Movement of Water in Rocks

Capillarity: Height of water rise as a function of time

Capillary action (sometimes capillarity or capillary motion) is the ability of a liquid to flow in narrow spaces without the assistance of, and in opposition to, external forces like gravity. It occurs because of intermolecular forces between the liquid and surrounding solid surfaces. If the diameter of the pore is sufficiently small, then the combination of surface tension (which is caused by cohesion within the liquid) and adhesive forces between the liquid and container act to lift the liquid. In short, the capillary action is due to the pressure of cohesion and adhesion which cause the liquid to work against gravity.

Examples on capillarity are:

- Capillary action is essential for the drainage of constantly produced tear fluid from the eye.
- Paper towels absorb liquid through capillary action, allowing a fluid to be transferred from a surface to the towel.
- The small pores of a sponge act as small capillaries, causing it to absorb a comparatively large amount of fluid. Some textile fabrics are said to use capillary action to "wick" sweat away from the skin.
- Capillary action draws ink to the tips of fountain pen nibs from a reservoir or cartridge inside the pen.
- With some pairs of materials, such as mercury and glass, the intermolecular forces within the liquid exceed those between the solid and the liquid, so a convex meniscus forms and capillary action works in reverse.
- In hydrology, capillary action describes the attraction of water molecules to soil particles. Capillary action is responsible for moving groundwater from wet areas of the soil to dry areas.

It is necessary to recognize the pores' structure of rock to determine its suitability for use as building stone. Porous rocks (such as thermostone and chalk) are suitable for use in heat and sound insulation, whereas non-porous rocks (such as marble, granite and hard limestone) are suitable for use in flooring and exterior applications. It is necessary to choose compact and solid rocks (non- porous types that do not allow water to rise by capillarity) for the exterior parts of building and also for the parts that are in direct contact with soil.

Capillarity of rock can be measured by calculating its capillary coefficient (C) which is measured by preparing cubic sample with dimensions of (7 cm x 7 cm x 7 cm) as shown in the following procedure:

1. Collecting the rock sample from the field and making a cube with dimensions of (7 cm x 7 cm x 7 cm).

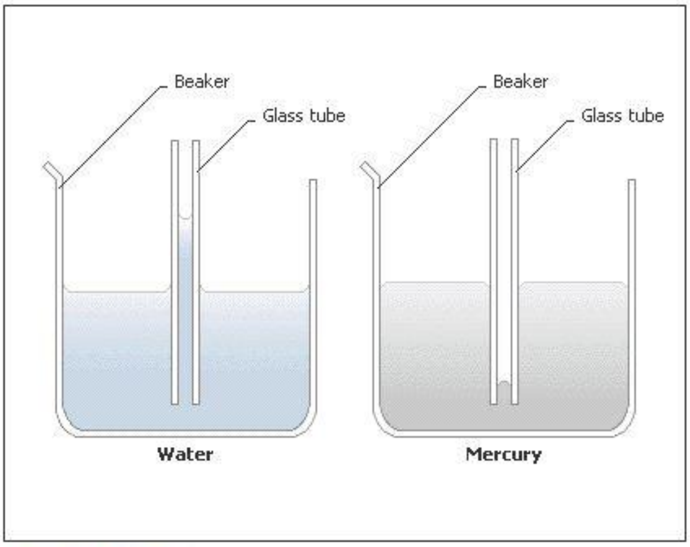
2. Drying the cubic sample in an oven at a temperature of (105 C^0) for 24 hours until the weight of the cube gets fixed.

3. Placing the cubic sample to the height of (2 mm) in a beaker filled with water, and maintaining the water level in the beaker to the same height by adding water to the beaker when decreases every time.

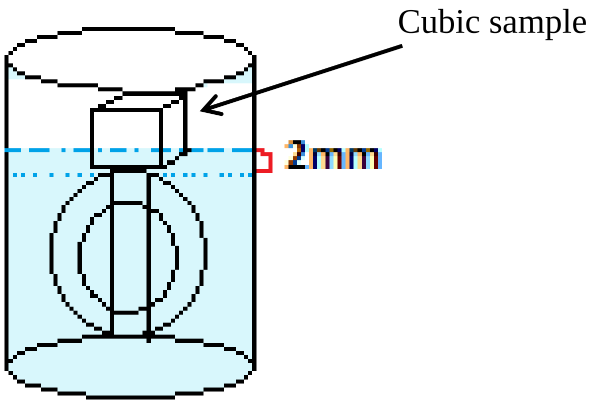
Note: the cubic sample must be placed in water horizontally and parallel to the bedding plane as water is absorbed perpendicular to the bedding plane.

4. Recording the difference in the weight of the cubic sample at different time intervals (1, 4, 9, 16, 25, 36, 49, 64…) minutes. The weight of the sample must be measured immediately after taking it out of the beaker.

In this method, beaker and stopwatch are needed and the stopwatch is stopped after certain period of time in order to measure the new weight of the cubic sample. After that, the sample is returned to the beaker, running the timer and stopping it after another period of time, measuring the new weight and so on. Time is added cumulatively after measuring the new weight of the cubic sample and returning it to the beaker.



Capillary Action



Water rises when the surface tension force overcomes the water column weight (gravity) in the pore's throat. When the two forces become equal, water rising stops at a certain height (at the level when the surface tension force and the weight of water in the pores become equal).

Capillary coefficient of rocks gives indication about their porosities. In general, the more porous the rock, the more water rises (i.e. higher capillary coefficient). However, **highly porous rocks are not always having high capillarity** as this property depends essentially on diameter of pores. The smaller the diameter of pores, the higher the water will rise. Rocks with large pores have low capillarity coefficient because the amount of water (i.e. the weight of water column) is greater than the surface tension force, so water will not rise. Capillarity Coefficient values range from zero (in non-porous rocks) to 50 $gm/cm^2 . Min^{-1/2}$ (in highly porous rocks).

Diameter of pores has a big influence on the behavior of rock when it is used for building (i.e. subjected to different weathering factors). Rocks with large pores resist frosting and, thus, can be used in the parts that are exposed to atmospheric conditions.

Problem: The table below shows the results of the capillary attraction tests of six cubic limestone samples (A, B, C, D, E and F) with dimensions of (7cm x 7cm x 7cm):

Sample No.	Dry Weight (gm)	Wet weight (gm) at Time							
		1 min.	4 min.	9 min.	16 min.	25 min.	36 min.	49 min.	64 min.
A	857.50	857.50	858.06	858.62	859.13	859.74	860.30	860.86	861.42
B	823.20	826.63	827.89	829.15	830.41	831.67	832.93	834.19	835.45
C	788.90	793.31	797.72	802.13	806.54	810.95	815.36	819.77	824.18
D	754.60	762.93	770.14	777.35	784.56	791.77	798.98	806.19	813.40
E	720.30	738.92	752.36	765.80	779.24	792.68	806.12	819.56	833.0
F	686.0	718.34	740.32	762.30	784.28	806.26	828.24	850.22	872.20

Required:

Q1): Calculate the capillary coefficient for each of these samples whose grain cohesion increases from the sample (F) to the sample (A).

Q2): Give the reason for the variation of capillary coefficient values of these samples.

Q3): Show the possibility of use of these rocks as building stones.

Solution:

Capillary coefficient of rocks is calculated as follows:

$$C = \frac{100 * \Delta M}{S\sqrt{t}}$$

Where;

C = Capillary Coefficient ($gm/cm^2 . min^{-1/2}$)

ΔM = Mass of water absorbed (gm) = difference in weight between wet and dry sample (new weight – dry weight)

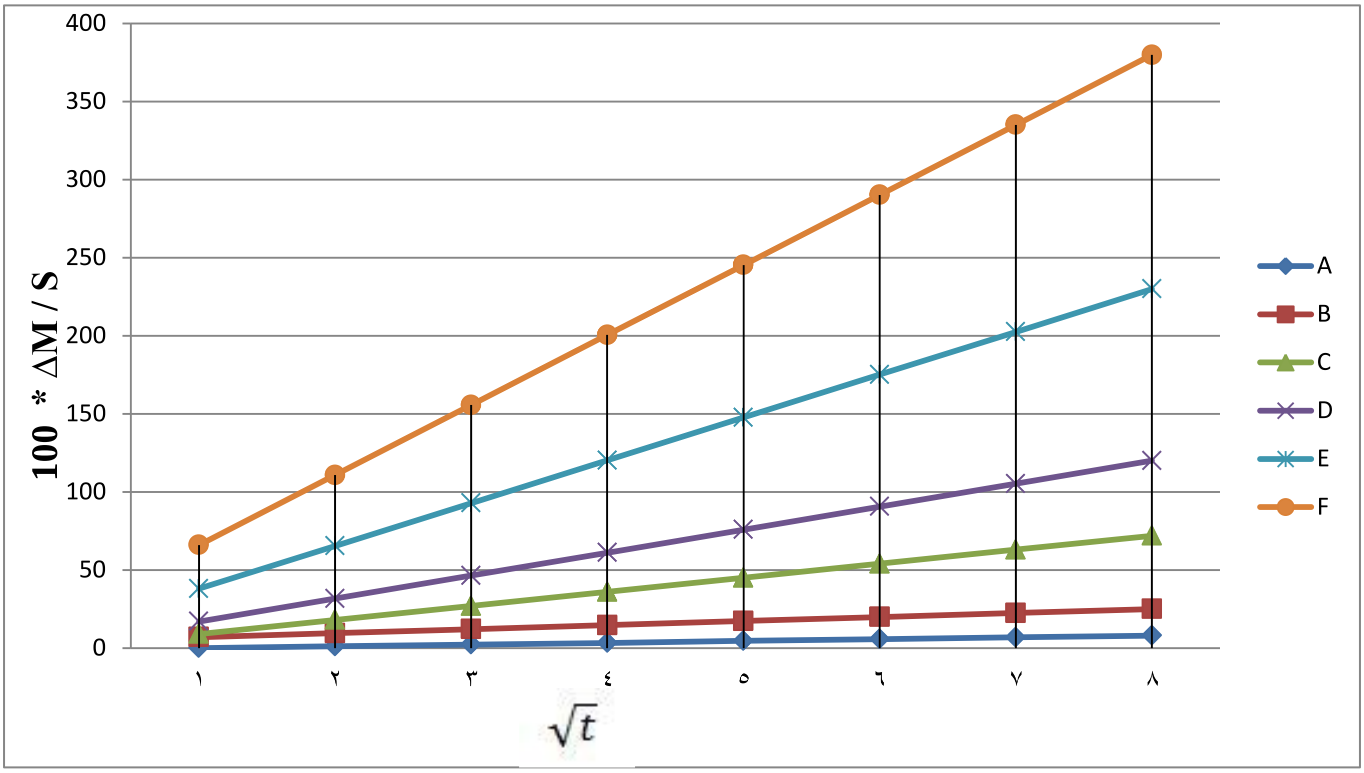
S = Section area of water absorbed (cm^2) = 7 cm x 7cm = 49 cm^2

t = time (in minutes)

$100/S^2$ = 100/49 = 2.04

Capillary coefficient of the sample is represented by the slope in the diagram.

	100 *ΔM/S					
$\sqrt{t}$	**A**	**B**	**C**	**D**	**E**	**F**
1	0.0	6.9972	8.9964	16.9932	37.9848	65.9736
2	1.1424	9.5676	17.9928	31.7016	65.4024	110.813
3	2.2848	12.138	26.9892	46.41	92.82	155.652
4	3.3252	14.7084	35.9856	61.1184	120.238	200.491
5	4.5696	17.2788	44.982	75.8268	147.655	245.33
6	5.712	19.8492	53.9784	90.5352	175.073	290.17
7	6.8544	22.4196	62.9748	105.244	202.49	335.009
8	7.9968	24.99	71.9712	119.952	229.908	379.848



$C_A = 1.78$ gm/ cm^2. min $^{-1/2}$

$C_B = 3.41$ gm/ cm^2. min $^{-1/2}$

$C_C = 8.89$ gm/ cm^2. min $^{-1/2}$

$C_D = 14.58$ gm/ cm^2. min $^{-1/2}$

$C_E = 31.25$ gm/ cm^2. min $^{-1/2}$

$C_F = 45.45$ gm/ cm^2. min $^{-1/2}$

From the results obtained and the diagram, it is concluded that the sample (A) has a very low capillary coefficient. This means that this sample is solid, compact and non-porous or may contain unconnected pores. Such type of rocks can be used as building stone in the parts that are in direct contact with soil and water, such as walkways, flooring, foundation and exterior applications. On the contrary, the sample (F) has a very high capillary coefficient, which means that this sample contains narrow and connected pores. This makes the rock not suitable for use in the parts of building that are in direct contact with water and soil because of the high possibility of water to rise through the narrow pores of this rock. The other samples (B, C, D and E) have different capillary coefficients depending on the pores diameter which reflects the variation of the rock type and depositional texture (pore shape and size). So, it is concluded that the grain cohesion of these rocks increases towards the sample (A).

ان معرفة تركيب الفجوات ضروري لاختيار الأحجار المناسبة للبناء ، إذ أن الصخور المسامية تكون مناسبة للعزل الحراري وبعيداً عن الماء مثل الثرمستون والحجر الطباشيري، أما في الرصف الخارجي والارضيات والذي تكون فيه الصخور بتماس مباشر مع التربة فمن الضروري اختيار صخور صلبة متماسكة (compact) لهذا الغرض بحيث لا تسمح للماء بالصعود إلى الأعلى بالخاصية الشعرية (capillarity) مثل الحجر الجيري الصلب والمرمر والكرانيت. وتضعف مقاومة الصخرة بزيادة الخاصية الشعرية لها.

وبالإمكان معرفة الخاصية الشعرية من خلال حساب معامل الشعرية الذي يتم قياسه من خلال عمل مكعبات للنموذج بأبعاد (٧سم × سم٧ × ٧ سم) وتكون طريقة العمل كالآتي:

١. نمذجة الصخرة وعمل مكعب بأبعاد (٧سم × سم٧ × ٧ سم).
٢. تجفيف النموذج في فرن بدرجة حرارة (١٠٥ م^0) لمدة ٢٤ ساعة إلى أن يثبت وزنه.
٣. غمر النموذج بالماء داخل دورق زجاجي beaker إلى حد ارتفاع (٢ ملم) من قاعدة النموذج مع الحفاظ على مستوى الماء على هذا الارتفاع ، أي يتم إضافة ماء عند النقصان في كل مرة بحيث يبقى النموذج مغموراً بالماء بعمق (٢ ملم).

<u>ملاحظة:</u> يجب وضع النموذج داخل البيكر بحيث يكون مستوي التطبق أفقياً لأن الماء يتم امتصاصه بصورة عمودية على مستوي التطبق.

٤. قياس وزن النموذج بعد فترات زمنية (١، ٤، ٩، ١٦، ٢٥، ٣٦، ٤٩، ٦٤ ...) دقيقة، ويكون قياس وزن النموذج مباشرةً بعد اخراجه من البيكر.

لقياس هذه الخاصية نحتاج دورق زجاج beaker ذو حجم كبير وساعة توقيت (أغلب الموبايلات فيها ساعات توقيت لحساب الثواني والدقائق والساعات) وتشغل الساعة ثم توقف بعد فترة زمنية معينة لقياس وزن النموذج ثم تشغل مرة أخرى ثم توقف وهكذا، ونضيف الوقت بشكل تراكمي بعد كل عملية قياس لوزن النموذج.

يحدث صعود الماء عندما تتغلب قوة الشد السطحي على وزن عمود الماء (gravity) وعندما يتساوى يقف الماء عند مستوى معين (عند مستوى تساوي قوة الشد السطحي مع ثقل الماء في المسام).

ان معامل الخاصية الشعرية يعطينا فكرة عن المسامية. بشكل عام كلما تزداد المسامية كلما كان ارتفع الماء اسرع اي تزداد الخاصية الشعرية، لكن لكل قاعدة شواذ إذ ان هناك أحجار ذات مسامية عالية تكون الخاصية الشعرية فيها قليلة ويرتفع فيها الماء بسرعة أقل من حجر قليل المسامية لأن الخاصية الشعرية تعتمد على قطر المسامات أيضاً، فكلما كان قطر المسامات أكبر كلما كانت الخاصية الشعرية أقل لأن كمية الماء في المسام ستكون أكبر مما في المسامات ذات الأقطار الصغيرة وبالتالي فأن ثقل الماء تكون أكبر من قوة الشد السطحي لذلك لا يصعد الماء إلى الأعلى. إن لحجم الفجوات تأثير كبير على سلوكية الصخور عند استعمالها لأغراض البناء وتعرضها لعوامل التجوية وهذا يعني ان الحجر ذي المسامات الكبيرة يقاوم ظروف الانجماد ويمكن استخدامه في الاجزاء المكشوفة من البناء والمعرضة للظروف الجوية.

قيمة (C) تساوي ميل الخط الناتج من رسم ($\sqrt{t}$) على المحور السيني و (ΔM/S *100) على المحور الصادي. وتتراوح قيمة (C) من الصفر للاحجار عديمة المسامية إلى ($50\ gm/cm^2.Min^{-1/2}$) للأحجار عالية المسامية.

الحل/ ميل المنحني في الرسم البياني يمثل معامل الشعرية للنموذج .