UNIVERSITI PUTRA MALAYSIA

DETERMINATION OF HYDRAULIC CHARACTERISTICS OF POROUS PIPE IRRIGATION LATERALS AND WATER DISTRIBUTION PATTERN IN SANDY SOIL

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By

MD FAKRUL ISLAM

Thesis Submitted in Partial Fulfilment of the Requirement for the Degree of Master of Science in Faculty of Engineering Universiti Putra Malaysia.

December 1999

Dedicated

To

Prophet Mohammad (s.w.s)

Who always used to encourage peoples in quest of knowledge

&

my beloved Parents

ACKNOWLEDGEMENTS

The author would like to express his sincere appreciation and gratitude to his supervisor, Associate Professor. Ir. Dr. Mohd. Amin Mohd. Soom. for his close guidance throughout the whole duration of the course of this study.

He would like to also express his gratitude to co-supervisors, Associate Professor. Dr. Salim Said and Dr. Abdul. Aziz Zakaria for their valuable advice and suggestions.

Finally the author would like to thank all the technicians in the DBAE for their assistance especially En. Ghazali Kasim and Hj. Sulaiman for their co-operation and help and also those who have helped in one way or another in the course of the study.

This research was fully supported by Malaysian Government IRPA Project No. 51350. I am very much greatful to the project leader (Associate Professor. Ir. Dr. Mohd. Amin Mohd. Soom) for allowing the author to work on the project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Plates

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirements for the Degree of Masters of Science.

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December 1999

Chairman: **Associate Professor Ir. Dr. Mohd. Amin Bin Mohd. Soom**

Faculty: **Engineering**

Irrigation systems are well known for their low efficiencies. Microirrigation system is becoming popular even in humid areas because of the many advantages it offers. Microirrigation is really the first irrigation method that can potentially maximize productivity while conserving soil, water and fertilizer resources and simultaneously protecting the environment. Since a micro irrigation system can achieve very high application efficiency, it should be further explored even for supplemental irrigation in a high-rainfall tropical country like Malaysia, with annual rainfall exceeding 2500mm.

Porous pipe is useful both for surface and subsurface micro irrigation systems and it can be used in a variety of ways to meet any irrigation need. However very little information is available about the discharge uniformity, operating characteristics and the moisture distribution pattern of porous pipe irrigation laterals. This research work on the hydraulics of two types of porous pipe was carried out to determine such performance criteria as the pressure-discharge relationship, pressure headloss, friction factor Reynolds number relationship and water dispersion in the soil. The water distribution pattern was observed in a soil box. Several lengths of imported porous pipes were subjected to various upstream pressure inputs to determine the average discharge along the lateral and the associated pressure losses.

The flow in the emitter lateral was found to be highly sensitive to pressure with discharge exponent ranging from 0.93 to 1.04 for the "Precision" porous pipe, and from 1.04 to 1.48 for the "Poritex" porous pipe. The discharge along the porous pipe is exponentially related to pressure head variation. The average discharge rate is low (<3 L/h/m for "Precision" and <5 L/h/m for "Poritex" porous pipe) for the pipe lengths tested in this study with operating pressures up to 1 bar. The study found high head loss due to rough inner pipe wall especially in "Precision" porous pipe though for good irrigation uniformity head loss should be small. Result from the moisture distribution pattern study in a fine-medium sand indicated that the wetted strip was oval shape with greater vertical movement rather than lateral spread. Based on the results of the study, graphs were developed to facilitate design of porous pipe irrigation laterals for various applications. The friction factor was found to be 387 %. for "Poritex" and 285 % for "Precision" porous pipes above than that of the smooth pipe. The placement of an impervious pvc channel 15 cm under the porous pipe increased lateral spread by 10%.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian daripada keperluan untuk ijazah Master of Sains.

PENENTUAN CIRI-CIRI HIDRAUL SALURAN SISI PAIP POROS DAN CORAK TABURAN AIR DIDALAM TANAH BERPASIR

Oleh

MD FAKRUL ISLAM

Disember 1999

Pengerusi: **Associate Professor Ir. Dr. Mohd. Amin Mohd. Soom**

Faculti: **Kejuruteraan**

Sistem pengairan mempunyai tahap kecekapan yang rendah. Sistem pengairan mikro semakin diminati, walaupun di kawasan berkelembapan tinggi kerana sistem ini mempunyai banyak kelebihan. Sistem pengairan mikro adalah kaedah pengairan yang pertama yang mempunyai potensi untuk memaksimumkan produktiviti dan pada masa yang sama dapat memelihara tanah, air dan baja serta mengawal alam sekitar. Oleh kerana sistem pengairan mikro dapat mencapai kecekapan applikasi yang tinggi, ianya harus dikaji lanjut untuk tujuan pengairan tambahan walau di kawasan tropika yang mempunyai tahap hujan yang tinggi, dimana jumlah hujan tahunan adalah melebihi 2500 mm setahun

"Paip Poros" amat berguna untuk sistem pengairan mikro pada permukaan dan di subpermukaan tanah dan dapat digunakan dalam berbagai cara untuk memenuhi tujuan pengairan. Walau bagaimanapun maklumat yang boleh diperolehi mengenai keseragaman luahan, ciri-ciri pengoperasian dan corak taburan lembapan daripada paip sisi jenis poros adalah terhad. Penyelidikan ini telah dijalankan ketas sistem hidraul dan jenis paip poros untuk membentuk kriteria prestasi bagi perhubungan tekanan-luahan, kehilangan turus, Faktor geseran-Reynolds number dan penyerapan air di dalam tanah. Pemerhatian ketas corak taburan air ini telah dibuat di dalam sebuah kotak tanah. Beberapa sampel paip poros yang diimport telah dipotong dengan saiz kepanjangan yang berbeza dan dikenakan tekanan di hulu untuk menentukan luahan purata disepanjang paip serta kehilangan turus.

Pengaliran di dalam paip poros didapati amat sensitif kepada tekanan dengan nilai eksponen luahan di dalam linkungan 0.93 ke 1.04 untuk "Precision porous pipe", dan didalan linkungan 1.04 ke 1.48 untuk "Poritex porous pipe". Purata kadar luahan adalah rendah (<3 L/h/m untuk "precision" dan <5 L/h/m bagi "poritex porous pipe" bagi paip-paip dengan kepanjangan yang berlainan yang diuji dalam penyelidikan ini, dengan tekanan kendalian sehingga 1 bar. Penyelidikan ini telah mendapati kehilangan turus yang besar disebabkan kekasaran dinding dalam paip terutamanya di dalam "Precision porous pipe". Bagi tujuan pengairan yang baik, kehilangan turus seharusnya kecil. Keputusan daripada kajian mengenai corak taburan lembapan di dalam tanah pasir halus sederhana mendapati bahawa jalur basah adalah berbentuk lonjong dengan pergerakan tegak melebihi pergerakan mendatar. Berdasarkan keputusan kajian ini, geraf telah dibentuk untuk memudahkan rekabentuk bagi pelbagai aplikasi. Faktor geseran telah didapati melebihi paip lian sebanyak 387 % untuk "Poritex" dan 285 %

untuk "Precision porous pipe". Penempatan paip PVC yang tak telap pada jarak 15 cm di bawah paip poros meningkatkan sebaran mendatar sebanyak 10%.

CHAPTER 1

INTRODUCTION

Irrigation systems are well known for their low efficiencies. Micro-irrigation is really the first irrigation method that can potentially maximize productivity while conserving soil, water and fertilizer resources and simultaneously protecting the environment. Micro irrigation is a relatively "new" method for accurately managing water, chemicals, crops, water and soil, and it can revolutionize crop productivity, but it requires new and higher levels of agronomic and technical competence (Phene, 1995).

At present micro-irrigation is undoubtedly a very popular irrigation system throughout the world and already it is recognized by the International Commission on Irrigation and Drainage (ICID) for its wonderful performance in the world of irrigation. Micro irrigation is one of the technologies which offers many unique agronomic, water conservation, and economic advantages needed to address the challenges for irrigated agriculture in the future (Bucks, 1995). In the last decade there has been a growing awareness all over the world for better and more efficient water management. The result of the continuous efforts in this direction is the evolvement of microirrigation systems in which water is judiciously applied to crops. Due to water scarcity and dramatic technological development, microirrigation systems are getting worldwide popularity very fast.

In microirrigation systems water is distributed through emitters and along the water delivery pipe. Water is applied in the form of drops, tiny streams, or miniature sprays. This type of irrigation system operates under relatively low pressures of 42 kPa - 210 kPa (6-30 psi) and can deliver water, nutrients and other chemicals directly into the root zone of the plant. Microirrigation system can be managed to apply small quantities of water and/or chemicals to precisely match evapotranspiration and nutrient demands of the crop. Crop yield can increase since it is possible to maintain low moisture tension in the soil due to frequent water application.

Microirrigation emitters use small orifices or long flow paths with small diameters to deliver low flow rates of water directly to the root zone of the plant. The water distribution devices are placed above or below the ground surface. Micro-irrigation includes Trickle, Drip, Mist-spray, Bubbler, Micro-jet, and other methods which delivers small amount of water, nutrients or fertilizers, and chemicals to the root zone of the plant to satisfy the crop requirements. It is a very efficient method of supplying water to the plant. This is a relatively new method for more precise placement of water, nutrients, and chemicals, even though it takes more knowledge to operate and maintain the equipment.

The conventional Drip or Trickle irrigation operates under pressures of 1-1.4 bar 98 kPa -140 kPa (14 -20 psi) in which commercial emitters deliver less than 12 l/h (3 gph), typically 4 and 8 l/h. Line source emitters generally give below 12 l/h/m of lateral. Bubblers deliver irrigation water in small streams less than 240 l/h (60 gph) and Mist-Spray emitter or Micro-Jets generally give discharges lower than 120 l/h (30 gph) (ASAE, 1983).

Porous pipe is useful both for surface and subsurface microirrigation systems and it can be used in a variety of ways to meet any irrigation need. It is not the rain which is reproduced but its direct effect upon the plants in the form of soil moisture which also supplies nutrients when it is buried, not only this a good amount of irrigation water which otherwise would be lost to evaporation and deep percolation will be saved. However very little information is available about the discharge uniformity, moisture distribution pattern and operating characteristics of porous pipe irrigation laterals.

Tanigawa and Yabe (1991) in their experiment found that the higher the permeability or the pressure in the porous pipe, the more the water supply and infiltration distance. However, their values were not always in proportion to the magnitude of pressure and permeability. The water supply was dependent on the degree of soil wetness as well as the magnitude of pressure in the porous pipe. It was considered that high water supply could be obtained by increasing permeability of the porous pipe.

Burt and Styles (1994) reported work on porous pipe in which the thick wall is porous and water "weeps" out along the complete length. Those pipes have extremely large variations in discharge per meter of pipe, a discharge exponent of more than 1.0, and appear to be highly susceptible to plugging. Also the small internal diameter of the pipe they tested contributed to high friction losses. Given those attributes, distribution uniformity (DU) achieved would probably be very low. Yoder And Mote (1995) found high manufacturing coefficient of variation between 9% to 15% even for a 6m length of a certain type of porous pipe. In the field, a uniform water distribution from a long lateral with low head loss is desired.

Though microirrigation system is a very efficient irrigation system it has some disadvantages especially its high initial installation and maintenance costs. The problems that have been encountered in using the system are emitter clogging, damage by ants and rodents, expensive filtration equipment and lack of experience in operating the system. Furthermore, there are some constraints, and pitfalls of drip irrigation and needs further research. According to Hillel (1985) among those are:

(1) Realistic methods for predicting the temporal and spatial variation of soil moisture under drip irrigation for different crop, weather, and soil conditions (including vertically and horizontally heterogeneous soil).

(2) Determining the minimal and optimal fraction of the soil volume needed for various crops.

(3) Setting the irrigation rate to account more precisely for the partial canopy cover prevailing in the early stages of each crop.

(4) Assessing and controlling downward seepage and leaching rates from the root zone under drip irrigation.

(5) Adjusting water discharge to the soil's infiltrability so as to avoid the penetration of water under the drippers (thus avoiding runoff to the inter-row strips) in tight or crusted soils, particularly on sloping ground.

(6) Reducing the capital cost and maintenance requirements, and increasing the reliability and longevity, of simplified versions of drip irrigation for the special needs of developing countries.

Subsurface microirrigation is a system where water and fertilizer are applied slowly and frequently to the plant root zone. The system is buried at some depth depending upon the soil texture and the depth of the plant root. Since water is discharged below the ground surface, the field surface is dry during the irrigation period thereby reducing weed growth and spread of diseases. This system has potential for conserving water while providing plant roots with water and nutrients in a direct way. However field uniformity of water and nutrients applications are particularly difficult to determine in a sub surface system.

The uniformity of water distribution in a microirrigation system is a function of both the pressure variation within the system, and the flow characteristics of the emission devices used, (Boswell, 1985). Uniformity is an important aspect of irrigation performance. The application uniformity deals with the even distribution of water over the crop area. The poorer the application uniformity, the greater the potential for soil erosion, loss of water and fertilizer, salt buildup in the root zone, and plant stress due to inadequate water uptake by the plant. The variation or non-uniformity of emitter discharge in a micro-irrigation (trickle) system is the result of a number of factors. The most important of these factors are the hydraulic variation and emitter discharge variation (Bucks et al., 1982). The hydraulic variation along the lateral line and submain manifold is a function of land slope, length and diameter of the pipe and emitter discharge relationships. Emitter variation at a given operating pressure caused by manufacturing variability, emitter plugging (complete or partial), water temperature changes, and emitter wear. Wetted volume of soil under an emitter is limited. Wetting a larger proportion of the crop root zone provide better assurance against crop failure. This can be achieved by having more emitters per tree or by using mini sprinkler.

Statement of the Problems

Presently porous pipe is widely marketed for microirrigation (both surface and subsurface) purposes. Porous pipe is made mostly from recycled rubber and polyethylene. The walls of porous pipe contain thousands of interconnecting channels within every inch of pipe and as the pores are not made mechanically, there is a very little direct control over the size and distribution of pores. There is little information on the discharge uniformity and operating characteristics of porous pipes. Also moisture spread in a subsurface installation of porous pipe in sandy soils need to be studied.

Research Objectives

The study was conducted to achieve the following objectives:

1. To analyze the hydraulic characteristics of different porous pipes by studying pressure-discharge relationship, head loss, and friction factor-Reynolds number relationship under low pressure head variation.

2. To determine the water distribution pattern of a subsurface installation of porous pipe in a sandy tin tailing soil.

Scope of the Study

The study focuses on two major things, first one is the analysis of the hydraulic characteristics of the porous pipe, and the second one is to find out the water distribution pattern of the porous pipe in the soil. The study would ultimately try to find out the pressure-discharge relationship, head loss, friction factor-Reynolds number relationship and water distribution pattern of the porous pipe in the soil under low pressure head variation.