

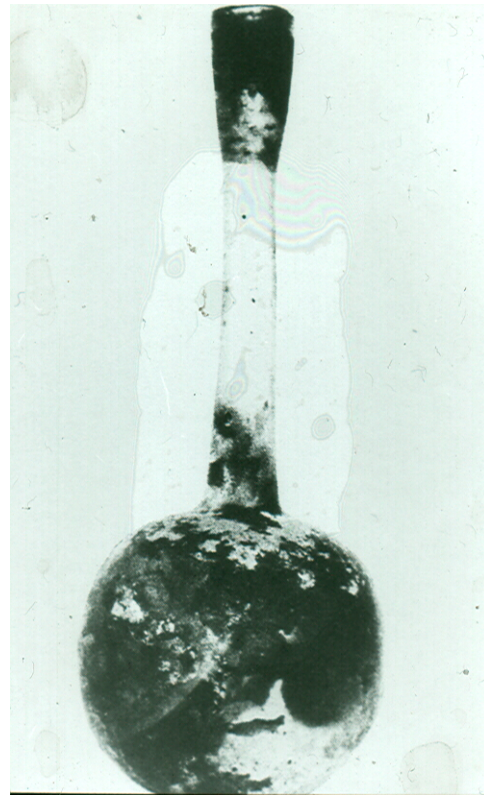
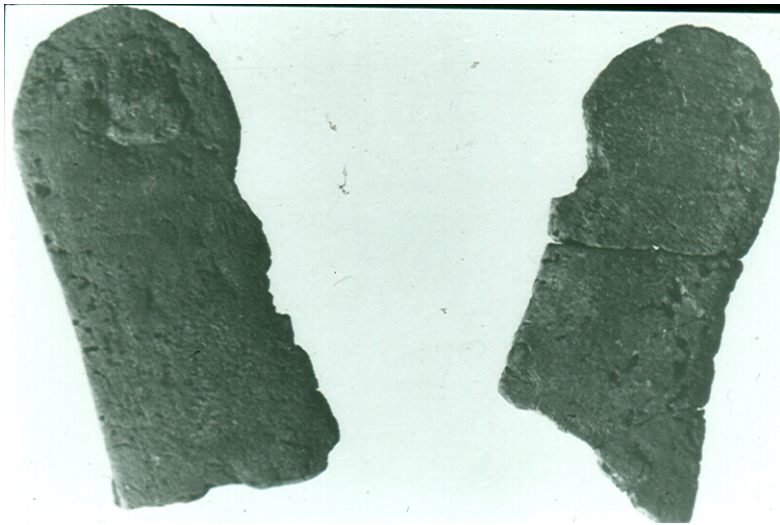
Cork

- Romans used cork for soles of shoes, to seal bottles (also sealed with pitch overcork)
 - Benedictine monks in 1600s perfected stopping bottles with clean, unsealed cork
 - cork is the bark of the cork oak tree (*Quercus suber*)
 - grows in Portugal, Spain, Algeria, California
 - all trees have a layer of cork in their bark
 - *Q. suber* unusual in that cork layer is several cm thick
-
- can cut bark off *Q. suber* + it regrows
 - cell walls of cork covered in unsaturated fatty acid -suberin- impervious
 - cork still used to seal bottles, as gaskets, for soles of shoes.

Structure

- Hooke's drawings, SEM: one plane, roughly hexagonal cells; other 2 -box-like
- axisymmetric - hexagonal cells normal to radial direction, corrugated walls
 - $x_1 = \text{tangential}$ $x_2 = \text{axial}$ $x_3 = \text{radial}$
- cell size $\sim 30\text{-}40\mu\text{m}$ (smaller than most engineering foams)
- density $\sim 170\text{ kg/m}^3$ $\rho_s \sim 1150\text{ kg/m}^3$ $\rho^*/\rho_s \sim 0.15$ typically.

Cork



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Quercus suber



Cork microstructure

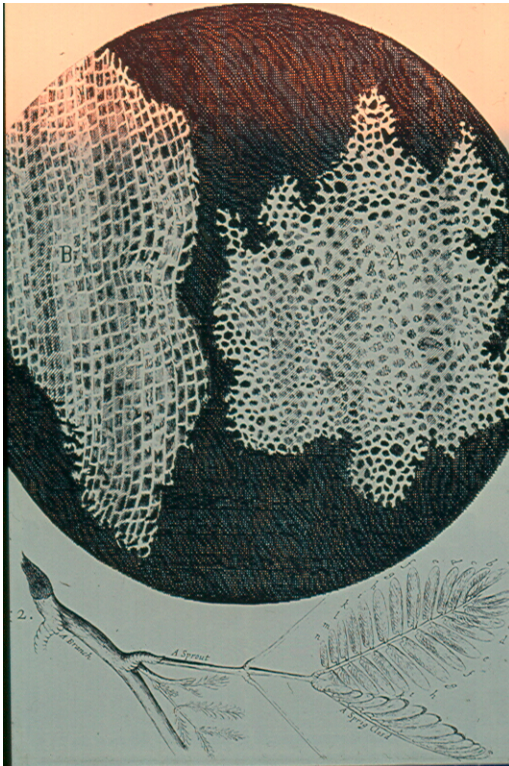


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Hooke, 1665

Cork microstructure

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"The Structure and Mechanics of Cork." *Proceeding The Royal Society. A* 377, no. 1769 (1981): 99-117.

Cork microstructure

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Mechanical behaviour

Modelling: 1-2 directions - honey comb (tang. / axial) loaded in plane

$$E_1^* = E_2^* = 0.5 E_s (\rho^*/\rho_s)^3 = 15 \text{ MPa}$$

$$G_{12}^* = 0.13 E_s (\rho^*/\rho_s)^3 = 4 \text{ MPa}$$

$$\nu_{12}^* = \nu_{21}^* = 1$$

$$(\sigma_{el}^*)_1 = (\sigma_{el}^*)_2 = 1.5 \text{ MPa}$$

Measured

13 MPa

4.3 MPa

0.25-0.50 (constraint of end membranes)

0.7 MPa

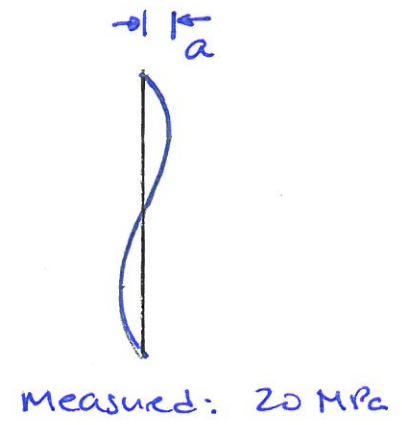
Modelling: radial direction (x_3)

- need to account for corrugations
- if walls straight - axial deformation
- corrugated walls - also have bending

$$E_3^* = \frac{0.7 E_s (\rho^*/\rho_s)}{1 + 6(a/t)^2} = 20 \text{ MPa}$$

$$\nu_{31}^* = \nu_{32}^* = 0 \quad (\text{corrugations fold up})$$

$$\nu_{13}^* = \frac{E_1^*}{E_3^*} \nu_{31}^* = 0; \quad \nu_{23}^* = 0$$



measured: 0-0.1

Stress-strain

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"[The Structure and Mechanics of Cork](#)." *Proceeding The Royal Society. A* 377, no. 1769 (1981): 99-117.

Table 12.2 Comparison between calculated and measured properties of cork†

	Calculated	Measured
<i>Moduli</i>		
E_1^*, E_2^* (MN/m ²)	15	13 ± 5
E_3^* (MN/m ²)	20	20 ± 7
G_{12}^*, G_{21}^* (MN/m ²)	4	4.3 ± 1.5
$G_{13}^*, G_{31}^*, G_{23}^*, G_{32}^*$ (MN/m ²)	—	2.5 ± 1
$\nu_{12}^* = \nu_{21}^*$	1.0	0.25 ^a –0.50
$\nu_{13}^* = \nu_{31}^* = \nu_{23}^* = \nu_{32}^*$	0	0–0.10 ^a
<i>Compressive collapse stress</i>		
$(\sigma_{el}^*)_1, (\sigma_{el}^*)_2$ (MN/m ²)	1.5	0.7 ± 0.2
$(\sigma_{el}^*)_3$ (MN/m ²)	1.5	0.8 ± 0.2

†Data from Gibson *et al.* (1981), except for (a) Fortes and Nogueira (1989).

Uses of cork

- stoppers for bottles: excellent seal due to elastic moduli $\nu = 0$, low E , K
 - compare with rubber stoppers: low E but high K ($\therefore \nu \rightarrow 0.5$)
 - also note orientation of still wine / champagne corks - in champagne corks, axis of symmetry aligned with bottle axis
 - gaskets: cork makes good gaskets for same reason (plus closed cells - impermeable)
 - also used as gaskets for musical instruments (woodwinds)
 - sheet cut with prism axis normal to sheet; when sections of instruments are mated $\nu = 0$ sheet gasket doesn't spread + wrinkle
-

• floor coverings, shoes: friction

- cork has high loss coefficient $\eta = \frac{D}{2\pi u} = 0.1 - 0.3$
- when deformed, dissipates energy
- results in high coefficient of friction, even when wet & soapy
- damping also exploited in tool handles.

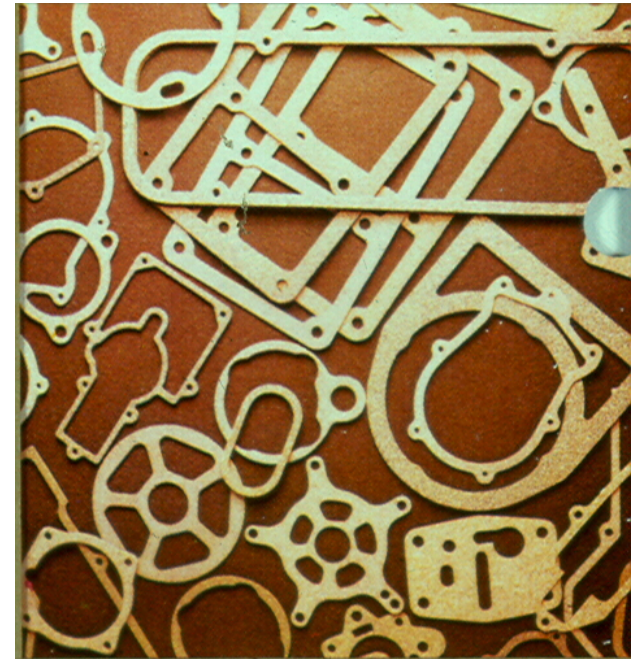
Stoppers for bottles

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"[The Structure and Mechanics of Cork](#)." *Proceeding The Royal Society. A* 377, no. 1769 (1981): 99-117.

Gaskets



Clarinet

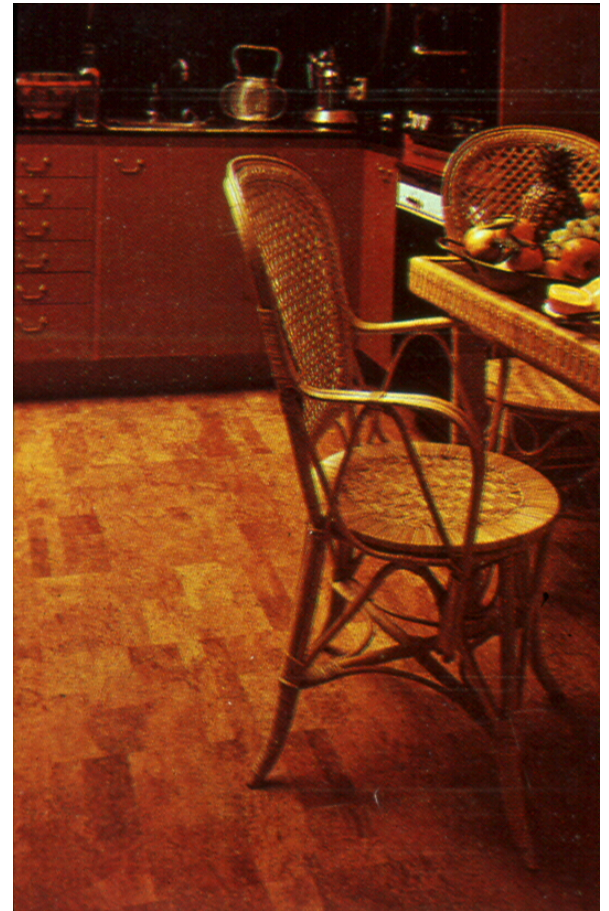


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Cork flooring

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insulation

- small cell size decreases thermal conductivity
- hermit caves in Portugal lined with cork
- cigarette tips - originally cork

indentation/bulletin boards

- cork densifies when indented; def^m highly localized
 - def^m elastic - hole closes up again when pin removed.
-

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"[The Structure and Mechanics of Cork.](#)" *Proceeding The Royal Society. A* 377, no. 1769 (1981): 99-117.

Indentation

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"[The Structure and Mechanics of Cork](#)." *Proceeding The Royal Society. A* 377, no. 1769 (1981): 99-117.

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