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Determining Planar Tile-drain Spacing (Axial) in Areas Subjected to Water-logging

Prasanta Biswas, Assistant Professor, Department of Civil Engg, Global Institute of Management & Technology, W.B., India, prasanta2k1119@gmail.com

ABSTRACT: On how soil-particles in land behave of on water-logging, status of the land shows & gives picture itself on the particularity of it. Basically, several direct as well as indirect characteristics to the response of causing water-logging include climatic agents (precipitation, rainfall intensity etc.), physiologic (land slope, feature of the basin, vegetation cover etc.) & historical behavioral pattern of the land-area subjected to water-logging. There is conventional derivation existing for the tile-drain spacing required to remove the water from water-logged basin – this one is approximate to some extent & also non-realistic too. In this study, the spacing equation has been derived & found using planar-area philosophy of the seepage-flow, following particular emphasis of this study, for having clearer, comparative & more useful derivation in its regards. This study has described the tile-drain spacing of seepage water to be passed through the tile-drain in 3-dimensional scenario with the dimensional philosophy by incorporating the differentiate soil-element; plane-wise axially. Several scopes of this study have also been mentioned & discussed in subsequent discussion.

Keywords: Water-logging; Tile-drain; Hydraulic gradient; G.W.T; Porosity, 3-dimension soil-seepage; Darcy's Law; Planar-area flow; Spacing.

Notation: Followings are the notation used in this study –
$G.L$= Ground level
$G.W.T$ = Ground Water Table
$i.e.$,= that is
A= Surface area served by Tile-drain
i= Hydraulic gradient of the G.W.T
H_L= Head loss
q= Quantity of flow (seepage) per unit length of Tile-drain
L= Tile-drain Length

1. INTRODUCTION

Unusual confinement of water is the issue. The confinement becomes so severe on its formation in cropping-field. It may be due to various reasons of concern of various degrees. People start to think remedies right from early period of its formation, particularly for the water-logging fields. In a territory of diverse elements of composition, fields (or open lands) & infrastructural establishments are the places of virgin origin & tracts of human's touch respectively. Often, the latter one is given major importance in protecting its areas of governance well against such stagnancy or the confinement, if occurred. Topography or the ground-slope of irrigated fields mostly plays the driving role in taking the water flow through the cultivating soils.

The system of land-drainage where the provision of Tile-drain is given to send off & impart the way of discharging the water from field from creating non-essential water for crop as well as for the costly useful fields – the water-logging is the result if not given it of the particular discharging system in its fields. Irrigation fields, everywhere, should be brought equally to under the land-drainage system to prevent the creation of water-logging [1].

Besides various direct & indirect factors, intensity of rainfall is the matter of object to form water-logging. Cultivable fields, if not equipped with underground drainage system or the usual land-drainage system, are inclined to suffer from water-logging. The rise of Ground Water Table (G.W.T) when stayed over long-period causes several damages to the crop & its field also.

A dimensional methodology of areal basis consideration, axially, has been brought into limelight & incorporated in this study to formulate the related finding about the tile-drainage spacing [2]. The methodology/approach is considerably new one & has been described in this study as **'PDM' (Philosophical Dimensional Methodology)**. Suitable as well as the variable selection in describing the correct & usual-to-be reckoned with in providing the land-drainage system equipped with the Tile-drain should thereby be expected to be easier in the determination of the Tile-drain spacing as given by this study's overall philosophy.

2. GENERAL OUTLINE

Fertile fields are like God's Heaven. Everywhere such fields of importance are kept protected with the severe attention.

Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

Water-logging is also a common picture in every year, especially for the cropping fields seasonally. Useful lands get affected hugely by it. Costly crops are lost away subsequently, particularly by the huge gathering of the water over the crop-field. In addition to this washing away of the valuable costly fruits of the field from its fields, the effect of water-logging which is mostly the after-effect of any seasonal or occasionally varied incident is also the most responsible creator of the unfavorable conditions (i.e., water-logging) of the field in reckoning the fateful fates of the sinless crops of the field upon its prolonged staying on the future of drained-off of water-logging days.

Cost of irrigation consequently increases for bringing the affected soils into under function/natural like earlier as it's before the water-logging.

Variability always exists in any wishful objects by kinds, but human nature has learnt how to reign over the troublesome variability suitably by making the wishful dreaming objects, into the rationality for their own pursuits of use. Continuous developments are everywhere in every field in the world. There is nothing constant. Revisions or overviews over the past methods or methodology are coming frequently now-a-days in every field of application as showing the new ways/paths to the days coming ahead for the world's people.

In this rapidly changing world, the enormous fields of the research & developments have made us to where we are today & to what altitudes we'll be on tomorrow. This study has described one of such kind of work which may be regarded as 'revisionary' over its earlier 'conventional' kind of establishment.

It's a 3-dimensionally described formulation as said. This study has considered the PDM approach make a quite difference in understanding in the tile-drainage spacing. It's to be towards getting much better version of it, in addition to the following ones.

3. GOALS OF THE STUDY

As this study is primarily at this stage of research is of theoretical interests indeed, its entirety of the underground drainage's spatial system for Tile-drainage has been derived & the objectives are –

a) To determine the spacing equation of tile-drain in a 'representative' dimensional methodology.

b) To ponder & examine the underground behavior of seepage, for each axial plane, to be served by its tile-drain using the 'planar-area' philosophy (PDM) for having better concept, vision & control.

c) To compare the 'conventional' spacing equation with the equation as determined by this study.

4. METHODOLOGY

Behind every physical motion certain philosophical formulations must exist, irrespective of abidance as well as behavior of stationery particles in the rules of such motion. And, for its better visibility, the 'factorial implication' of it is always to be selected, extracted & determined properly, owing to the regards of untimely happenings & its uncertainties in each of those movements under consideration. In order to know & interlink the physicality so attached with & required in the related estimation, behind the related physical formation of dimensional variability[3], followings are the assumption of this particular study, of one of such nature & kind, for attaining at the objectives & conformance of this study, satisfactorily –

ASSUMPTIONS OF THE PHILOSOPHICAL APPROACH (PDM):

a) The soil-medium is homogeneous, isotropic & saturated.

b) The permeability coefficient of soil-formation is constant in all the feasible direction.

c) The subjected dimension of the 3-dimensional sectional elements of the soil-medium, by its own virtue of formation in its dimensional configuration, is infinitesimal – it's a factor in the flow-area.

d) The subjective fundamental flow-mechanism in the soil-medium of groundwater hydrology as given by the Darcy's law, & etc. has been kept unaltered & is equally valid for this study in its description.

e) The dynamic behaviour of water-particle beneath the ground has been considered in this study by the (second) moment of inertia (I) of the G.W.T.

f) The Tile-drain length is assumed to be always with the line of action of the segmental dimension along the Z-direction, by the same magnitude also on integration.

g) Each axial plane has its own 'separate', 'individual' & 'unique' assets of the flow creation to the Tile-drain of length 'L'.

Determining the (axial) tile-drain spacing for a water-logged basin –

In water-logging, the seepage follows its own path to traverse through the open spaces of soil-medium. This nature of entire seepage operation for a water-logged area, under ground-level(G.L), has been considered solely through the 3-dimension pattern of the soil-element subjected to water-logging & its entire methodology termed as **'Philosophical Dimensional Methodology', PDM,** is now discussed as followed –

Philosophical Dimensional Methodology (PDM):

Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

The assumption explained earlier is valid for the PDM indeed. Derivational details using the PDM & its related pictures given along-with this study have been furnished in the following way –

a) First of all, flow dynamics as described by the Darcy's law of seepage flow through the soil-medium has been explained dimensionally as to form the general one. Small element of soil-mass, after given the 3-dimensional distribution axially, has been brought under discussion with its related axial area & the gradients in active consideration, plane/axes wise, with the concern of the G.W.T (Table 1).

c) Then, the subjective equation of spacing of the tile-drain has been evaluated & determined for each axial planar area of 3-dimensional XYZ soil-element.

d) Afterwards, comparison with the 'conventional' tile-drain spacing has been discussed, exemplarily.

Regarding the figure provided, Fig. 1 shows the typical position of the tile-drain spacing subjected to water-logging condition 3-dimensionally. The Fig. 2, Fig. 3 & Fig. 4 are the axial representation of the soil-medium in the X-Y, Y-Z & Z-X planar formation of areal magnitudes respectively. The foregoing discussion shall have the need to go through these figures as applicable to subsequently.

The basic principle in deriving estimation of the spacing as well as corresponding Length of the Tile-drain for the flow passing through the drains is to equate the total quantity (Q) of the seepage-flow which may be entering into the Tile-drains per unit length of the drain with the total amount of flow (q) allowed over the catchment basin in order the flow to pass through the soil-medium & consequently through (desired) length of the Tile-drain, on water-logging.

The derivational applications shall be treated to be acting under the 'prevailing' G.W.T curve. Definition of the Darcy's law derives the following two properties,

<u>Property 1</u>: $Q \propto (A)$

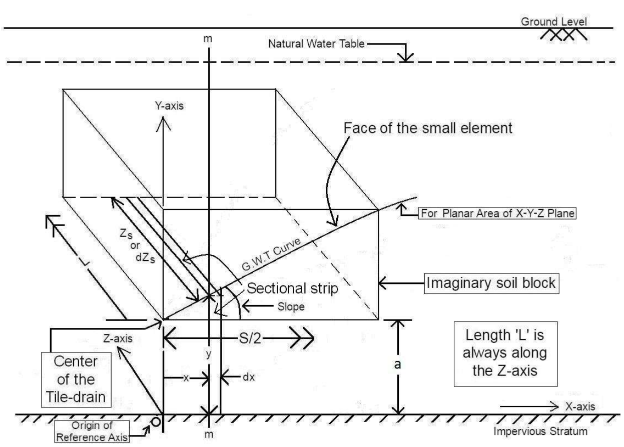


Fig.1: Axial Tile-drain spacing

<u>Property 2</u>: $Q \propto (i)$

General Philosophical Formulation is based on the Darcy's law which states that the discharge (Q) passing through a soil-formation (segmental & dimensional) is proportional to its (subjected) cross-sectional area (A) & loss of head (H_L). All

Where, A = Surface area (cross-sectional) of seepage flow through the soil-element; i = Hydraulic Gradient = the water-pressure difference (H_L) per unit traversed length (L) = (H_L/L); H_L = Loss of Head of water; L_S = Traversed length of water particle through the subjected soil mass. The 'L_S' value gives tile-drain spacing.

Evaluating the Property 1 & Property 2 of the Darcy's Law, Q = (K)(A)(i) ; where, K = constant of proportionality = roughness coefficient & the remaining the same as discussed.

In this research study, the soil-formation in general has been viewed & described with its 'elemental' three dimensional perspectives (see the given figures) where the soil-medium has been considered as consisting of no. of soil blocks each having the dimensional magnitude for a specified volume. Subjected soil-medium, particularly its flow-contribution under G.W.T, is consisting of soil-elements having dimensional dimension of ∂x, ∂y & ∂Z_S along the three axes (X, Y, Z) which have been here assumed to form the orthogonal (i.e., mutually perpendicular about the origin O) nature of the axial planes always; particularly when considering it on two-dimensional nature of plane during the flowing nature of seepage. These two-dimensional planes are herein termed as the planar area. Each such axial plane and/or planar area of such flow is X-Y, Y-Z & Z-X of the 3-dimensional soil-element. In general, all these planes/planar areas act simultaneously together while seepage flows through the soil-medium, particularly for water-logging. In order to have the view of the seepage kinetics with regards to the tile-drain spacing clear & broadly transparent, this study has determined the spacing equation for each of such axial planes or planar areas (of 2-dimensional). It has been found that the several equation based on such planar area has explained their own nature & pattern of formation.

Planar area, once under such consideration as said by any two axes (orthogonal in nature) of 3 – dimensional soil-medium, it is then to be the basis of question of its use/utilization. The various axial/planar-area based spacing equation gives clear estimation contributed by the two axes – there'll be thereby three kinds of such equation for an entire soil-formation consisting of the 3 –dimensional axial scenario. When summed up of such axial seepages of 2-dimensional each, it gives the entire/total seepage to be passed through tile-drain, resulting into a better estimation in regarding of the way, in comparison, by which the conventional equation has been formulated. Further research may be done in seeing through various (possible) outlets of use of the formulated equation of spacing.

Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

In order to introduce & propagate the philosophy by the three 'axiomatic' planes of the kind, the 'dimensional' concept of the methodological derivation of PDM is now determined as follows –

Let's consider a soil-medium equipped with the tile-drain, subjected to water-logging, is consisting of M-th sectional segment such as $m_1, m_2, m_3, m_4, m_5, \ldots M$, &, $x_1, x_2, x_3, x_4, x_5, \ldots, x_M$ be the corresponding sectional distance at the sections from the axis of reference i.e., O – Y axis (Fig.1). Over the entire tile-drainage area, the respective ordinate values for the sections so chosen of the soil-medium are $y_1, y_2, y_3, \ldots, y_M$ of the G.W.T above the impervious stratum.

The impervious bed, as shown, is here with respect to the axis of reference (O-X) for the entire 3-dimensional derivation of the soil-element. Table 1 gives the planar-area based values of related variables such as area, gradient etc. in differential form contributed by such axial planar areas. Say for X-Y planar area, the strip of thickness 'dx' is at a distance of 'x' from O-Y axis. Its corresponding ordinate, with regards to G.W.T, is 'y' above the O-X axis (Fig.4). As explained, there are three such obvious planar areas for the entire 3-dimensional soil-formation. In this way, Fig.4, Fig.5 & Fig.6 shows respective axial behaviors or contribution of the axial seepage flow.

The derivation has been done by the 'principle' as explained, taking the strips at the required

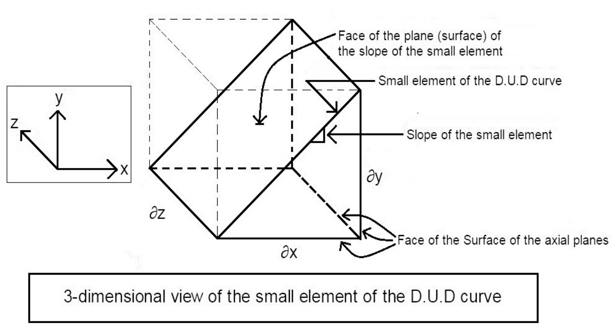


Fig.2: The Axial Dimension of the Areal Small Element & its Slope under the G.W.T

sectional distances from the origin, O, of the reference axis from O-Y base. Thickness of the small element of soil dimensionally/axially at each strip location contributing to the entire flow-estimation (axially) is given in the Fig. 2 & Fig. 3 - these elemental thicknesses constitute the triangular shape of the soil-element contributing to the seepage-flow resulting of the entire soil-medium.

The dimensional elemental thicknesses are described as:

$\partial x = dx$= thickness of the small element at the strip-section (m-M) in the X-direction.

$\partial y = dy$= thickness of the small element at the strip-section (m-M) in the Y-direction.

$\partial Z_s = dZ_s$ = thickness of the small element at the strip-section (m-M) in the Z-direction.

Here,dx, dy, dZ_s are infinitesimal in magnitude & their directions are axial for the small element.

The sub-script 's' used in dZ_s or ∂Z_s indicates related dimension of the considered soil-element (Fig.2), from the viewpoint of water-logging, The value of L has inter-relation with the X-direction & the(dx)value gives the tile-drain spacing; L = summation of sub-divided length (dZ_s) of the small element or the tile-drain which ultimately gives the total drain-length under the effect, i.e., $L = \sum_{m=1}^{M}(dZ_s)_{xy}\}_m$.

Incorporating the flow-contribution of the 3-dimensional soil-element of the subjected catchment area(A) into the evaluated equation of the Darcy's law, $(Q)_{x,y,z} = \{K(i)(A)\}_{x,y,z}$; $(Q)_{x,y,z}$ be the dimensional (total) flow of the soil-medium per unit length of the tile-drain. And, the value of $'K'$ is assumed to be constant as told in the assumption, i.e.,$K_{x,y,z} = K_{xy} = K_{yz} = K_{zx} = K$

The subjected surface area, A or $(A)_{x,y,z}$, of hydrologic catchment under the drainage system is the plan-area which is under the action of water-logging. This dimensional area of soil-medium, as shown in Fig. 1, has different axial values by magnitude dimensionally. By the defining formulation of the area for the 3-dimensional aspect,$(A)_{x,y,z} = \sum_{m=1}^{M}\left[(dA)_{x,y,z}\right]_m$; where, $(A)_{x,y,z}$ Summation of the sectional but dimensional areas, forming the total area of subjection, &, $(dA)_{x,y,z}$ be the sectional, elemental & cross-sectional area of the flow of water through the 3-dimensional soil-specimen (Table 1). Thereby, total of the sectional flows$(Q)_{x,y,z} = \sum_{m=1}^{M}\left[(dQ)_{x,y,z}\right]_m = K\sum_{m=1}^{M}\left[(i)(dA)_{x,y,z}\right]_m$; where, the dimensional sectional flows are represented by$(dQ)_{x,y,z}$ per unit length of the drain.

In the 3-dimensional **plane-area based description**, the X-axis is defined for signifying the 'longitudinal progress' of the Drain's Spacing, the Y-axis is the 'vertical dimension' of the soil-layer & the Z-axis (i.e., normal to X-axis) is designated for indicating the 'progress along the Length' of drain. All these axial progresses are very segmental & infinitesimal. Placing the dimensional value of (i) & (A) into the dimensional equation of,

$$(Q)_{x,y,z} = \sum_{m=1}^{M}\left[(dQ)_{x,y,z}\right]_m$$

$=(K)\sum_{m=1}^{M}\left[\{(i)\}_{x,y,z}\{(dA)_{x,y,z}\}\right]_m$

$(Q)_{x,y,z} = (K)\sum_{m=1}^{M}\left[\{(i)\}_{x,y,z}\{(A)_{x,y,z}\}\right]_m$...(1)

Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

Eq. (1) is formed after the inclusion of the contribution of the 'elemental' sections, in all. And for regards, this flow,$\{(Q)_{x,y,z}\}$, is per unit length of the tile-drain. As said in assumption (c) it is again to be mentioned that the gradient (i.e., hydraulic gradient) of seepage flow has been kept unalteringly equal in all the direction & is of same magnitude, irrespective of any subjective planar area under consideration; it's also kept the same for all related possibility. It is because of the fact of the dynamic behavior of water particle moving along the G.W.T is at a same gradient of head loss(H_L) & it's the underlying concept of the assumption(c). Thereby, as i_{xyz} or (i) is the same for all planar areas in the 3-dimenional discussion (Fig.3) of soil-element of the soil-medium, the (identical) gradient which is slope of water particle moving along the G.W.T is,

$$i_{xyz} = \left(\frac{H_L}{L_s}\right) = i_{xy} = i_{yz} = i_{zx} = \frac{\partial y}{\partial x} = \frac{dy}{dx}$$

Let, the total (elemental) flow received from the catchment area (A) shall likely to be entering into the Tile-drain per unit length on 3-dimensional basis after passing through the strips dimensionally is,

$$\sum_{m=1}^{M} \left[\{(Q)\}_{x,y,z}\right]_m = \sum_{m=1}^{M} \left[\frac{q}{UnitLength}\right]_m$$

q= Total subjected flow over the catchment area (A) due to water-logging.

$$\sum_{m=1}^{M} \left[\{(Q)\}_{x,y,z}\right]_m$$

$$= \sum_{m=1}^{M} \left\{\frac{q}{(dZ_s)_{x,y,z}}\right\}_m = \frac{q}{L} \qquad ...(2)$$

For the flow of water through the strip subjected to the G.W.T curve subjected to 3-dimensional soil-element, from the Eq. (2) the governed perimeter of the flow-dynamics of total seepage flow (q) is –

$$q = K \sum_{m=1}^{M} \left[\{(Q) dZ_s\}_{x,y,z}\right]_m$$

$$q = KL \sum_{m=1}^{M} \left[\{(i)(dA)\}_{x,y,z}\right]_m$$

$$q = K(i) \sum_{m=1}^{M} \left[(A)_{x,y,z} (dZ_s)_{x,y,z}\right]_m \qquad ...(3)$$

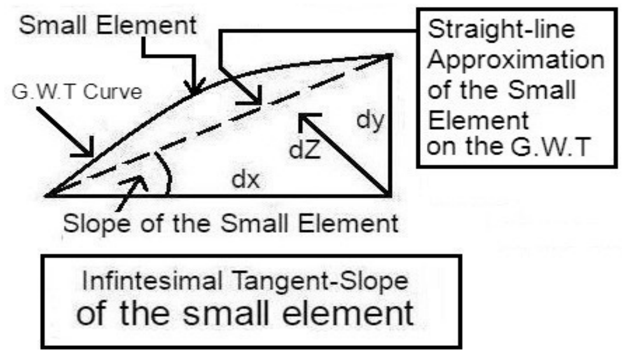


Fig. 3: Dimensional Description of Hydraulic Gradient of G.W.T Curve

It is observed that the maximum value in the ordinate of the G.W.T curve occurs at the position creating & giving the guideline of the boundary condition of the G.W.T curve itself so favorable by the soil-medium & etc. that the maximum is formed. On this basis, the nature of G.W.T curve forms to geometric shape & size. The spacing equation also needs to be incorporated with such formation (symmetric and/or un-symmetric) of the G.W.T curve. Say, for G.W.T curve of 'symmetric' nature about the mid position in geometry of the G.W.T itself in between the Tile-drains, maximum ordinate-value of G.W.T occurs at the position of S/2 (i.e., at the M-th section) & the Spacing of the Drain also requires to be expressed in according to the particular configuration of the G.W.T; where, S is the spacing between the tile-drain. In this way, the G.W.T curve may be of symmetric nature or non-symmetric kind but the spacing equation should be made up with accordingly. Following equation, Eq. (4) & Eq. (5), describes this enunciation briefly (Fig. 1). Equation of the flow-justification of 'symmetric' G.W.T with respect to the receiving position of the Tile-drain:

q= Q_{xyz}(coming from the right-sided G.W.T) $+Q_{xyz}$(coming from the left-sided G.W.T)

$$\left(2Q_{xyz}\right) = q \qquad ... (4)$$

The Eq. (4) is thereby subjected to a complete G.W.T curve (symmetric).

In case the configuration of the G.W.T is other than that in the Eq. (4), the Eq. (4) should then be written as, $\left(Q_{xyz}\right) = q$ ... (5)

Eq. (5) describes derivation of the tile-drain spacing for G.W.T resting on each side of the drain itself. In this case, suitable adjustments are required to make the seepage into estimation as applicable. However, in this study all the spacing equation have been determined looking the vision of Eq. (5). Now, the final derivation related to the pertinent axial planes is given as followed, separately for particular axial plane. Except mentioned otherwise, for each planar area the determination shall be done by Table 1 & always after viewing of the general figures given in Fig. 1, Fig. 2 & Fig. 3 applied for all the axial planar areas in addition to the respective ones.

Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

Table 1. Planar-area kinetics of the seepage-flow; where, $\oint dZ_s = \oint Z_s = L$

Sl.	Name of the Planar area (of best kind)	Planar area (by PDM)	(Second) Moment of Inertia (I)	Hydraulic gradient (i)
		of Differentiated(dA)		of Differentiated$(i)_{xyz}$
1	X-Y plane	ydx	$\oint 2y^2(dA)_{xy} = I_{xy}$	$\left(\frac{dy}{dx}\right)$
2	Y-Z plane	ydz	$\oint 2y^2(dA)_{yz} = I_{yz}$	
3	Z-X plane	$Z_s dx$	$\oint 2z^2(dA)_{zx} = I_{zx}$	

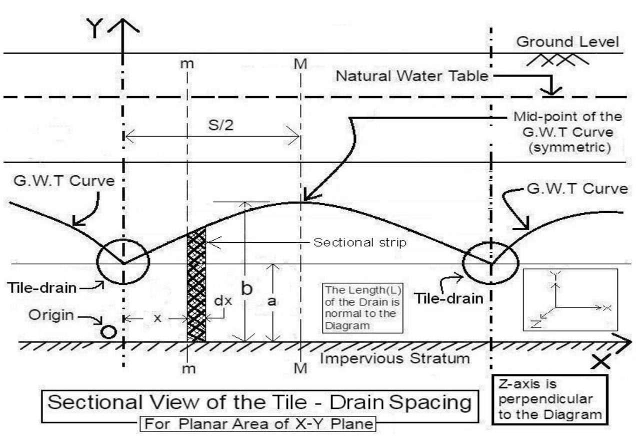
Now the outcomes of the PDM for the axial planes are discussed in its subsequent mode of formation by segment tag of **Outcome X, Outcome Y& Outcome Z**, as to be known over by these given as followed -

Spacing by $X - Y$ planar-area –

$$q = \sum_{m=1}^{M} [\{Q(dZ_s)\}_{xy}]_m$$

$$q = K \sum_{m=1}^{M} \left[\left\{\left(\frac{dy}{dx}\right)(dA)(dZ_s)\right\}_{x,y,z}\right]_m \quad \dots (6)$$

Now from the Eq. (6), for the X-Y planar area $q = K \sum_{m=1}^{M} \left[\left\{\left(\frac{dy}{dx}\right)(y)(dx)(dZ_s)\right\}_{x,y}\right]_m$ ... (7)



Here, the drainage spacing is determined by the X-Y planar area only. Let, (Q_{xy})= discharge per unit length passing through X-Y planar area (Fig. 4). Discharge is from Eq. (3),

The cross-sectional Area (A_{xy}) is the total subjected strip-area of the elemental soil-specimen of the subjected X-Y axial plane of 3-dimensional elemental flows,

i.e., $A_{xy} = \sum_{m=1}^{M}[(dA)_{xyz}]_m = \sum_{m=1}^{M}[\{(y)(dx)\}_{xyz}]_m$

Fig.4: Dimensional Tile-drain spacing for X-Y axis

Eq. (7) is the dimensionally expressive form of the Eq. (3) for X-Y plane (Table 1) & its related association is with Eq. (5). At this stage of formulation, if the figurative three values out of the four axial progresses like $y, dx, dy \& dZ_s$ are known then the remaining may be obtained for a given flow (q).

Further, the equation while to be in use may be the one of the following form of the Eq. (7) as

$$\sum_{m=1}^{M} [\{(i)(ydx)(dZ_s)\}_{xy}]_m$$

$$= \sum_{m=1}^{M} \left[\left\{\left(\frac{dy}{dx}\right)(ydx)(dZ_s)\right\}_{xy}\right]_m = \left(\frac{q}{K}\right) \quad \dots (8)$$

Or simply, for the X-Y planar area of the soil-element, segmentally,

$$(q) = K[\{(i)(ydx)(dZ_s)\}] \quad \dots (9)$$

Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

Or, by the following one, as discretely, after having got specified by the planar area to some extent,

$$K[\{(dy)(y)(dZ_s)\}] = (q) \qquad \dots (10)$$

Now the outcomes (Outcome X's) of the PDM for the axial plane X-Y are discussed as follows:

Outcome X1 –

This is Outcome **X1** which signifies a particular basis of derivation for the spacing. Here, as the dimensional subjecting planar area is X-Y only, let's start with integrating both sides of the Eq. (8) over the defining depth of $(b - a)$ of the G.W.T curve & the Spacing (S) of the Tile-drain –

$$\sum_{m=1}^{M}\left[\left\{\left(\frac{dy}{dx}\right)(ydx)\right\}_{xy}\right]_m = \left(\frac{q}{KL}\right)$$

$$(i)\sum_{m=1}^{M}\left[\{(ydx)\}_{xy}\right]_m = \left(\frac{q}{KL}\right)$$

$$\Sigma_{m=1}^{M}\left[\{(ydx)\}_{xy}\right]_m = \left(\frac{q}{KLi}\right) \qquad \dots (11)$$

Multiplying Eq.(11) by$\left(\frac{1}{i}\right)$ on both sides,

$$\sum_{m=1}^{M}\left[\left\{(ydx)\left(\frac{dx}{dy}\right)\right\}_{xy}\right]_m = \left(\frac{q}{i^2KL}\right)$$

$$\sum_{m=1}^{M}\left[\{(dx)^2\}_{xy}\right]_m = \left(\frac{q}{i^2KL}\right)\sum_{m=1}^{M}\left[\left\{\left(\frac{dy}{y}\right)\right\}_{xy}\right]_m$$

Integrating both sides,

$$S_{xy} = \left(\frac{2}{i}\right)\sqrt{\left(\frac{q}{KL}\right)log_e(b-a)} \qquad \dots (12)$$

Where,

$\int_0^{S/2} dx = \left(\frac{S}{2}\right)$; [see Eq. (4) & Eq. (5)].

$\int_0^{L}(dZ_s) = L$; (see figures).

$\int_a^{b}\left(\frac{dy}{y}\right) = log_e\left(\frac{b}{a}\right)$; (see figures).

Spacing(S) of the Tile-drain is thereby found as the function of the reciprocal of the total discharge of seepage water, but proportional to the Length (L) & other factors of the Tile-drain. The equation may also be determined for planar area Y-Z & Z-X in the same way till the Eq. (12) is derived (Table 2).

Now applying the Eq. (4), the Eq. (12) transforms to as,

$$\left(S_{xy}\right)_T = \left(\frac{1}{i}\right)\sqrt{\left(\frac{2q}{KL}\right)log_e(b-a)} \qquad \dots (12a)$$

$\left(S_{xy}\right)_T$ = Total spacing required in between the Tile-drain subjected to the X-Y axial-plane.

In this way, the Eq. (12) & Eq. (12a) are the tile-drain spacing equation the way of which should also be required to be applied to the other cases of the axial areas in order to find out the similar like this as determined in the X-Y planar area including accounting the flow from both the sides of the Tile-drain about the O-Y axis (Fig. 1 & Fig. 4) as explained.

Multiplying Eq. (11) by(ydx)on both sides,

$$\sum_{m=1}^{M}\left[\{(ydx)\}_{xy}\right]_m = \left(\frac{q}{KLi}\right)$$

$$\Sigma_{m=1}^{M}\left[\{(ydy)(ydx)\}_{xy}\right]_m = \left(\frac{q}{KL}\right)\Sigma_{m=1}^{M}\left[(ydx)_{xy}\right]_m$$

$$\sum_{m=1}^{M}\left[\{(y^2dy)(dx)\}_{xy}\right]_m = \left(\frac{q}{KL}\right)\sum_{m=1}^{M}\left[(A)_{xy}\right]_m$$

Integrating,

$$\left\{\frac{(b^3-a^3)}{3}\right\}\left(\frac{S_{xy}}{2}\right) = \left(\frac{q}{KL}\right)(A)_{xy}$$

$$\left(\frac{S_{xy}}{2}\right) = \left(\frac{3q}{KL}\right)\left\{\frac{A_{xy}}{(b^3-a^3)}\right\}$$

$$S_{xy} = 6\left(\frac{q}{KL}\right)\left\{\frac{A_{xy}}{(b^3-a^3)}\right\} \qquad \dots (13)$$

Spacing(S) of the Tile-drain is thereby found as the function of the reciprocal of the total discharge of seepage water, but proportional to the Length (L) & other factors of the Tile-drain.

Now applying the Eq. (4), the Eq. (13) becomes,

$$\left(S_{xy}\right)_T = 3\left(\frac{q}{KL}\right)\left\{\frac{A_{xy}}{(b-a)^3}\right\} \qquad \dots (13a)$$

$\left(S_{xy}\right)_T$ = Total spacing required in between the Tile-drain subjected to X-Y plane.

The equations of the X-Y planar area are thereby of similar kind of equation by the variables so involved but are different by the way it's formulated - comparison among these may be done to have its inside information which is out of scope of this study, but may be a research field of interest.

Outcome X2 –

Multiplying Eq. (9) by (y) on both sides,

International Journal of Civil Engineering Research (IJCER)

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Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

$$dx(y^2dy)(dZ_s) = \left(\frac{q}{K}\right)(ydx)$$

$$(ydx)(y^2)\left(\frac{dy}{y}\right)(dZ_s) = \left(\frac{q}{K}\right)(ydx)$$

$$(2y^2dA)\left(\frac{dy}{y}\right)(dZ_s) = \left(\frac{2q}{K}\right)(ydx)$$

Integrating,

$$\oint(2y^2dA)\int_a^b\left(\frac{dy}{y^2}\right)\int_0^L(dZ_s)$$

$$= \left(\frac{2q}{K}\right)(\oint dx)$$

$$S_{xy} = \left(\frac{KL}{q}\right)(I_{xy})\left(\frac{1}{a} - \frac{1}{b}\right) \quad \ldots (14)$$

Eq. (14) is also the essential equation in designing the particular land-area suitably, if required so – it may be a scope of research field of interest. Eq.(14) is the spacing equation involving the dynamic as well as inertial effect of groundwater under G.W.T; where, $I_{xy} = \oint(2y^2dA)$ from Table 1. Below are also some other forms of it.

Alternatively,

Multiplying Eq. (10) by (ydA) on both sides, $\left(\frac{K}{q}\right)(dZ_s)(y^2dA)\left(\frac{dy}{y}\right) = dA \quad \ldots (15)$

Multiplying $(i) = \left(\frac{dy}{dx}\right)$ on both sides

$$\left(\frac{K}{2q}\right)(dZ_s)(2y^2dA)\left(\frac{dy}{y}\right)(i) = ydx\left(\frac{dy}{dx}\right)$$

$$\left(\frac{K}{2q}\right)(dZ_s)(2y^2dA)\left(\frac{dy}{y}\right)(i) = ydy$$

Integrating both sides,

$$\left(\frac{KL}{2q}\right)\oint(2y^2dA)\left(\int_a^b\frac{dy}{y}\right)\sum_{m=1}^{M}(i)_m = \int_a^b ydy$$

$$S_{xy} = 2\left(\frac{KL}{q}\right)\left(\frac{I_{xy}}{b+a}\right)\left\{log_e\left(\frac{b}{a}\right)\right\} \quad \ldots (16)$$

Again alternatively,

Multiplying Eq. (10) by (ydA) on both sides,

$$K[\{(dy)(y^2dA)(dZ_s)\}] = (q)(ydA)$$

$K[\{(dy)(y^2dA)(dZ_s)\}] = \left(\frac{q}{L}\right)(y^2dx)$; Where, $A = ydx$;

$$K(2y^2dA)(y^{-2}dy)(dZ_s) = 2q(dx)$$

Integrating both sides,

$$S_{xy} = \left(\frac{KL}{q}\right)(I_{xy})\left(\frac{b-a}{ab}\right) \quad \ldots (17)$$

Except slight modification, Eq. (16) & Eq. (17) is quite having the similar implication like the Eq. (14).

Outcome X_3 –

In this, the spacing equation has been found as a factor or the ratio $\left(\frac{I_{xy}}{A_{xy}}\right)$ which has been formed as a functionary element of spacing, for providing further scope/works in its related spacing equation.

Multiplying Eq. (10) by $(2ydx)$ on both sides,

$$K[\{(dy)(2y^2dx)(dZ_s)\}] = 2ydx(q)$$

Multiplying (y) on both sides,

$$K[\{(dy)(2y^2)ydx(dZ_s)\}] = 2y^2dx(q)$$

$$K\left[\left\{\left(\frac{dy}{y}\right)(2y^2dA)(dZ_s)\right\}\right] = 2ydx(q) = 2q(dA)$$

Dividing (dx) on both sides,

$$K[\{(dy)(2y^2dA)(dZ_s)\}]\left(\frac{1}{ydx}\right) = \frac{2(q)dA}{dx}$$

$$dx = \frac{2(q)(dA)(dA)}{K[\{(dy)(2y^2dA)(dZ_s)\}]}$$

Integrating both sides,

$$S_{xy} = \left[\frac{4q(A_{xy})}{KL\left(\frac{I_{xy}}{A_{xy}}\right)log_e\left(\frac{b}{a}\right)}\right] \quad \ldots (18)$$

Like the earlier outcome/equation, Eq. (18) is also a specifically relevant one to its involved variables.

In this way, Outcomes given by the X-Y planar area as explained from the Eq. (11) to Eq. (18), has represented & determine the tile-drainage spacing requirement.

Incorporating sloping surface of small element of G.W.T –

Now, the following derivation is attempted to consider the sloping surface of the small element of soil-medium under G.W.T into the hydraulic gradient to derive the spacing equation. The straight-line approximation of the G.W.T curve (Fig. 3) shall exist but in the gradient equation the tangent of the slope of the small element of G.W.T shall be taken in estimation instead of its sine value. In including the sloping surface,$(i) = \left(\frac{dy}{dW}\right)$, dW = the sloping length. For the X-Y planar area, equation of spacing is then found out as followed –

Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

From Eq. (8), $K(i)(ydx) = \frac{q}{L}$

$$K\left(\frac{dy}{dW}\right)(ydx) = \left(\frac{q}{L}\right)$$

From the figure (Fig. 2 & Fig. 3),

$$\partial W = (dW) = \sqrt{(dy)^2 + (dx)^2}$$

$$[K(ydx)(dy)]^2 = \left(\frac{q}{L}\right)^2 (dW)^2$$

$$=\left(\frac{q}{L}\right)^2 (dy + dx)^2$$

Integrating both sides,

$$\left[K \int_a^b y^2 dy \int_a^b dy \int_0^{\frac{S}{2}} dx \int_0^{\frac{S}{2}} dx\right] =$$

$$\left(\frac{q}{L}\right)^2 \left[\int_a^b dy \int_a^b dy + \int_0^{S/2} dx \int_0^{S/2} dx + 2\int_0^{S/2} dx \int_a^b dy\right]$$

$$\text{Or, } K\left[\frac{(b^3-a^3)}{3}(b-a)\left(\frac{S^2}{4}\right)\right] =$$

$$\left(\frac{q}{L}\right)^2 \left[(b-a)^2 + \left(\frac{S^2}{4}\right) + (S)(b-a)\right]$$

Or, $\left(\frac{q}{L}\right)^2 (b-a)^2 = \left(\frac{S^2}{4}\right)\left[\left\{\frac{K(b^3-a^3)}{3}(b-a)\right\} - \left(\frac{q}{L}\right)^2 - 2\left(\frac{q}{L}\right)^2 (i)\right]$

Where, for the G.W.T's straight-line consideration $(S)(b-a) = \left(\frac{S^2}{2}\right)\left\{\frac{(b-a)}{S/2}\right\} = \left(\frac{S^2}{2}\right)(i)$

Dividing by $(b-a)^2$ on both sides,

$$\left(\frac{S}{2}\right)^2 \begin{bmatrix} \left\{\frac{K(b^3-a^3)}{3(b-a)}\right\} - \left\{\frac{q}{L(b-a)}\right\}^2 \\ -2(i)\left\{\frac{q}{L(b-a)}\right\}^2 \end{bmatrix} = \left(\frac{q}{L}\right)^2$$

$$\left(\frac{S}{2}\right)^2 \begin{bmatrix} \left(\frac{K}{3}\right)\{(i)(A_{xy}) + 3ab\} \\ -(Q_{xy})^2\left\{\frac{1}{(i)(A_{xy})}\right\}\{1+2(i)\} \end{bmatrix} = \left(\frac{q}{L}\right)^2$$

... (19)

Where, $(i) = \frac{b-a}{S/2}; \left(\frac{q}{L}\right) = Q_{xy}$

$$(i)(A_{xy}) = \left\{(b-a)\left(\frac{2}{S}\right)\right\}(b-a)\left(\frac{S}{2}\right)$$

$$(i)(A_{xy}) = (b-a)^2$$

&, $\frac{(b^3-a^3)}{b-a} = \left\{\frac{(b-a)^3 + 3ab(b-a)}{(b-a)}\right\}$

or, $(b-a)^2 + 3ab = (i)(A_{xy}) + 3ab$

From the Eq.(19),

$$(Q_{xy})^2 = \left(\frac{S}{2}\right)^2 \left[(Q_{xy})\left\{\left(\frac{1}{3}\right) + \frac{ab}{(b-a)^2}\right\}\right]$$

$$-\left(\frac{S}{2}\right)^2 (Q_{xy})^2 \left\{\frac{1}{(b-a)^2}\right\}\left\{1 + \frac{4(b-a)}{S}\right\}$$

... (20)

where, $\left(\frac{K}{3}\right)\{(i)(A_{xy}) + 3ab\}$

$$=(KiA_{xy})\left\{\left(\frac{1}{3}\right) + \frac{ab}{(i)(A_{xy})}\right\}$$

$$=(Q_{xy})\left\{\left(\frac{1}{3}\right) + \frac{ab}{(i)(A_{xy})}\right\}$$

$=(Q_{xy})\left\{\left(\frac{1}{3}\right) + \frac{ab}{(b-a)^2}\right\}$ &, by the Darcy's elemental seepage flow, $KA(i_{xy}) = Q_{xy}$; &, $(iA_{xy}) = (b-a)^2$; also, $1 + 2(i) = 1 + \frac{4(b-a)}{S}$

Now from the Eq.(20),

$$\left(\frac{S}{2}\right)^2 \begin{bmatrix} \left\{\frac{1}{(Q_{xy})}\right\}\left\{\left(\frac{1}{3}\right) + \frac{ab}{(b-a)^2}\right\} \\ -\left\{\frac{1}{(b-a)^2}\right\}\left\{1 + \frac{4(b-a)}{S}\right\} \end{bmatrix} = 1$$

Or, $\left[\left(\frac{2}{S}\right)^2 + \frac{4}{(b-a)S}\right] = \frac{1}{(Q_{xy})}\left[\left(\frac{1}{3}\right) + \left(\frac{1}{4}\right)\left\{\frac{(b+a)^2}{(b-a)^2} - 1\right\}\right] - \frac{1}{(b-a)^2}$

where, $\left(\frac{1}{4}\right)\left\{\frac{(b+a)^2}{(b-a)^2} - 1\right\} = \left(\frac{1}{4}\right)\frac{(b+a)^2-(b-a)^2}{(b-a)^2}$ $\qquad \frac{ab}{(b-a)^2} = \left(\frac{1}{4}\right)\frac{4ab}{(b-a)^2} =$

Now assuming, $= \left(\frac{2}{S}\right)$, &,

$$d = \frac{L}{q}\left[\left(\frac{1}{3}\right) + \left(\frac{1}{4}\right)\left\{\frac{(b+a)^2}{(b-a)^2} - 1\right\}\right] - \frac{1}{(b-a)^2};$$

where, $q = L(Q_{xy})$

$(c)^2 + \frac{2}{(b-a)}(c) - d = 0$; it's a quadratic equation whose roots be

$$c = \left(\frac{2}{S}\right) = \left(\frac{1}{2}\right)\left[\frac{-2}{(b-a)} \pm \sqrt{\frac{4}{(b-a)^2} + 4d}\right]$$

From the Eq.(20),

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Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

$$S_{xy}=\left\{\left(\frac{1}{4}\right)\left[\frac{-2}{(b-a)}\pm\sqrt{\frac{4}{(b-a)^2}+4d}\right]\right\}^{-1}$$

...Eq.(21)

Eq. (21) is inverse equation, to be determined suitably, whose further justification is as followed –

In order to make the $c$value positive & real,

$$\sqrt{\frac{4}{(b-a)^2}+4d}>-\left(\frac{2}{b-a}\right)$$

which means $d>0$.

Again, it's evident from the Eq. (19),

$$\left(\frac{S}{2}\right)^2\left[(f)(Q_{xy})-(Q_{xy})^2\left\{\frac{1}{(i)(A_{xy})}\right\}\{1+2(i)\}\right]$$

$$=(Q_{xy})^2 \qquad ...(22)$$

where, assuming $\left(\frac{K}{3}\right)\{(i)(A_{xy})+3ab\}=(f)(Q_{xy})$ ...(23)

f= factor function of Q_{xy}

$$f=\left(\frac{K}{Q_{xy}}\right)\left\{(i)\left(\frac{A_{xy}}{3}\right)+ab\right\} \qquad ...(24)$$

As,$(Q_{xy})\neq 0$, from Eq.(22),

$$(Q_{xy})=\left(\frac{S}{2}\right)^2\left[(f)-(Q_{xy})\left\{\frac{1}{(i)(A_{xy})}\right\}\{1+2(i)\}\right]$$

$$\left(\frac{S}{2}\right)=\sqrt{\left[\frac{(Q_{xy})}{(f)-(Q_{xy})\left\{\frac{1}{(i)(A_{xy})}\right\}\{1+2(i)\}}\right]}$$

where, $(L)(A_{xy})$ = Volume V_{xy} = solid volume = Q_{xy}, neglecting the mass of solid-soil due to saturated soil condition.

$$S=2\sqrt{\left[\frac{(i)}{(f)(i)-\{L\}\{1+2i\}}\right](A_{xy})(L)}$$

$$-=2\sqrt{\left[\frac{(i)}{(i)(f-2L)-L}\right](L)(A_{xy})} \qquad ...(25)$$

The denominator is evaluated as follows

$$(i)(f-2L)-L=(i)(f-2L)-\left\{\frac{L}{(i)}\right\}(i)$$

From Eq.(25),

$$S=2\sqrt{\left[\frac{1}{(f-2L)-\left\{\frac{LS}{2(b-a)}\right\}}\right](L)(A_{xy})}$$

Where, from Table 1, for the X-Y planar area,

$\frac{L}{(i)}=\frac{LS}{2(b-a)}$; &, $(i)\neq 0$

$$S_{xy}=S=2\sqrt{\left[\frac{1}{\left(\frac{f}{L}-2\right)-\left\{\frac{S}{2(b-a)}\right\}}\right](A_{xy})}$$

... (26)

Moreover, the evaluation of the f-value is done as followed –

$$f=\left(\frac{KiA_{xy}}{Q_{xy}}\right)\left\{\left(\frac{1}{3}\right)+\frac{ab}{(i)(A_{xy})}\right\}$$

$$f=\left\{\left(\frac{1}{3}\right)+\frac{ab}{(b-a)^2}\right\}$$

Where, by the Darcy's elemental seepage flow,

$\frac{KiA_{xy}}{Q_{xy}}=1$; &, $(iA_{xy})=(b-a)^2$

Thereby it is evidently found that the tile-drain spacing is of general kind of determination by the Eq. (21) of the dimensional variables, although it may also be found by trial & error method by Eq. (26). For the planar areas Y-Z & Z-X, this similar incorporation has thereby been applied to determine the spacing equation of tile-drain.

Equation, like to the derivation of equations as obtained for the Outcome X from Eq. (11) to Eq. (26) for X-Y axial plane, may also be determined for the planar area of Y-Z & Z-X & it's given as followed –

Estimation by Planar area of the $Y-Z$ plane –

The flow-contribution along the 'formative' planar area of the Y-axis & the Z-axis shall be considered here, i.e., the areal section under the effect of flow-area of the Y-Z plane, in the kind of manner as explained in the case X-Y plane. Here, elemental area, $(dA)_{yz}=y(dZ_s)$.

Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

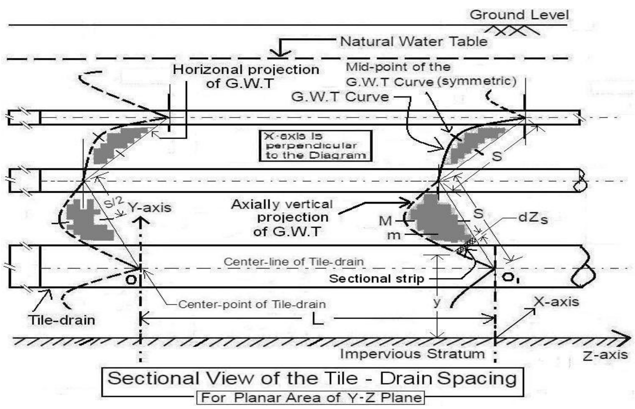

Fig.5: Tile-drain spacing for Y-Z axis

The tile-drain is herein considered to be of perforation kind so that on all along its length (L) the seepage can enter into the drain from the overburden soil-medium. From the Table 1 & the respective Fig. 5, total (contributed) area of the Y-Z planar area, $A_{yz} = \oint(dA)_{yz} = \oint y(dZ_s)$

&, by Eq. (3), the flow of subjecting plane as formed by the Y-Z axis, $q = (Q)_{yz}(dZ_s)_{yz} = K(A)_{yz}\sum_{m=1}^{M}[\{(i)(dZ_s)\}_{yz}]_m$

$=(KL)\sum_{m=1}^{M}\left[\left\{\left(\frac{dy}{dx}\right)(y)(dZ_s)\right\}_{yz}\right]_m$

Or, segmentally, $q = (QdZ_s)_{yz}$

$=(KL)\left\{\left(\frac{dy}{dx}\right)(y)(dZ_s)\right\}$ ... (27)

In the Fig. 5, the shaded area under G.W.T as shown indicates the dimensional perspective with regards to the Y-Z planar area. Now, the outcome (i.e., Outcome Y) is determined as followed for the case of the Y-Z plane wherein each outcome has tried with the similar way of formation as done in the Outcome X -

Outcome Y1 –

From Eq. (27), $(KL)\left\{\left(\frac{dy}{dx}\right)(y)(dZ_s)\right\} = q$

$(KL)(ydy)(dZ_s) = q(dx)$

Integrating both sides –

$S_{yz} = \left(\frac{KL^2}{2}\right)\frac{(b^2-a^2)}{q}$ ... (28)

Eq. (28) is the required spacing equation conforming to the Eq. (5) subject to the methodological Y-Z axial planar area.

And, applying the Eq. (4) into Eq. (28), for the wholeness of the tile-drain, like earlier,

$$\left(S_{yz}\right)_T = (KL^2)\frac{(b^2-a^2)}{q}$$

Outcome Y2 – From Eq. (27), $q = K\left\{\left(\frac{dy}{dx}\right)(dZ_s)(dA)\right\}$

Multiplying (y^2) on both sides,

$$q\frac{(dx)}{(dZ_s)} = K\{(y^{-2}dy)(y^2dA)\}$$

$q(dx) = K\{(y^{-2}dy)(y^2dA)(dZ_s)\}$ ... (29)

Integrating both sides,

$S_{yz} = \left(\frac{KL}{2q}\right)(I_{yz})\left\{\frac{(b-a)}{ab}\right\}$ ... (30)

Again, Multiplying Eq. (27) by (ydA) on both sides,

$$q(ydA) = K\left\{\left(\frac{dy}{dx}\right)(y^2dA)(dZ_s)(dZ_s)\right\}$$

$$K(y^{-2}dy)(2y^2dA)(dZ_s)(dZ_s) = 2q(dx)$$

Integrating both sides,

$S_{yz} = \left(\frac{KL}{2q}\right)(I_{yz})\left(\frac{b-a}{ab}\right)$ ...(31)

Outcome Y3 –

Multiplying Eq. (27) by (ydA) on both sides,

$$K\left\{\left(\frac{dy}{y}\right)(2y^2dA)(dZ_s)(dZ_s)\right\} = 2q(dA)(dx)$$

Integrating both side,

$S_{yz} = \left(\frac{KL^2}{2q}\right)\left(\frac{I_{yz}}{A_{yz}}\right)\left\{log_e\left(\frac{b}{a}\right)\right\}$ ...(32)

Thereby, like X-Y axis, the tile-drain spacing determined for the planar area made by the Y-Z axis is obtained & given from Eq. (27) to Eq. (32). In addition to this, incorporated equation of G.W.T's sloping length may also be found in the similar manner as discussed by Eq. (27).

Now, the continued discussion of tile-drain spacing is given for the Z-X planar area as it follows –

Estimation by Planar area of $Z - X$ planar area –

In this case of Z-X planar area, the propagation of this study should also find the spacing equation of the tile-drain in the similar way. In this case, from Table 1 the elemental area$(dA)_{zx} = Z_s dx$; &, from Fig. 6, total (contributed) area of Z-X axis only, $A_{zx} = \oint(dA)_{zx} = \oint Z_s dx$; wherein the area$(A_{zx})$ is the plan-area formed by the Z-X axis.

From Eq. (3), flow of the subjecting plane formed by the Z-X axis is given by,

$$q = \{Q(dZ_s)\}_{zx}$$

International Journal of Civil Engineering Research (IJCER)

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Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

$=(KL)\sum_{m=1}^{M}\left\{\left(\frac{dy}{dx}\right)\{(Z_s dx)\}_{zx}\right\}_m$

Or, segmentally, $q=(QdZ_s)_{zx}=K\left\{\left(\frac{dy}{dx}\right)(Z_s)(dx)(dZ_s)\right\}$

Or, $q=(KL)\left\{\left(\frac{dy}{dx}\right)(Z_s)(dx)\right\}$

The flow-equation is thereby the difference between the elemental distance of soil-element & the sectional thickness of the element in the soil-medium

$$q=K\left\{\left(\frac{dy}{dx}\right)(Z_s)(dx)(dZ_s)\right\} \quad \dots (33)$$

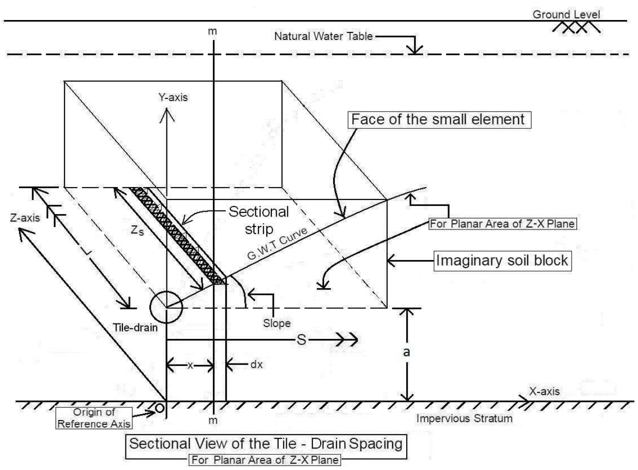

Fig.6: Tile-drain spacing for Z-X axis

Like earlier for the X-Y & Y-Z planar area, the similar way of formative equation is done for the planar area formed by the Z-X axes & is given as followed –

Outcome Z1 –

From Eq. (33), $K\left(\frac{dy}{dx}\right)(dA)=\frac{q}{(dZ_s)}=\frac{q}{L}$

Integrating both sides,

$$S_{zx}=2\left(\frac{KL}{q}\right)(b-a)(A_{zx}) \quad \dots(34)$$

Again,

Multiplying $(dA=Z_s dx)$ on both sides of Eq. (33),

$K(dy)(Z_s^2)(dZ_s)dx=q(dA)$

Integrating both sides,

$$S_{zx}=\left(\frac{6}{b-a}\right)\left(\frac{q}{K}\right)\left(\frac{A_{zx}}{L^3}\right) \quad \dots (35)$$

Outcome Z2 –

Multiplying Eq. (35) by $(Z_s{}^2)$ on both sides,

$q(Z_s{}^2)=K\left\{\left(\frac{dy}{dx}\right)(Z_s{}^2)(Z_s dx)(dZ_s)\right\}$

$q(dx)=K\{(dy)(Z_s{}^2dA)(Z_s{}^{-2}dZ_s)\}$

Integrating both sides,

$$S_{zx}=\left(\frac{2}{q}\right)\left(\frac{K}{L}\right)(I_{zx})(a-b) \quad \dots (36)$$

Again, multiplying Eq. (33) by $(2Z_s{}^2dA)$ on both sides,

$K(dy)2Z_s{}^2dA(Z_s)(dZ_s)=q(2Z_s{}^2dA)$

$K(dy)(2Z_s{}^2dA)\left(\frac{dZ_s}{Z_s}\right)=2q(dA)$

Integrating both sides,

$\left(\frac{I_{zx}}{A_{zx}}\right)=\left(\frac{1}{KL}\right)\left(\frac{q}{log_e L}\right)\left(\frac{2}{b-a}\right)$

Again,

$K(I_{zx})(b-a)(log_e L)=\frac{2q}{L}\left(\frac{SL}{2}\right)=qS$

$$S_{zx}=\left(\frac{K}{q}\right)(I_{zx})(b-a)log_e L \quad \dots (37)$$

Again, multiplying Eq. (33) by $(Z_s dx)$ on both sides,

$q(Z_s dx)=K(Z_s{}^2dx)(dy)(dZ_s)$

$K\{Z_s{}^2(dA)\}(dy)\left(\frac{dZ_s}{Z_s}\right)\left(\frac{dZ_s}{Z_s}\right)=q(dZ_s)$

Integrating both sides,

$$K(I_{zx})(b-a)\{2log_e L\}=qL \quad \dots (38)$$

Again,

Multiplying Eq. (33) by $(Z_s dA)$ on both sides,

$K(dy)(2Z_s^2dA)(dZ_s)=2q(Z_s^2dx)$

Integrating both sides,

$$S_{zx}=\left(\frac{K}{qL}\right)(a-b)(I_{zx})\left(\frac{1}{L}\right) \quad \dots (39)$$

Outcome Z3 –

Multiplying Eq. (33) by $(2Z_s dx)$ on both sides,

$q=K\left\{\left(\frac{dy}{dx}\right)(Z_s)(dx)(dZ_s)\right\}$

$q(2Z_s dx)=K\left\{\left(\frac{dy}{dx}\right)(2Z_s^2dx)(dZ_s)\right\}$

Volume 2, Issue 1 | Pages: 10-23 | *March 2021*

$$2q(dA)dx = K\left\{(dy)(2Z_s^2)(Z_s dx)\left(\frac{dZ_s}{Z_s}\right)\right\}$$

Integrating both sides,

$$S_{zx} = \left(\frac{b-a}{q}\right)\left(\frac{I_{zx}}{A_{zx}}\right) log_e L \qquad \ldots (40)$$

Thereby, the PDM, the general philosophy of the 3-dimensional methodology, has derived the several equation of tile-drain spacing till the Eq. (40), for each of the planar area. The philosophy of the Eq. (4) may also be involved into the discussion of the subjective planar area, if required of. The entire formulated equation are given in the Table 2.

This best suitable planar area for the tile-drainage spacing determination may be done on the basis of best criteria & it must vary with degree of output - this may be a field of research also. However, it's not of the goals of this study, indeed. Thereby, in summary, this study has shown the various spacing requirement of tile-drain corresponding to subjective planar-areas, individually & separately.

Brief comparison between the subsequent equations of the PDM, as described herein, may be understood with the conventional equation in order to have the difference & its related importance. In view of this, the conventional equation for the tile-drainage spacing is here given by $S = \left(\frac{4K}{q}\right)(b^2 - a^2)$ ... (41)

For information, the Eq. (41) is with the formative equation Eq. (5) as explained. The equation so determined by the PDM must have the certain degree of comparison with the Eq. (41) of conventional kind. There are different aspects of the comparative significance of this comparison with regards to each planar area; but, the relative importance lies in its correct suitable finding & needs further works.

Table 2. Tile-drain spacing

	Equation of the Tile-drain Spacing#			
	Factor of Planar-area	**Factor of Inertia**	**Factor of Planar-area & Inertia both**	**Inclusion of Sloping surface of G.W.T**
X-Y plane	$\left(\frac{2}{i}\right)\sqrt{\left(\frac{q}{KL}\right) log_e(b-a)}$ $6\left(\frac{q}{KL}\right)\left\{\frac{A_{xy}}{(b^3-a^3)}\right\}$	$2\left(\frac{KL}{q}\right)\left(\frac{I_{xy}}{b+a}\right) log_e\left(\frac{b}{a}\right)$ $\left(\frac{KL}{q}\right)(I_{xy})\left(\frac{b-a}{ab}\right)$	$\left[\frac{4q(A_{xy})}{KL\left(\frac{I_{xy}}{A_{xy}}\right) log_e\left(\frac{b}{a}\right)}\right]$	$2\sqrt{\left[\frac{(i)(Q_{xy})}{(f)(i)-\left(\frac{Q_{xy}}{A_{xy}}\right)\{1+2i\}}\right]}$ $2\sqrt{\left[\frac{1}{\left(\frac{f}{L}-2\right)-\left\{\frac{S}{2(b-a)}\right\}}\right](A_{xy})}$
Y-Z plane	$\left(\frac{KL^2}{2}\right)\frac{(b^2-a^2)}{q}$	$\left(\frac{KL}{2q}\right)(I_{yz})\left\{\frac{(b-a)}{ab}\right\}$	$\left(\frac{KL^2}{2q}\right)\left(\frac{I_{yz}}{A_{yz}}\right) log_e\left(\frac{b}{a}\right)$	Similar mathematical incorporation may be done like the X-Y plane for the Y-Z axial plane, subject to dimensional changes as applicable.
Z-X plane	$2\left(\frac{KL}{q}\right)(b-a)(A_{zx})$ $\left(\frac{6}{b-a}\right)\left(\frac{q}{K}\right)\left(\frac{A_{zx}}{L^3}\right)$	$\left(\frac{2}{q}\right)\left(\frac{K}{L}\right)(I_{zx})(a-b)$ $\left(\frac{K}{q}\right)(I_{zx})(b-a)log_e L$ $\left(\frac{K}{qL}\right)(a-b)(I_{zx})\left(\frac{1}{L}\right)$	Not found	Similar mathematical incorporation may be done like the X-Y plane for the Z-X axial plane, subject to dimensional changes as applicable.

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#considering the flow coming from one side of the Tile-drain about Y-O-Y axis.

5. RESULTS & DISCUSSION

i) Every explanation of axial derivation of the Tile-drain spacing must have the encompassing guideline as given in the assumption in this study.

ii) The three axes X, Y & Z jointly gives 3-dimensional co-ordinates for any point on the G.W.T of the soil-medium. Positioning of G.W.T or the water particle of the flow may be such made. The converse application of this study may thus be to implement a designed G.W.T of likeness apart from the naturalness of its formation, using the equations so derived in this study. In that case, usual & useful start (assumption & validation as needed) shall be the key.

iii) The basic equation of Spacing(S) is quite having a better impact of control on its subjected cross-sectional areas underneath the G.L, as well.

iv) The inertial effects of the ground water have been determined for the research interests & it becomes the most interesting outcome of this study while it is with the areal effects axially.

6. CONCLUSION & FUTURE SCOPE

i. The Spacing & Length together has formed the spatial nodes of tuning or coordinates of the entire land-drainage methodology & create the broader spectrum of field of applications of it, even by suitable variety of the G.W.T curve also.

ii. One of the future aspect of this study is making the best-plane aspect to the viability & reliable-ness. This aspect, as discussed in this study, is quite of sustainability ground & needs a matter of field of further research works in this regard, besides the 3-dimensional spacing equation.

iii. The value of 'KL' implies that the effective zonal area of pore spaces in soil-mass. It also indicates the existing or impounded acceleration of the pores giving such forces to the water particle. Thereby the inside inertial effect of water inside the soil-pores during its journey along the G.W.T curve has been established by the derived methodology. And, here lies the further research study of it. The 'active planes', as the case may be, dimensionally, should be handled with care for having lesser errors & in estimating the corrective evaluation of the Spacing.

iv. It's quite nonetheless to discuss about the dimensional unit with which the Tile-drain spacing has come out of from each equation of the spacing owing to the regards of 'q' & its formative length of the drain itself.

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No Development has ever got fulfilled unless well appreciated. The Degree of recognition depends on the acceptability of the work. Innovation leads & moulds any existing work to form the better way - the way of new outlooks for the new sunshine. This Research Study has traversed through the related fields of field-drainages with concern to water-logging. While making up the entire drainage methodology into the present form, the experiences were slowly inevitable & mesmerizing. The author would like to remind those without whom this elaborative work would have not been completed in to this present one. It's the last but not the least to keep reminiscing the lessons the Author learnt during his stay in Jalpaiguri Government Engineering College, Jalpaiguri, West Bengal, India which played a lot in making the things done in the fascinating way. It's also a desire of the author to bring out more of this work in its forthcoming publication & would oblige to hear critique/suggestion from well-wishers.

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