several jointing systems available for use with GRP pipes. These can be classified as either rigid or flexible. The types of flexible joint available include spigot with rolling or restrained O-ring, loose collars or sleeve, whereas the types of rigid joint available include butt and overlap, spigot and socket with bonding compound and screwed or flanged joints. Figure 2.4 shows various types of joints for GRP pipes.

e) Prestressed concrete pipe

Joints for prestressed concrete pipes are normally rubber gasketed spigot and socket types (see Figure 2.5). These are not interchangeable for different types of pipe. The angular deflection capability of such joints is strictly limited. Table 2.4 presents typical maximum values of deflection. The as-laid deflection of flexible joints should not exceed 75% of the maximum recommended value, and less if there is a possibility of subsequent movement [7]. The joints are relatively inflexible, which limits the ability to accommodate changes in alignment [2].

f) Polyethylene (PE)

PE pipes are commonly jointed by butt fusion welding, socket fusion welding, electrofusion welding, push-fit spigot and socket joint and mechanical couplers (refer Figure 2.6 – 2.10).