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Short communication

# Quasi-static compressive strength of cement-based materials

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ABSTRACT

Wet cementitious materials show a noticeable dependence on the rate of quasi-static loading. While dry cementitious materials are almost independent of loading rate in the quasi-static region, the mechanical strength of wet materials increases with increasing rate of loading. Therefore, the Abrams' formula for the static mechanical strength cannot provide reliable values with wet materials at higher rates and should be corrected. Some possibilities for its improvement have been discussed.



## 1. Introduction

It has long been recognized that the behavior of cement-based materials under dynamic loading differs from their behavior under static loading. Results of loading tests have confirmed an increase in compressive strength of concrete subjected to dynamic loading. This general result has been confirmed by many researchers in the course of many decades. For example, Abrams [1] even in 1917 reported that an increase in the rate of loading was accompanied by an increase in the compressive strength of concrete. The same finding was announced by Jones and Richard [2] in 1936 or Glanville [3] in 1938. Similar results were published by Watstein [4] in 1953 and Atchley and Furr [5] in 1967 or Hughes and Gregory [6] in 1972. A comprehensive overview of more recent works of this topic can be found in several surveys and books [7–10].

A further general conclusion which resulted from experiments concerned the different behavior of wet and dry materials. The wet in contrast to dry materials show a higher increase in compressive strength. This was confirmed even as early as in 1966 by Cowell [11] or by Kaplan [12] in 1980 who pointed out that the moisture content of concrete is one of the main factors influencing the relationship between strength and loading rate. More recently Rossi and Toutlemonde showed that it is the viscous effects of pore water that are responsible for the strength increase in the quasi-static region ($10^{-4}s^{-1}$, $10^{0}s^{-1}$). On the other hand, only weak or no relationship between the strength increase and the type of aggregate, water-to-cement ratio or age at testing has been found.

The purpose of this paper is to present some analytical consequences which follow from the results published about the quasi-static compressive strength of cement-based materials.

## 2. Factors influencing dynamic strength of cementitious materials

There is a wide scatter in the magnitudes of strength increase with increasing rate of loading. These discrepancies exist mainly because the behavior of concrete is dependent on many variables such as the *static* strength, curing conditions, size and shape of samples and type of loading. As soon as the rate of loading is further increased, other factors such as viscous effects of pore water, inertia forces, stress-wave propagation or plain stress effects become important.

Fig. 1 schematically shows some dynamic regions and their typical factors influencing the dynamic compressive strength of concrete. In the quasi-static region, which is of our primary concern, the porous water plays a decisive role as to the dynamic behavior of concrete. This fact was repeatedly demonstrated by Rossi, Toutlemonde and others [13–17] within the series of tensile experiments. Rossi and Toutlemonde expressed a hypothesis [16] concerning the mechanism of viscous resistance which pore water develops against the tensile disruption. The mechanism is based on the physical phenomenon called the Stéfan effect and may be described as a viscous adhesion of pore water to the pore walls. Similar although not identical viscous effects were observed by Scherer [18] in flexure experiments when studied the time-dependent relaxation process during three-point bending of cement-based samples. Scherer's viscous effects may be described as “hindered viscous flow” of pore water that tends to act against loading. The faster the loading, the larger hindering is established. During the static loading (~$10^{-5}s^{-1}$) the hindered

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