Elastic anisotropy of bone

Biomechanics, BME 315

Tensorial elastic moduli (GPa), determined ultrasonically

	Fresh bovine phalanx (2.2.9)	Dry human femur (2.2.10)
C_{1111}	19.7	23.4
C_{1122}	12.1	9.06
C_{1133}	12.6	9.11
C_{3333}	32.0	32.5
C_{2323}	5.4	8.71

Elastic anisotropy of bone. **Technical** elastic moduli. Wet human femoral bone by mechanical testing (2.2.2) and bovine femoral bone by ultrasound (2.2.11).

Young's moduli (GPa)			*Shear moduli(GPa)*			*Poisson's ratios (dimensionless)*		
	Human	Bovine		Human	Bovine		Human	Bovine
E_{long}	17	22	G_{long}	3.6	5.3	ν	0.58	0.30
E_{transv}	11.5	15	G_{tr}	3.3	6.3	ν	0.31	0.11
E_{transv}	11.5	12	G_{tr}	3.3	7.0	ν	0.31	0.21

The stiffness of compact bone tissue depends on the bone from which it is taken. Fibular bone has a Young's modulus about 18% greater, and tibial bone about 7% greater, than that of femoral bone. The differences are associated with differences in the histology of the bone tissue. Bone is elastically anisotropic, i.e. its properties depend on direction. Such behavior is unlike that of steel, aluminum and most plastics, but is similar to that of wood.

Material	**Strength** σ^{ult}[MPa]	**Density** ρ(g/cm^3)	σ^{ult}/ρ
polyethylene (high density)	20-40	0.95	21-42
polymethyl methacrylate (PMMA)	70	1.18	59.3
human compact bone			
longitudinal	148	2.0	74 .
transverse	49		
steel (structural)	400	7.8	51.3
aluminum (1100-H14)	110	2.71	40.6
granite	20	2.77	7.2
concrete (compression)	28	2.32	12.1

Material	**modulus** E[GPa]	**Density** ρ(g/cm^3)	E/ρ	E/ρ^2
polyethylene (high density)	0.5	0.95	0.53	0.55
polymethyl methacrylate [PMMA]	3.0	1.18	2.5	2.15
human compact bone				
longitudinal	17	1.8	9.4	5.2
Dentin	13-18			
Enamel	50-84			
steel(structural)	200	7.86	25.4	3.23
aluminum	70	2.71	25.8	9.53
concrete	25	2.32	10.8	4.6
wood(pine)	11	0.61	18.0	29.6

References

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