Jurnal Kej. Awam Jil. 10 Bil. 2 1997

STEADY STATE OPEN DRAINAGE SYSTEM FOR MINIMIZING FIRE HAZARD ON PEAT AREAS

by

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Key words: Drainage, peat, fire, water table

ABSTRACT

The principle of steady state drainage theory was employed to estimate an appropriate open drainage system on peatland. It is aimed at minimizing the occurrence of fire hazard that frequently happened on peat areas especially during the dry spell. Computation analysis shows that a certain open drainage design is required in order to keep the water table high, so that a fire could be minimized. Besides drain spacing, other physical parameters associated to peat soil are also required to materialized the theory. Depending on the size of the drains, the hydrogeological properties of the peat materials and the design drainage rate, a drain spacing between 51 to 525m would be required to accommodate the fire control on peat.

INTRODUCTION

Peat soil is a highly porous perishable material. It is formed from organic forest materials. Generally, it has a low bulk density, high porosity and low water retention capacity. Such soil properties would make this material catches fire easily when withstand under deep field water table condition. For this particular reason, in order to minimize fire hazard in the peat areas, their field water table must be kept shallow so that their porosity would be in water saturated condition. In fact, the best mean of avoiding the peat areas from burning is by letting the areas under the flooded condition all the time. Unfortunately the peatlands need to be developed substantially especially for logging and agricultural purposes. Peatland are rich in soil nutrient and found very favourable to some commercial crops likes palm oil, pineapple, coconut, tapioca, vegetables and sago. To work on peat areas, especially for commercial production, basic infrastructures such as drainage and road system are required.

A good drainage system would provide a good working environment for both man and machines. However, improper design of the drainage system on peatland would create a serious problem leading to peat fire hazard. An over-design in drainage system can expedite the drainage process but without a proper water table control it would expose to the fire problem. A good drainage design for peatland development is the one that can accommodate both drainage (a process of lowering the field water table) during the rainy season, and subirrigation (the rising of the water table) during the dry spell. Both the lowerings and rising the field water table can be implemented by means of manipulating water level in the drainage system. A system which could provide these types of field condition would be able to reduce the risk of fire in the peat areas. This paper highlights an approach using a steady state drainage theory to calculate suitable open drain spacing on peatland for the purpose of minimizing fire risk.

STEADY STATE DRAINAGE EQUATION

The steady drainage formula for homogeneous soil profile or the Hooghoudt parallel open drain spacing may be written as (Smedema and Rycroft, 1983):

$$L^2 = [\,4\,K\,h\,(2d + h)]/q \qquad (1)$$

for drains or ditches located above an impervious layer, and

$$L^2 = [\,4\,K\,h^2]/q \qquad (2)$$

for drains or ditches reaching an impervious layer, where,

L = drain spacing (m)
K = saturated hydraulic conductivity of soil (m/d)
H = desired hydraulic head midway between drains (m)
d = effective or equivalent depth of flow above impermeable layer (m)
q = design drainage rate (m/d)

The individual terms in Equation 1 and 2 can be measured or obtained from published reports except for the effective depth of flow, d, which can be estimated as,

$$d = D/[\,(8D/\pi L)\ln(D/u) + 1] \qquad (3)$$

for $D > 0.25\,L$ or

$$d = \pi L/[8\ln(L/u)] \qquad (4)$$

for $D < 0.25\,L$

where

D = depth to impermeable layer (m)
L = drain spacing (m)
u = wetted perimeter of drain (m)
ln = $\log_e 10$

DESIGN PROCEDURES

Design parameter

The parameter required (as shown in Figure 1) in the drain computation process for peatland are the hydraulic head midway between drains, h, the hydraulic conductivity of soil, K, the depth to impermeable layer, D, the design drainage rate, q, the permissible water table depth, H and the drain depth, dd.

Design steps

The following steps are employed to compute the drain spacing using steady state equation.

a. Formulation of q and H

The estimation of q is laborious and it involves the measurement of the water balance parameters such as rate of leaching, deep percolation and seepage. Under steady state condition, however, q can be assumed to be equalled to that of rainfall intensity of the area (Skaggs 1987). During the dry season where the probability of rainfall is minimum the fire hazards on peat areas are expected to be at high potential. Under such situation, the drainage outflow must be kept minimum to accommodate a minimum water table lowering rate. The permissible field water table depth, H, is the designed depths of water level in the field that are permitted for a specific objective of field operation. For example, for mechanical operation purposes on peat areas an H value of at least 0.6m would be required (Ooi 1992).

b. Setting up a drain depth, dd

It is typical for open drain's depth on peatland be kept minimum, normally less that 2 m. A drain depth of 1.5m is quite common for a collector or secondary drain. A deeper drain depth is not advisable as this will increase the cost the maintenance. A newly contructed open drain on peat would require frequent maintenance works because the tendency of the side drain to collape is high. Peat is a very soft soil with a small value in cohesion and angle of friction.

c. Establishment of K, and D

The hydraulic conductivity of peat soil is one and the most important design parameter in determining a suitable open drain design. Field measurement conducted by several researchers found that under the saturated soil condition, the K value of the Malaysian peats were in the order of 10^{-3} cm/s . For example Ayob and Mutalib (1997) found that the K value of some some Malaysian peat were in the range of $0.55x10^{-3}$ to 6.32x10-3 cm/s or 0.47 to 5.46 m/day depending on the development stage of the material. The K value of peat however is specifically located in the sense that the formation of peat swamp is strongly influenced by the hydro-geological characteristic of that particular areas. Its value can easily be measured using field method either auger hole method, piezometer method, drain outflow method or infiltrometer method (Smedema and Rycroft, 1983).

The value of D is the height from the drain base to the impermeable layer. On peat land the location of the impermeable layer can be assumed to be the subsoil layer of the soil profile. The depth of Malaysian peat can generally be classified as shallow (50-100cm), moderate deep peat (150-300cm) and deep peat (>300 cm).

d. Determination u

For drains located above an impervious layer, the drain wetted perimeter, u , is depended upon the flow condition of the drain. Its value can be computed after having mesured the geometry of the drains. There can be two different values of u for the same size of drain. A bigger value in u is obtainable during the full flow while the least value in u would be obtained during least flow in the drain. Again during the dry season, where a fire harzard potential is high, the drain flow is expected to be minimum, thus the value of u.

e. Determination of L

After having set or known all the geometrical dimensions of the drain, the determination of drain spacing, L, can be done easily. For shallow to moderate deep peat, i.e. peat depth of less than 1.5m, equation 2 can be used. In this case the drains are supposed to reach the subsoil layer. In the case where the peat depth is more that 1.5m , the combination of equations 1, 3 and 4 are applied. Solving L for the later case would be very tediuos trial-and-error process. The use of computer spreadsheet such microsoft excel, lotus or quattro would greatly simplify the job.

EXAMPLE OF DRAIN SPACING COMPUTATION

An example of an open drain spacing computation using steady state principle was carried out for a rainfall condition recorded in Batu Pahat, Johor, for 1995. Batu Pahat was chosen as this station is located in one of the major peat areas in Malaysia. A moving average analysis of the daily rainfall for 10, 15, 20, 25 and 30 days enabled us to determine the minimum possible rainfall intensity of that particular time span. The result of the moving daily analysis is summarized in **Table 1** and was used in this example.

Using a selected K peat value, a suitable drain spacing can be computed for different design drainage outflow rate. **Table 2** presents the results of the 1.5m depth drain spacing computation for both shallow and deep peats, for various value of H, h, and q. Considering different values in q and H, a drain spacing of 51-360m would be required for shallow peat and 125-525m for deep peat depending on the designed drainage rate. Results also showed that with the same value of designed q, the drain spacing, L, decreased as the value of permissible water table depth, H, increased. A higher designed drainage rate would require a closer drain spacing as a larger volume of drainage water can be expected. A bigger value in H would result in a larger peat layer that would be located above the water table line. Under such situation the dry peat profile would increase and it would definitely expose to more fire hazard.

CONCLUSION

Minimizing the fire hazard of a highly porous perishable soil like peat would be done through manipulating open drainage system in that particular area. It is a fact that the occurrence of fire hazard on peat is generally due to a very dry soil condition with deep water table. In order to minimize these problems the soil must be kept moist with a shallow water table. A proper water level control in the drain would provide a suitable depth of water table in the field. A steady state drainage principle is one of the approaches to provide these requirements. Although drainage process is not a steady-state in most cases, a good approximation of drain spacing can be estimated from a proper technical design including the hydrological factor of the area.

ACKNOWLEDGEMENT

A special thank is given to Dato'Prof.Ir.Dr.Mohd Noor Hj Salleh for his constructive comments during the preparation of this paper.

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Table 1: Summary of the daily moving average minimum rainfall for Batu Pahat

Rainfall Station: Batu Pahat, Johore
Located at 1° 03 ′ N, 103 ° 05′ E, 6.3m M.S.L.
Year : 1995

Moving average analysis (day)	10	15	20	25	30
Minimum rainfall intensity (m/d)	0.00033	0.00060	0.00114	0.00117	0.00207

Table 2 : An example of computed drain spacing for different peat depth

Drain depth = 1.5m
Depth to impermeable layer, D< 0.25L
Saturated K = 5.46 m/d

A. Shallow peat < 150cm

Design q (m/day)	Drain spacing, L(m) at various H and h									
	H(m) 0.1 h (m) 1.4	0.2 1.3	0.3 1.2	0.4 1.1	0.5 1.0	0.6 0.9	0.7 0.8	0.8 0.7	0.9 0.6	1.0 0.5
0.00033	360	334	308	283	257	232	205	180	154	129
0.00061	265	246	228	209	190	171	152	133	114	95
0.00114	194	180	166	152	138	125	111	97	83	69
0.00117	191	178	164	150	137	123	109	96	82	68
0.00207	144	134	123	113	103	92	82	72	62	51

B. Deep peat > 150cm

Design q (m/day)	Drain spacing, L(m) at various H and h									
	H(m) 0.1 h (m) 1.4	0.2 1.3	0.3 1.2	0.4 1.1	0.5 1.0	0.6 0.9	0.7 0.8	0.8 0.7	0.9 0.6	1.0 0.5
0.00033	525	520	512	505	497	491	484	476	470	461
0.00061	366	360	352	346	338	330	322	314	305	296
0.00114	244	240	234	227	221	216	210	202	196	189
0.00117	240	235	181	223	217	212	206	200	192	185
0.00207	168	163	160	155	151	146	141	136	131	125

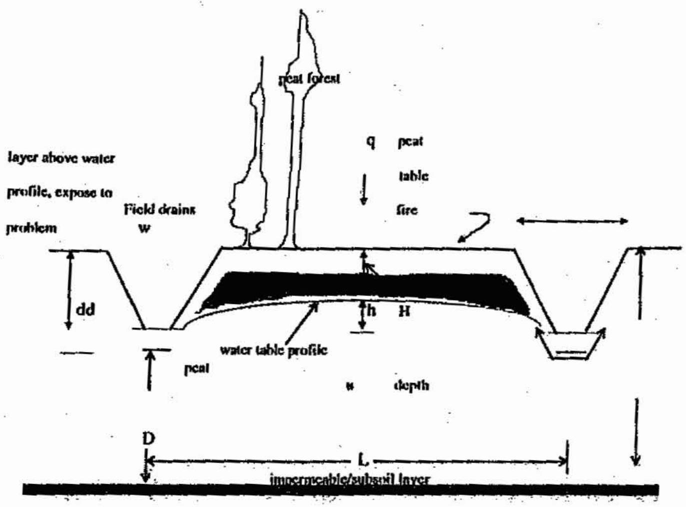

Figure 1 : Cross-section of field drains under steady state condition showing layer the peat that would potentially expose to fire hazard

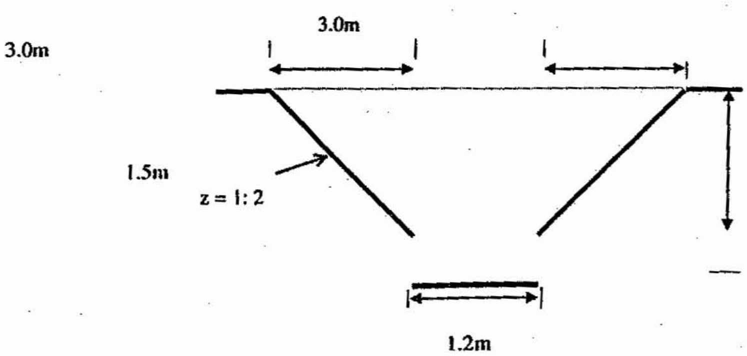

Figure 2 : Typical cross-section of a collector drain on peat