Work Hardening

The mechanism of work hardening should not require particular comment. There is a further consequence of this phenomenon: The reorientation and reorganization of a polycrystalline aggregate for greater elastic stability to a compressive load, for example, means that the material should then be weaker for a tensional load along the same axis. This is observable in push-pull load-extension diagrams of "overstrained" steels.

Effect of Hydrostatic Pressure on Strength

If hydrostatic pressure is applied to a crystal lattice, r decreases by an amount $r_0-r_p=\epsilon_p$ and if the electrostatic force field is symmetric in space the decrease will be uniform in all directions. If now an additional stress is applied by means of a superimposed unidirectional compressive load π then r along this axis will decrease to r_π by the additional amount $\epsilon_\pi=r_\pi-r_p$.

The lattice, assuming "normal" behavior, expands laterally doing work against the confining pressure until a new equilibrium is established between the repulsive, attractive, and external forces.

It might be anticipated that Poisson's ratio should bear a functional relation to r. The evidence from seismic data indicates, however, that within the earth σ remains approximately constant, at about 0.27, independent of pressure (depth).

The lateral extension will increase as the longitudinal compressive load is increased and thus r will gradually move back through r_0 to r_m at which point the specimen becomes unstable and ruptures. The load for this condition will represent the compressive strength of the specimen.

Rupture, here the "brittle" potential type of fracture, will occur then for the condition

$$\int_{F=-p}^{F=-\pi}\frac{dr}{dF}dF=\frac{\displaystyle\int_{F=0}^{F=-p}\frac{dr}{dF}dF-(r_m-r_0)}{\sigma},$$

where $[(\pi)_m-p]$ denotes the "elastic" compressive strength of the specimen under confining pressure p.

The slope of the $r-F$ curve,

$$\frac{dr}{dF}=\frac{r^{j+1}}{jC_j-iC_ir^{j-i}}$$

flattens rapidly as r decreases and approaches zero as a limit. This initial change in slope may be observed graphically in the curves of compressibility plotted as a function of pressure. Hence the smaller the r, and consequently the higher the hydrostatic confining pressure, the larger must be the unidirectional thrust for the same r_m-r_p but this distance, as a matter of fact, is itself also increasing by virtue of increasing p. The compressive strength of the specimen should therefore accelerate rapidly with increasing confining pressure and become infinitely strong elastically as the confining pressure continues to increase indefinitely. If, therefore, the compressive strength be plotted as ordinate and hydrostatic confining pressure as abscissa the curve should be found to rise gently at first and then to steepen rapidly, eventually becoming infinitely steep.

The above conclusions from this theory, depending entirely on seismic data, have been held in abeyance until they could be further confirmed. Recently confirmation has been obtained from the experimental work of Griggs.[16] Experimental work is also being conducted at the Geophysical Laboratory to verify the calculated strengths for steel. The initial pressure effect is complicated by the geometry of cracks but these cracks close up at a few thousand atmospheres pressure.

The curve of compressive strength *versus* hydrostatic confining pressure for substances which have polymorphic pressure modifications should exhibit discontinuities at such transformation points. In fact if such transformations took place rapidly while the substance was under unidirectional load the structure should break down. These points represent therefore loci of instability, so that the above conclusions would be applicable only to the homogeneous regions above and below such loci.

[16] D. T. Griggs, J. Geol. 44, 541–577 (1936). D. T. Griggs and J. F. Bell, Bull. Geol. Soc. Am. 49, 1723–46 (1938).