Second Reply to R. Altindag
'Brittleness and drillability'

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by H.G. Denkhaus

Please allow me the temerity to reply to your reply to my contribution as follows:.

A fracture is brittle if plastic deformation is absent or, conversely a fracture is ductile if plastic deformation is present. Consequently, brittleness is specified by the degree of plastic deformation at fracture. This is the generally accepted definition.

If other material properties (e.g. the quorient or the product of the uniaxial compressive and tensile strengths) under certain conditions are influenced by brittleness, or brittleness by them, these should not be called brittleness. If the one or the other author does that, he simply uses imprecise language. Even your remark, that 'Inyang and Pitt (1990) stated that the ratio of the compressive strength (σ_c/σ_t) is directly proportional to brittleness', confirms that the two quantities are not considered the same. For example:" The well known definition that a material is linear—elastic if the strain is directly proportional to the stress—does not mean that stress (measured in MPa) and strain (measured in %) are the same thing.

By the way, it is well known that, under normal conditions, the ratio σ_c/σ_t for materials is higher the greater their brittleness of fracture (the less their plastic deformation at fracture). Whether direct proportionality between the two quantities is valid *for all materials* appears extremely doubtful. It may have been found for certain materials under certain conditions. Unfortunately, I cannot lay my hands on the paper by Inyang and Pitt.

In my contribution I did not touch the problem with your graph of σ_c versus σ_t, but in your reply you show the graph again. So, forgive me if I criticize: The graph is extremely misleading; it conveys the impression that the compressive strength is always proportional to the uniaxial tensile strength, which of course is not true. Surely, any ratio (say compressive to tensile strength or the exchange rate of dollar to rand, for that matter) can be represented by the tangents of a straight line in a graph of that sort. Then for each material another line with different slope β must be drawn because the ratio differs for different materials. Likewise one can every day draw such a line for the dollar/rand exchange rate and draw a line with different slope β for any change of the exchange rate. But what for?

The product $\sigma_c\sigma_t$ can only be presented as the area of a rectangular triangle under a straight line (obviously under that for the corresponding ratio σ_c/σ_t if at the same time the applicable value of σ_c (or σ_t, for that matter) is given to limit the area. Otherwise the area under the straight line would of course be infinitely large.

In the sketch below I have tried to illustrate the above comments. I think you had in mind that the area would lead to some concept which would give the product $\sigma_c\sigma_t$ some physical meaning such as, for instance. the area under the curve of stress over strain is a measure for the specific strain energy. In the case under discussion, however, one can only state:

- The ratio of uniaxial compressive to tensile strength is the ratio of uniaxial compressive to tensile strength and nothing else. Full stop.
- The product of uniaxial compressive and tensile strength is the product of uniaxial compressive and tensile strength and nothing else. Fullstop.

I did not query the validity of some relationship between σ_c/σ_t or $\sigma_c\sigma_t$ and drillability but I consider it of academic interest only and doubt its practicability compared with the Schmidt hammer test. Taking rock specimens and determining their strength is cumbersome and costly. In particular, determining the tensile strength of rock is difficult. What method is to be used—the so called Brazilian test or testing with carefully machined standardized tensile specimens?

I trust that you find these remarks valuable. ◆