EWCE 341: Seepage Analysis

What learned in the last class?

- What is seepage?
- Importance of Seepage Flow
- Flow line, Equipotential line, Flow net, Flow channel
- Study from the flow net
- Basic Flow net construction –Vertical Flow

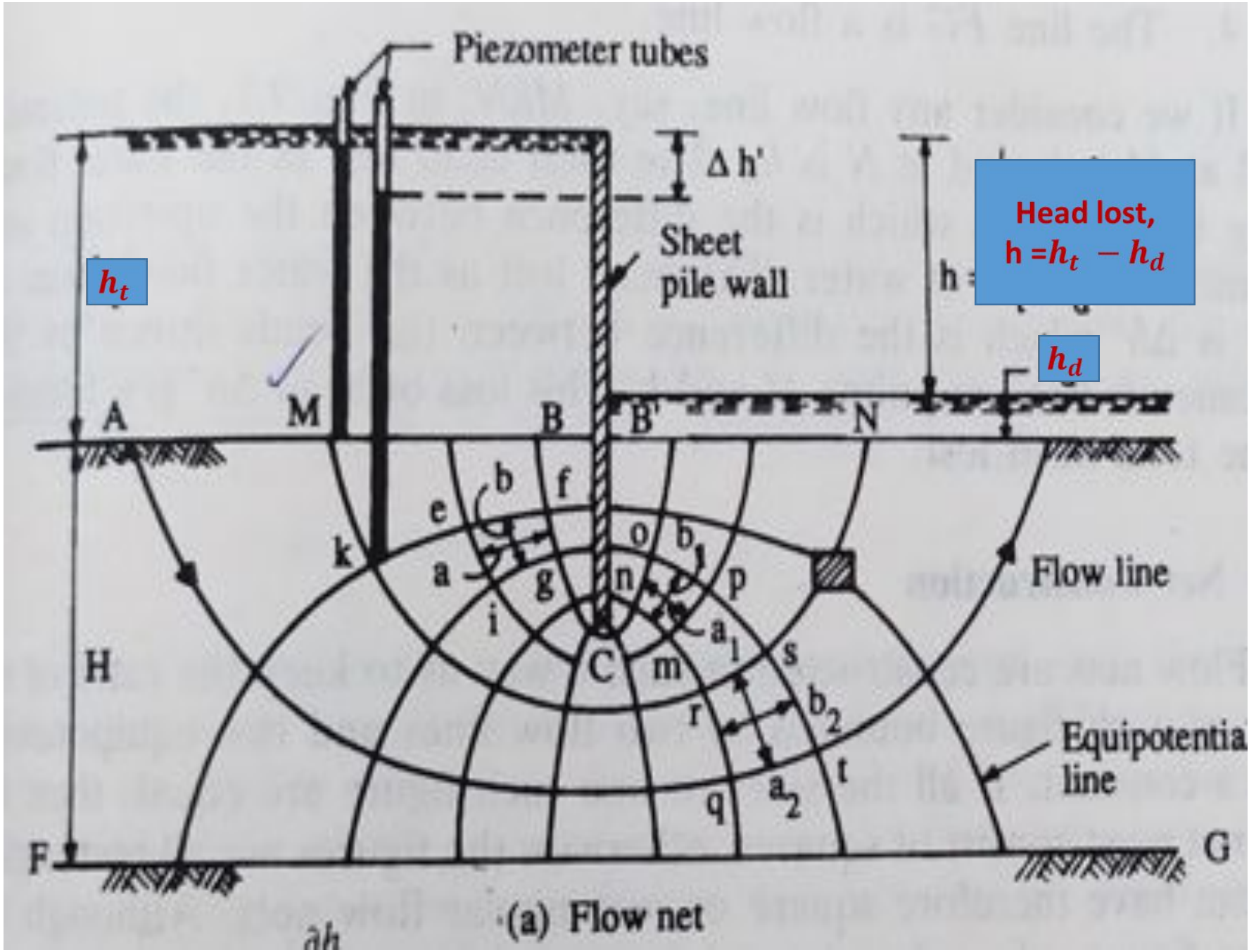
What we are going to learn today:

- **Boundary conditions.**
- **Elements to Construct Flow Net.**
- **Methods for the construction of flow nets**

Example of a Flow net for the flow below a sheet pile.

Figure: A typical example of a Flow net for the flow below a sheet pile.

- Head of water on the up-stream side of the sheet pile is h_t.
- Head on the downstream side is h_d.
- **Head lost** as water flows from up steam to down stream Side is h.









Boundary conditions: Consists of statements of head or flow conditions at all boundary points.

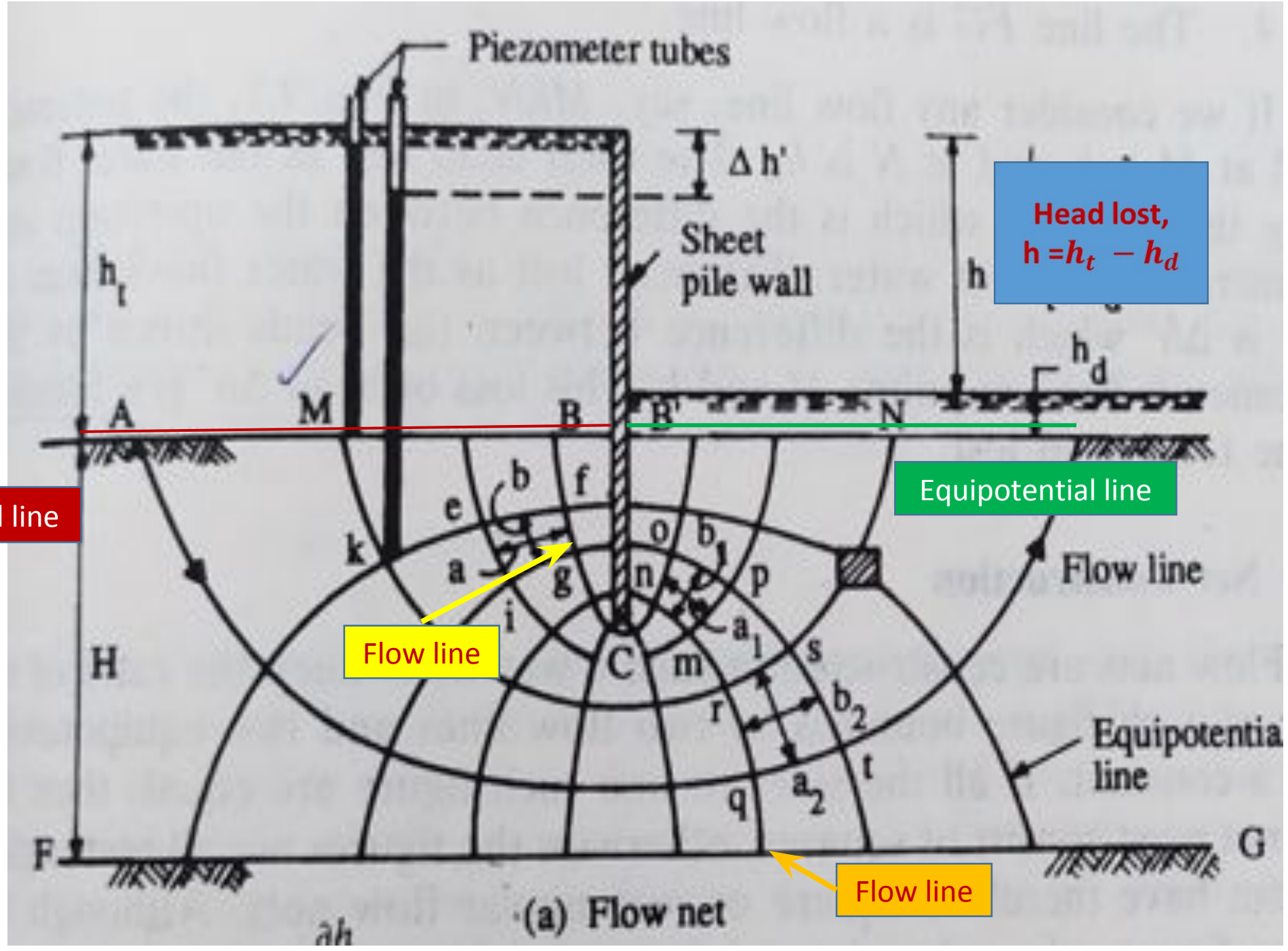
- Assume that the **flow is two dimensional**, ie. all flow lines are parallel to the plane of the figure.
- All flows are in the **steady state case**.

Steady-state flow:

- Refers to the condition where the **fluid properties** at any single point in the system **do not change over time**.
- Fluid properties include **temperature, pressure, and velocity**.
- One of the most significant properties that **system mass flow rate is constant.**

Figure: A typical example of a Flow net for the flow below a sheet pile.

- Head of water on the up-stream side of the sheet pile is h_t.
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Boundary Conditions- Generally in four in number:

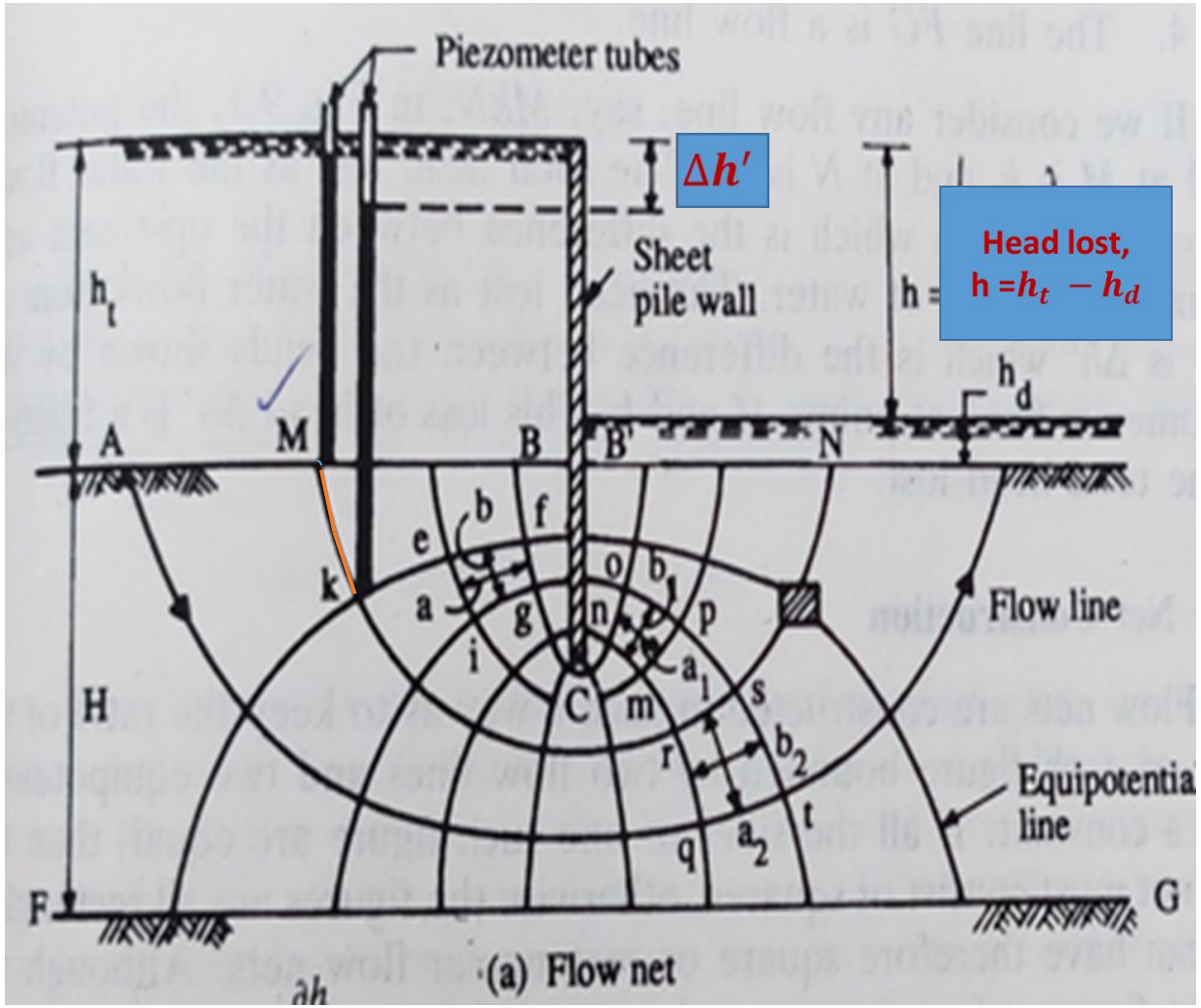
- Line **AB is an equipotential line** along which the **head is h_t**.
- **Line BCB'** along the sheet pile wall is a **flow line**.
- Line **B'N is an equipotential** line along which the head is equal to h_d.
- Line **FG is a flow line**.

Elements to Construct Flow Net:

Head Lost:

- If we consider any **flow line** **say**, MkN, **potential head** at M is h_t and at N is h_d.
- **Total head lost** as water flows from M to N is h= h_t - h_d.

- **Head lost** as water flows from **M to k** is $\Delta h'$, difference between head shown by piezometers fixed at points at **M and k.**
- **Loss of head $\Delta h'$** is a **fraction of the total head lost.**



Ratio of Sides of Flow Elements/Fields:

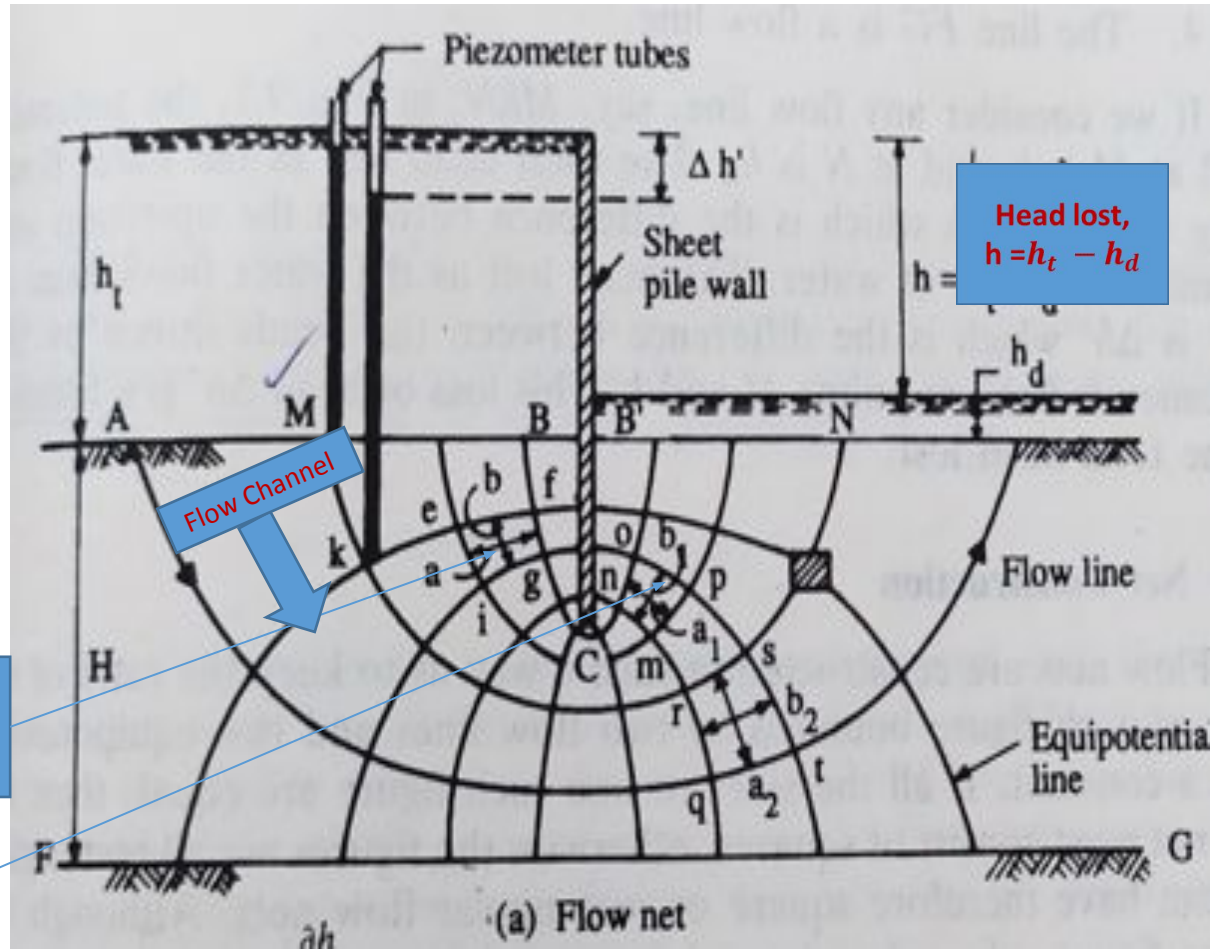
- Flow nets are constructed in such a way as to keep the **ratio of sides of each figure** bounded by two flow lines and two equipotential lines, **a constant ie.** ($\frac{a}{b}$=constant).

- If all the **sides of one such figure/field are equal**, then the flow net must consist of **square**, otherwise **rectangles**.

- **Average width of the square are equal**

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- In the figure, width 'a' of **efgi** is equal to its length 'b'.



Flow element: efgi

Flow Element: nopm

Flow channel:

- **Area bounded by any two neighboring flow lines** is called as a flow channel.

If the flow net is constructed, in such a way that **ration a/b remains the same** for all figures/flow elements/fields, then it can be shown that there is the **same quantity of seepage** in each flow channel.

- Consider two figures/flow element/field, ***efgi* and *nopm* in one flow channel**.
- Figure ***rstq* is chosen** in such a way that it lines within the **same equipotential line** that bound the figure ***nopm***.

- Darcy's law for the **discharge through** any Flow element/fields/figure such as **efgi per unit length of the section** may be written as,

  $\Delta q = kiA = k\frac{\Delta h}{b}a = k\Delta h\ \frac{a}{b}$, where, Δh=head loss in crossing the Flow Element/Field, **efgi** .

- For three Flow Element/Fields, expression in this form are:

$$\Delta q = k \Delta h \frac{a}{b}, \qquad \Delta q_1 = k \Delta h_1 \frac{a_1}{b_1}, \Delta q_2 = k \Delta h_2 \frac{a_2}{b_2}$$

- Value of **k remains same** for all three figures. If the Flow Elements/Fields are **all squares** then,

$$\frac{a}{b} = \frac{a_1}{b_1} = \frac{a_2}{b_2} = 1$$

- Since the Flow Element/Fields **efgi and nopm are in the same flow channel**, then $\Delta q = \Delta q_1$
- Since **nopm and rstq** are **within the same equipotential lines**, then, $\Delta h_1 = \Delta h_2$
- We get the following relationship, $\Delta q = \Delta q_2$ and $\Delta h = \Delta h_2$.

Here **proves** that the **same quantity flows** through each Flow Element/Field and there is **same head drop/lost** in crossing each Flow Element/Fields, **if all the Flow Elements/Fields are squares or posses the same ratio a/b.** (Question)

- Flow nets can be rectangular or square. But square flow nets are generally used in practice since this is easier to construct.

Methods for the construction of flow nets: Important methods,

- Analytical method
- Electrical analog method
- Scaled modeled method
- **Graphical method**.

Graphical method:

Most commonly used method.

- **Boundary conditions** to be identified and established.
- **Reasonably good flow net** can be drawn even **by a novice but require practice**.
- Accuracy of **hydraulic quantities** such as discharge, pore water pressure does **not depend on the exactness of flow net.**

Following Points should be kept in mind while sketching the flow net:

- **Many flow channels** distract the attention from the essential features. **Normally three to four channels are sufficient.**
- Appearance **of entire flow net to be watched** and not that part of it. Small details can be adjusted after the entire flow net has been roughly drawn.
- **Curve** should be roughly **elliptical or parabolic** in shape.
- **All transitions** should be **smooth**.
- Flow lines and equipotential lines **should be orthogonal** and **form approximate squares.**
- **Size of the squares** in a **flow channel should be changed** gradually from upstream to the down stream.

Procedures for drawing the flow net:

Step-1:

- Identify the hydraulic **boundary condition**:

-Upstream bed level GDAK represent 100% **potential line** and down stream bed level CFJ, 0% **potential line**.

-First **flow line KLM**, hugs the hydraulic structures and KLM is formed by the flow of water on the upstream of the sheet pile, the downstream sheet pile and at the interface of the base of the dam and soil surface.

-Last **flow line** is indicated by the impervious stratum NP.

Step-2:

- Draw a **trial flow line ABC**, adjacent the boundary line. Line must be at right angles to the upstream and down stream beds.

Location of first trial line is **determined from experience**

Step-3:

- **Starting from the up stream end**, **divide the first flow channel** into approximate squares **by the equipotential lines**. **Size of the square should change gradually**.
- Some of the squares may be quite irregular. Such squares are called singular squares.

Step-4:

- **Extend downward the equipotential lines** forming the sides of the squares. These extensions, point out approximates **width of the squares**, such as squares marked (1) and (2).
- **Other sides of the square are set equal to the widths** as determined above.
- Irregularities are smoothened out and **next flow line DF** is drawn joining these bases. While sketching the flow line, care should be taken to make flow fields as approximate squares through out.

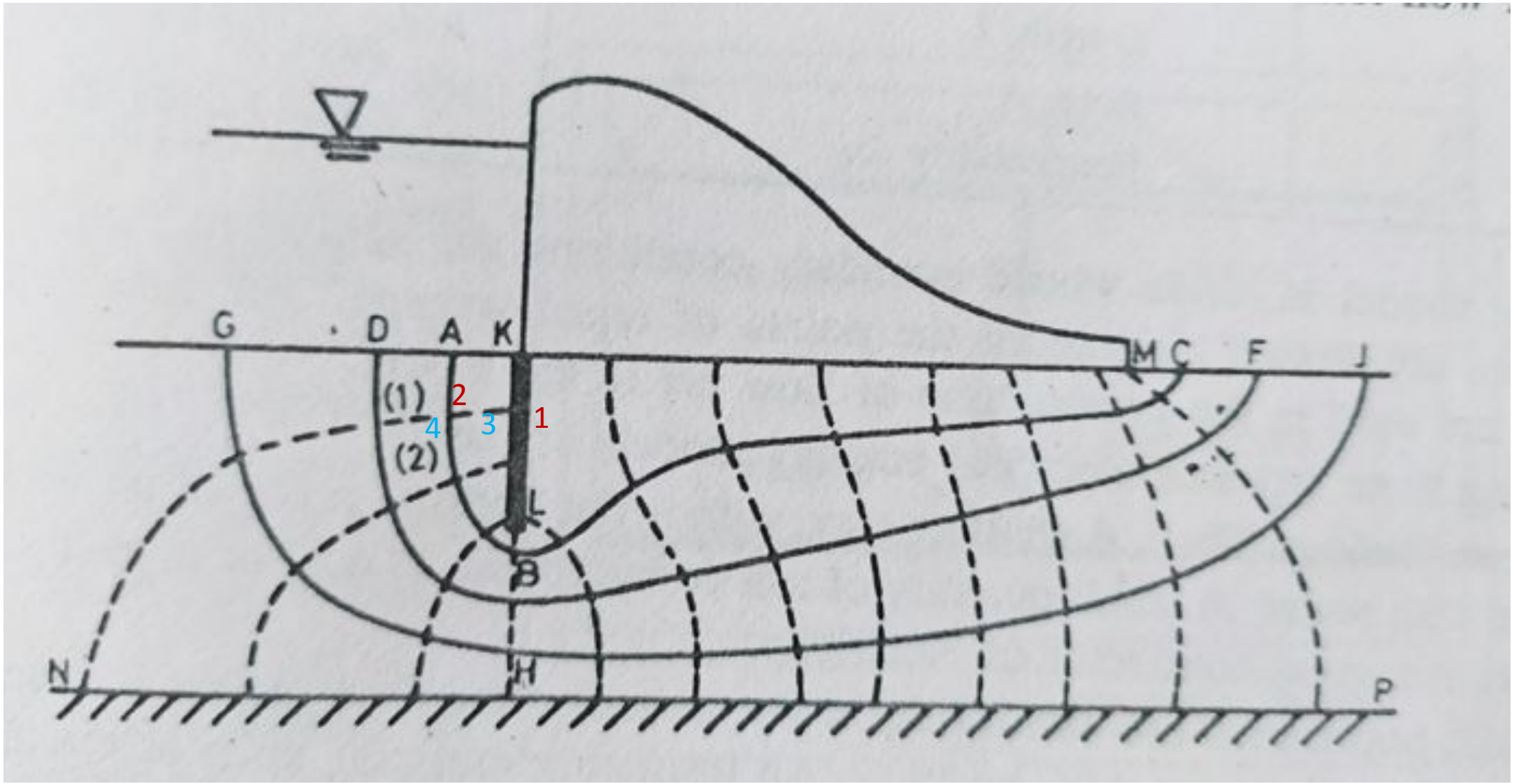
Step-5:

- **Equipotential lines are further extended downward**, and one more **flow line GHJ is drawn**, repeating steps 4.

Step-6:

- If the **flow fields in the last flow ch**annel are **inconsistent** with **actual boundary** conditions, the whole procedure is repeated after taking a new trial flow line.

It is **not necessary** **that the flow elements/fields** of the last flow channel should make complete squares. Flow elements/fields in the last flow channel may be approximately rectangles with the **same length to width ratio**. In this case number of flow channels would not be full integer. Flow channels will be an integer only by chance.



Flow net construction by graphical method

Draw a flow net for a single row sheet pile driven in to a permeable soil as shown in the figure, given following data:

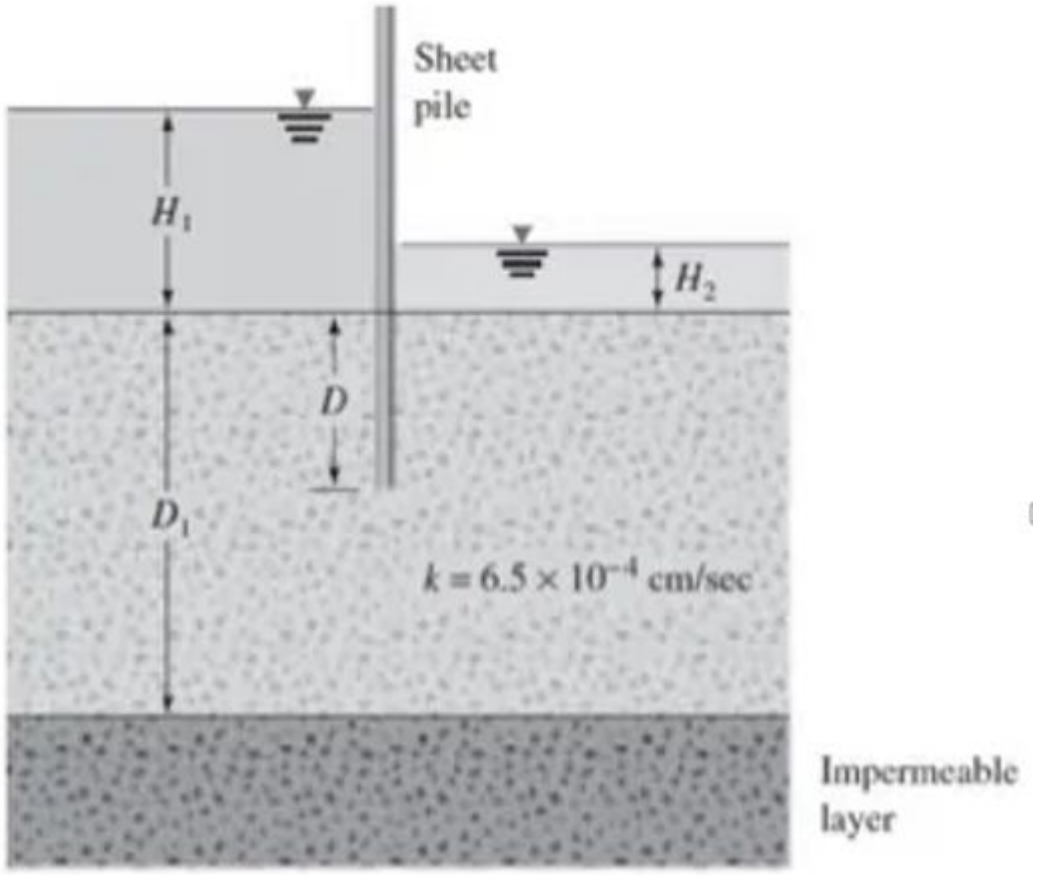
H_1=5.o m

H_2=0.4 m

D_1=10.0 m

D=4.0 m

Also calculate the seepage loss per meter length of sheet pile (at right angle to the cross section).



Total Head loss

H= $H_1 - H_2$=5.o m−0.4 m= 4.6 m

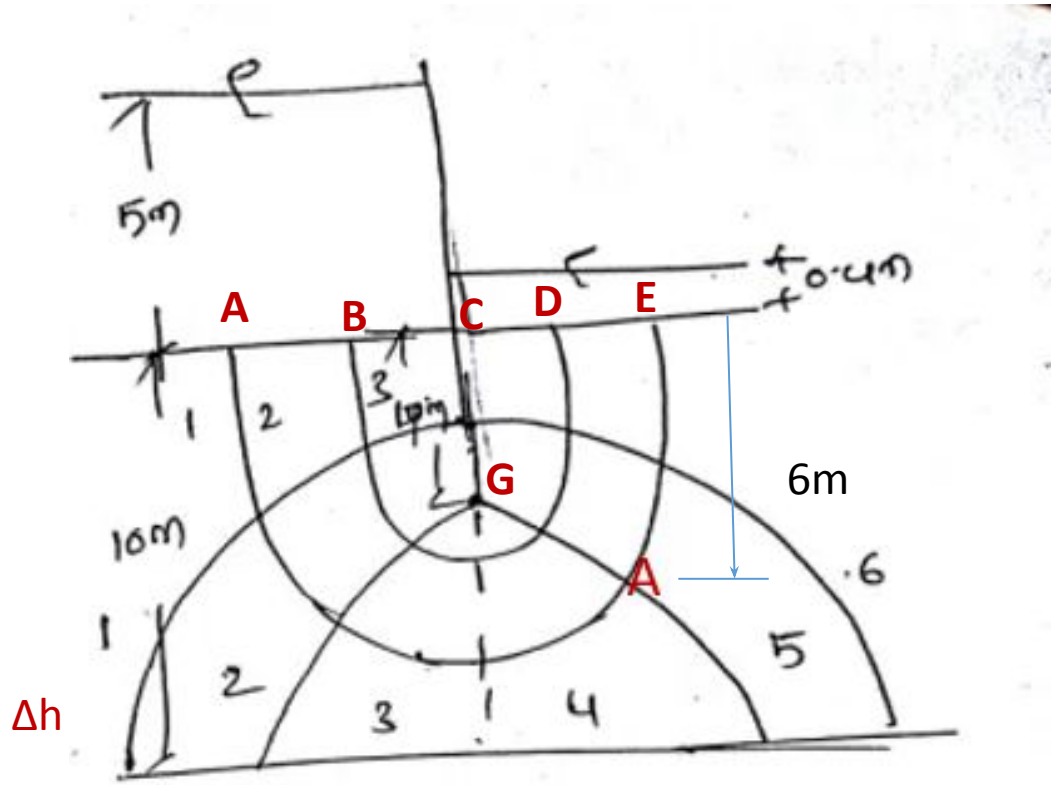
Number of flow Channel, N_f=3

Number of Equipotential drop, N_d=6

Potential drop between two adjacent potential line, $\Delta h = \frac{H_1}{N_d} = \frac{5}{6}$ = **0.833m**

Square flow element, $\frac{b}{a}$=1

K= 6.5x 10^{-4}cm/sec = 6.5x 10^{-6} m/sec



Seepage loss, $\mathbf{q = k \frac{H}{N_d} N_f \frac{b}{a}}$ = k Δh N_f

q = 6.5x 10^{-6}x 0.833 x3 x1=16.24 x 10^{-6} m^3/sec/m =14.03 m^3/day/m

Pore Water Pressure at Pont A

u_A= ?

Need to know the water head at point A

Water coming from upstream, how many potential drop to reach at A

Experiencing number of potential drop N_d= 4

Each time you cross a equipotential line total head loss Is equal to Δh

At point A water experiencing $4\Delta h$ (from u/s)

Total Head at A, h_A= Initial Head at u/s –Head Loss = H_1 - 4Δh =5.0 -4x0.767= 1.93m
(w.r.t above GS, GS as our datum)

Now the elevation head, z_A= directly from the graph = - 6.0 m (negative)

Pressure at A, $u_A = \gamma_w$ x (h_a - z_a) = 9.81x(1.93 – (-6))= 9.81x7.93=77.79 kN/m^2

Thank You

