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ASSESSMENT OF TILE AND MOLE DRAINAGE SYSTEM BY A HELE-SHAW MODEL FOR ARTESIAN CONDITIONS

" تقييم نظام الصرف المغطى والمشكل فى حالة الضغوط البيزومترية باستخدام جهازهيلى شو "

By

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خلاصة : يقدم هذا البحث دراسة معملية لمشكلة الاراضى الطينية الزراعية المعرضه لضغوط بيزومترية ، والمعمول بها نظام الصرف المغطى . تم فى هذه الدراسه عمل نظام إضافى (مساعد) من المصارف المشكله لتدعيم نظام الصرف المغطى وذلك من خلال تصميم جهاز معملى والمعروف ب " هيلى شو " بمعمل قسم هندسة الرى والهيدروليكا لتمثيل الدراسه عمليا . فى هذا البحث تم اجراء عدد ٢٩٣ تجربة عمليه لدراسة المتغيرات المختلفة مثل المسافة بين المصارف المغطاه ، المسافه بين المصارف المشكلة ، عمق المصارف وارتفاع المصارف عن الطبقة المنفذه . ثم تمثيل البيانات المعملية فى صورة منحنيات بين المتغيرات المختلفة وقد اتضح من تحليل البيانات انها متوافقه ، ويلعب نظام المصارف المشكلة دورا هاما لزيادة كفاءة الصرف المغطى المعمول به حاليا .

ABSTRACT

The authors present in this paper an exprimental study for the problem of an agricultural soil subjected to an upward potential gradient. The present study deals with an existing tile drainage system assisted by mole drains of the same diameter. A Hele-Shaw model is designed and constructed to investigate the drainage characteristics of the proposed drainage system. About three hundreds runs were carried out using an oil with a certain viscosity. The effect of various parameters on the discharges of both tile and mole drains are calculated and plotted in dimensionless forms. It was found that the mole drains play an important role for the design of the combined tile and mole drainage system from the economical point of view.

INTRODUCTION

The rise of groundwater table in agricultural lands is often due to percolation of excess irrigation water through soil surface or seepage of foreign water . Also , when an agricultural soil of a low hydraulic conductivity overlies a highly permeable aquifer of high piezometric head , artesian pressur causes an upward seepage flow in the agricultural soil [1 & 2].

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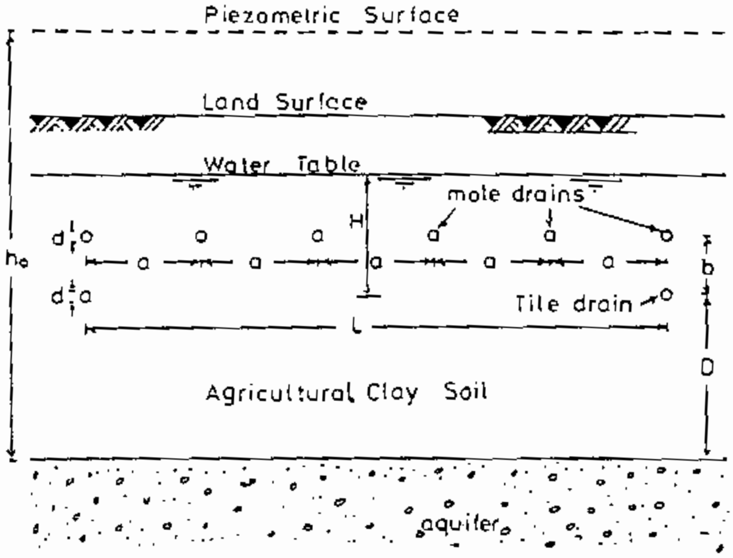
Many works have been published for studying the design of tile drainage such as those given by Far and Gardener (1933). Muskat (1937), Kirkham (1940), Hammad (1957), Luthin (1973), Hathoot (1981), and Younges (1985) [1 & 2].

Hinesly (1961) solved the problem of simultaneous flow of steady rainfall and upward seepage from an aquifer into parallel subsurface drains. A similar solution was developed by Najammi and Kirkham (1978) for the case of a stratified soil overlying an aquifer. Abd-El-Dayem et-al (1985) used a Hele-Shaw model to investigate the problem of a falling water table above drains in a clay cap overlying an artesian aquifer. However in the past Hammad (1957) attempted to develop the problem of drainage of an irrigated clay cap underlain by an artesian aquifer according to hydrodynamical treatment based on the complex function and conformal mapping. Recently the problem of an existing tile drainage system which is assisted by a system of mole drains of the same diameter for a clayey soil underlain by a highly permeable aquifer of high piezometric head was solved mathematically by Sobeih (1989). This solution was hydrodynamically based on the theory of complex functions and the theory of images. This paper presents an experimental work to investigate the case of an existing tile drainage system assisted by a new mole drainage system Fig. (1).

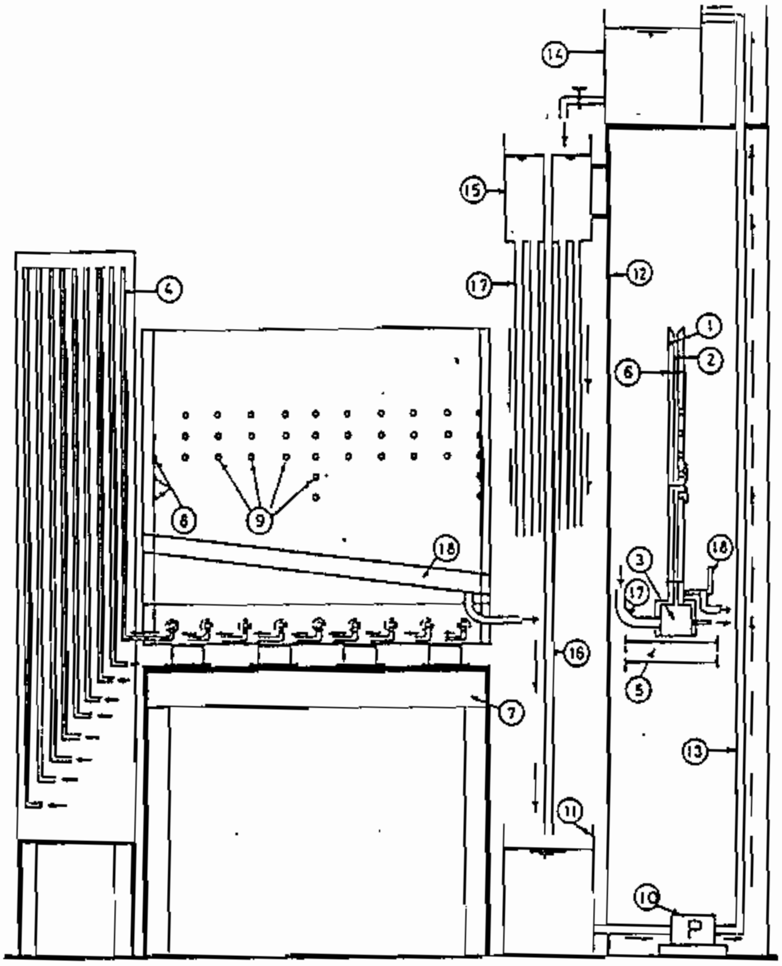


Fig(1):Geometry of The Problem

EXPERIMENTAL SET-UP

The experiments were conducted on a viscous fluid model, commonly known as a Hele-Shaw model, Fig.(2). It is a laboratory device which can be used to study and analyse steady and unsteady groundwater flow problems. A good review of its use for investigating a variaty of these problems was given by Pricket [9]. The model consists mainly of two closely spaced vertical prespex plates of 800 x 800 x 10 mm. A spacing of approximately 1.62 mm are maintained between the plates by inserting a washer, 10 mm diameter and approximately 1.6 mm thick between the plates at each bolt. The washers are installed between the plates at suitable points to fix interspace between them. The number of washers is kept as small as possible to minimize their disturbance effect on the flow between the plates. Also, strips of blingarite of the same material and the thickness of washers work as impermeable boundaries along both sides of the prespex plates installed between the plates. Two rows of opening 10 mm diameter were drilled in one side of plates to represent the tile drains with vertical distance D, 250 and 300 mm below drains. The horizontal spacing between the openings in each row is 400 mm and the out ones are half circles for the sake of symmetry. Also, there are three rows of openings 10 mm diameter above the two previous rows to represent mole drains. The vertical spacing between any two rows is 50 mm. Therefore, the vertical spacing b, between lines of tile drains and mole drains are 50, 100, 150, and 200 mm. The horizontal spacing between openings in each row of lines of mole drains is 40 mm. Also, the out openings in mole drains rows are half circles for the sake of symmetry. With the help of this arrangement of openings, different combinations of cases are as follows: spacing between two successive tile drains L, depth of clay layer below tile drains D, spacing between two successive mole drains a, and vertical spacing between lines of tile drains and mole drains b. This was carried out by the help of replacing the openings closures .

A mineral oil with a kinetic viscosity of 55.013 centistoke at 26^{o} C was used in the experiments. By using interspace interval of 1.62 mm, the hydraulic conductivity of the model was 2.4049 cm/sec. The oil was supplied from a movable constant head tank having an adjustable overflow pipe. It was connected to the pressure tank via five plastic tubes which were connected to the pressure tank at five equally spaced openings in order to give uniform distribution of pressure. The oil was supplied into movable constant head tank from an elevated tank higher than the supply tank. The elevated tank which was connected to a centrifugal pump via plastic pipe. The centrifugal pump was used to pump the oil from the collecting tank into the elevated tank.



Fig(2): Experimental model

1. Two prespex plates 800*800*10 mm.
2. Interspace 1.62 mm wide.
3. Pressure tank.
4. Peizometric tubes.
5. An aluminum base.
6. Brass bolt with rubber washer.
7. A wooden stand.
8. Half drains.
9. Full drains.
10. Centrifugal pump.
11. Lower collecting tank.
12. Aluminum stand.
13. Main pipe.
14. Upper reservoir.
15. Constant head tank.
16. Over flow pipe.
17. Supply plastic tubes.
18. Inclined collecting channel.

Nine piezometers and nine plastic tubes were connected to the pressure tank to measure the height of the piezometric head and water table height. The pressure tank was installed beneath the plastic plates and was connected to the interspace. The experiments were conducted inside an internal room with small temperature variations, however temperature was carefully recorded to correct the oil viscosity for the room temperature.

A sloping collecting channel fixed to the back plate and fitted with a plastic tube at the end was used to carry the flowing oil out of openings which represent mole drains to a graduated vessel. Also, a plastic tube carry the flowing oil out of opening which represented tile drain to a graduated vessel fixed on the back plate. the drained oil flux , which represent the available discharge, was measured by collecting oil in graduated vessels in a certain time.

RESULTS AND DISCUSSIONS

The experimental data were collected and analysed to provide some relations between the different parameters of drainage system. Generally the relations are linear and have the same trend. Figures (3) to (6) show the variation of relative discharge per unit length of both tile and mole drains (q_t /Km.d & q_m/Km.d) and piezometric head (ho/d) with relative head (H/d). The effect of changes in piezometric head is also shown in these figures. It is clear that, the water head H, increases with increasing value of the piezometric head ho, for all cases of different spacing of tile drains L, spacing of mole drains a, thickness of clay layer below tile drains D, and different vertical spacings between lines of tile drains and mole drains b.

Figures (3), and (4) illustrate the effect of vertical spacing on the discharge per unit length of both tile and mole drains. From these figures , it is evident that, when the vertical spacing b, increases the unit discharge of mole drain decreases for all cases. This is because increasing b, i.e water head above mole drains decreases. Figure (5) shows, the effect of depth of clay layer below tile drains D, on the discharge per unit length of both tile and mole drains. It is evident that the discharge of both tile and mole drains decreases when the drain height above the aquifer- aquifard interface D, increases.

Figure (6) illustrates the effect of number of mole drains on the discharge per unit length of both tile and mole drains. When the number of mole drains increases per unit length of two adjusted tile drains the tile discharge decreases while the discharge of mole increases. Moreover,the water head ratio H/d decreases. Generally, when the number of mole drains increases the discharge of both tile and mole drains increases and the water head decreases. Actually it is due to the increase of H which means the depression of water table from the original water surface increases.

CONCLUSIONS

The problem of tile drainage system that assisted by a mole drainage system for soil subjected to artesian water table was studied by using a Hele-Show viscous flow model. About three hundreds experimental runs were carried out. The effect of different parameters such as vertical spacing between lines of tile drains and mole drains b, the piezometric head h. water head H, tile drain spacing L, depth of top clay cap below tile drains D, and mole drain spacing a, on the discharge per unit length of both tile and mole drains were studied.

The experimental data are analysed and plotted to provide the relations between the discharge per unit length of drains and each of different parameters. It is observed that the relationships exist between both tile and mole discharge ratios are linear when plotted versus the head ratio. Therefore, the mole drains play an important role in the drainage process that give economical designs of the tile drainage system assisted by mole drains.

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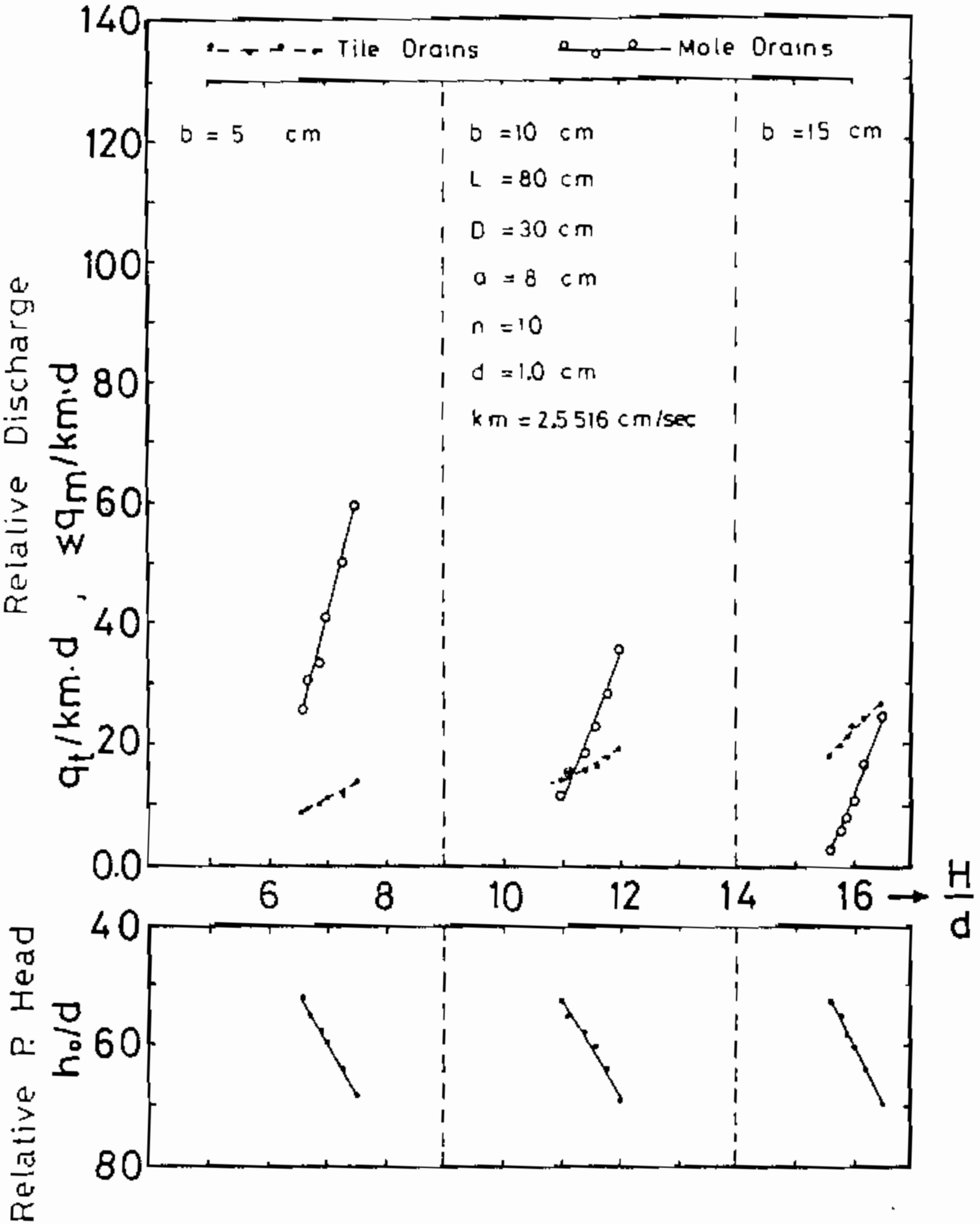
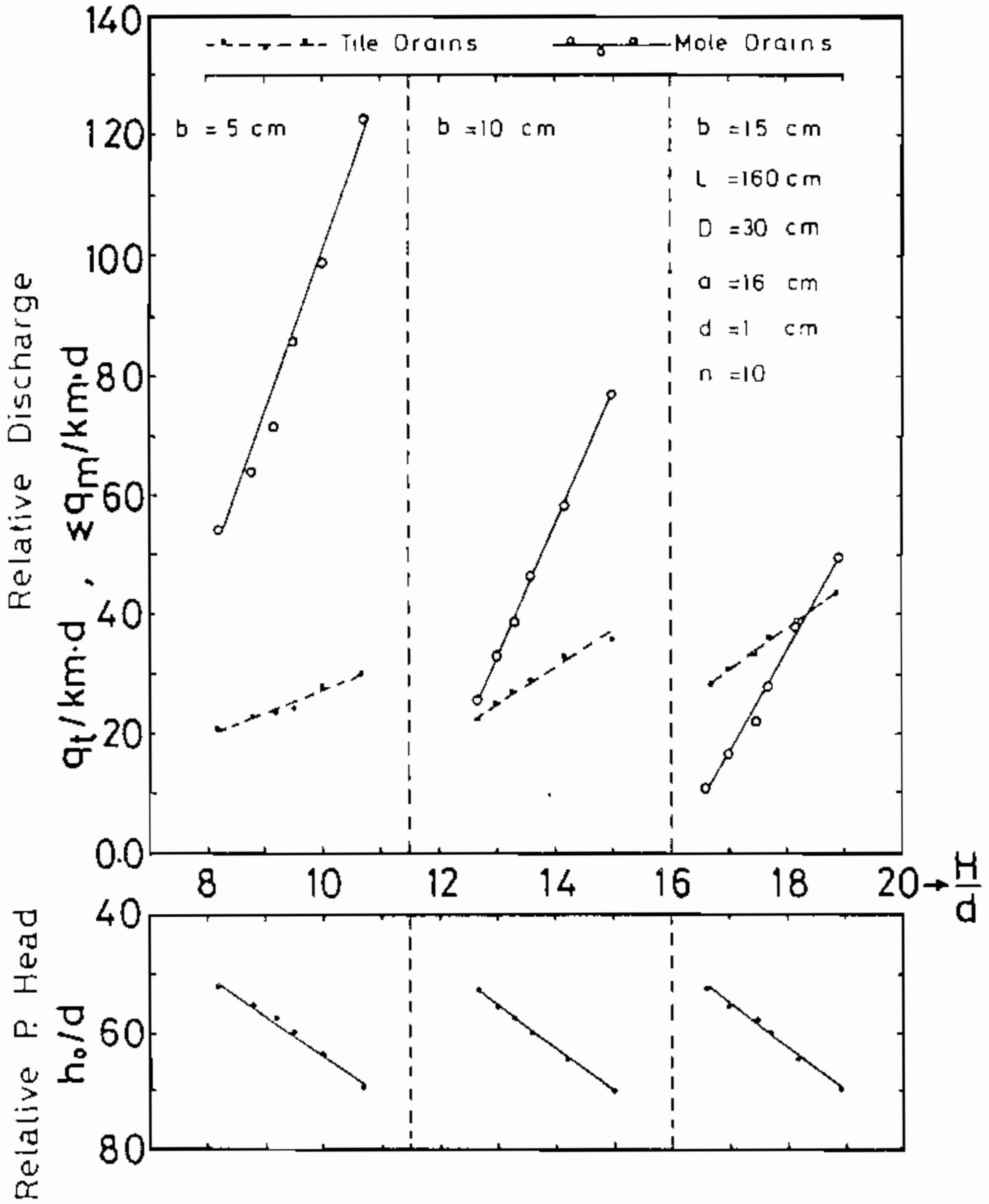
NOTATION

The following symbols are used in this paper :

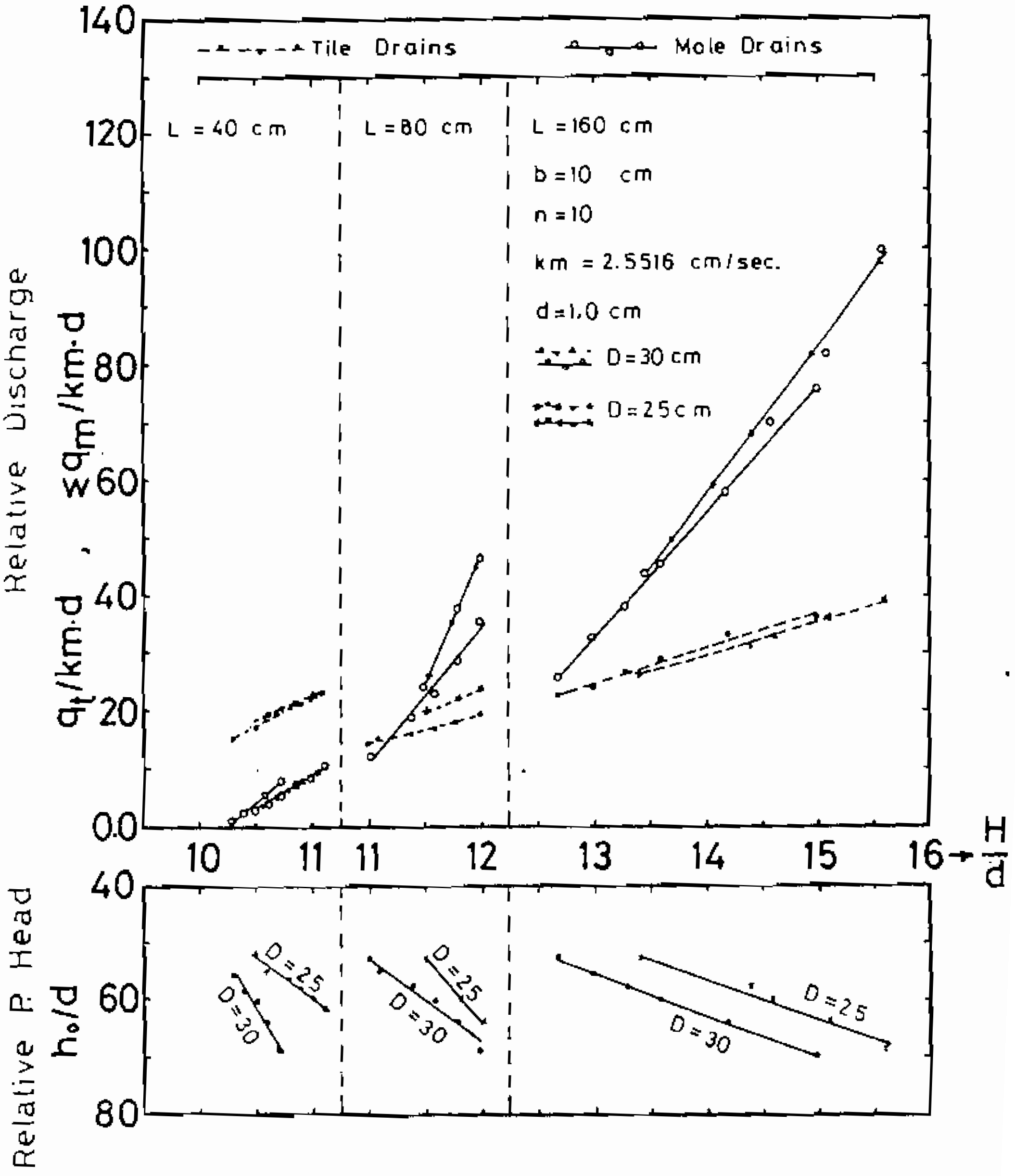
a = spacing between two successive mole drains;
b = vertical spacing between lines of tile drains and mole drains;
d = drain diameter for both tile and mole drains;
D = depth of top clay cap below tile drains;
g = acceleration due to gravity;
h_o = piezometric head of sand and gravel aquifer;
H = height of water table above tile drains at the mid point between two successive tile drains;
K_m = equivalent hydraulic conductivity of a Hele-Show model;
L = spacing between two successive tile drains;
n = number of mole drains in one row;
q_m = discharge reaching each unit length of mole drains;
q_t = discharge reaching each unit length of tile drains; and
ν = kinematic viscosity of oil;



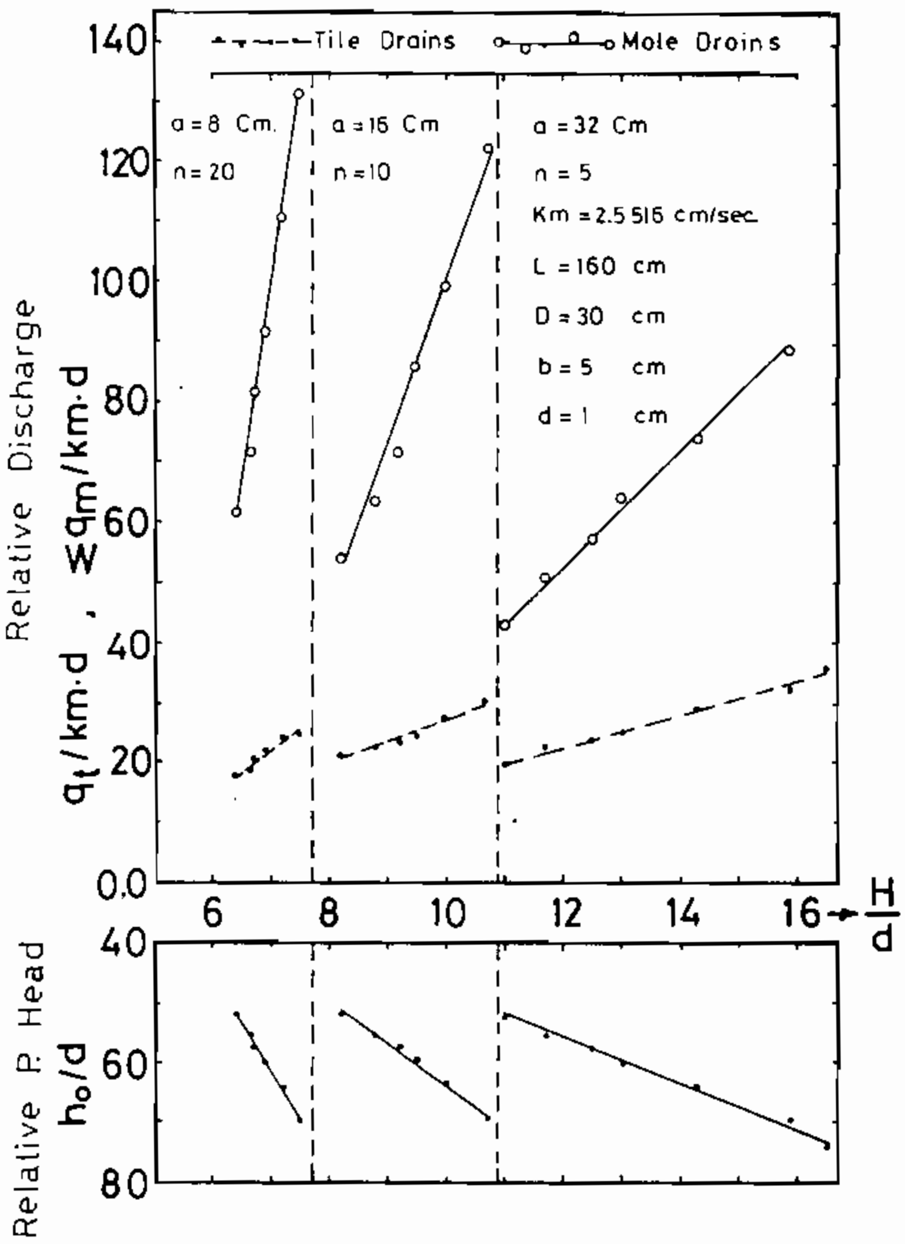
Fig(3): Variation of Relative Discharge and Relative Piezometric Head versus Relative Head($\frac{H}{d}$).



Fig(4) Variation of Relative Discharge and Relative Piezometric Head versus Relative Head($\frac{H}{d}$).



Fig(5): Variation of Relative Discharge and Relative Piezometric Head versus Relative Head($\frac{H}{d}$).



Fig(6): Variation of Relative Discharge and Relative Piezometric Head versus Relative Head($\frac{H}{d}$).