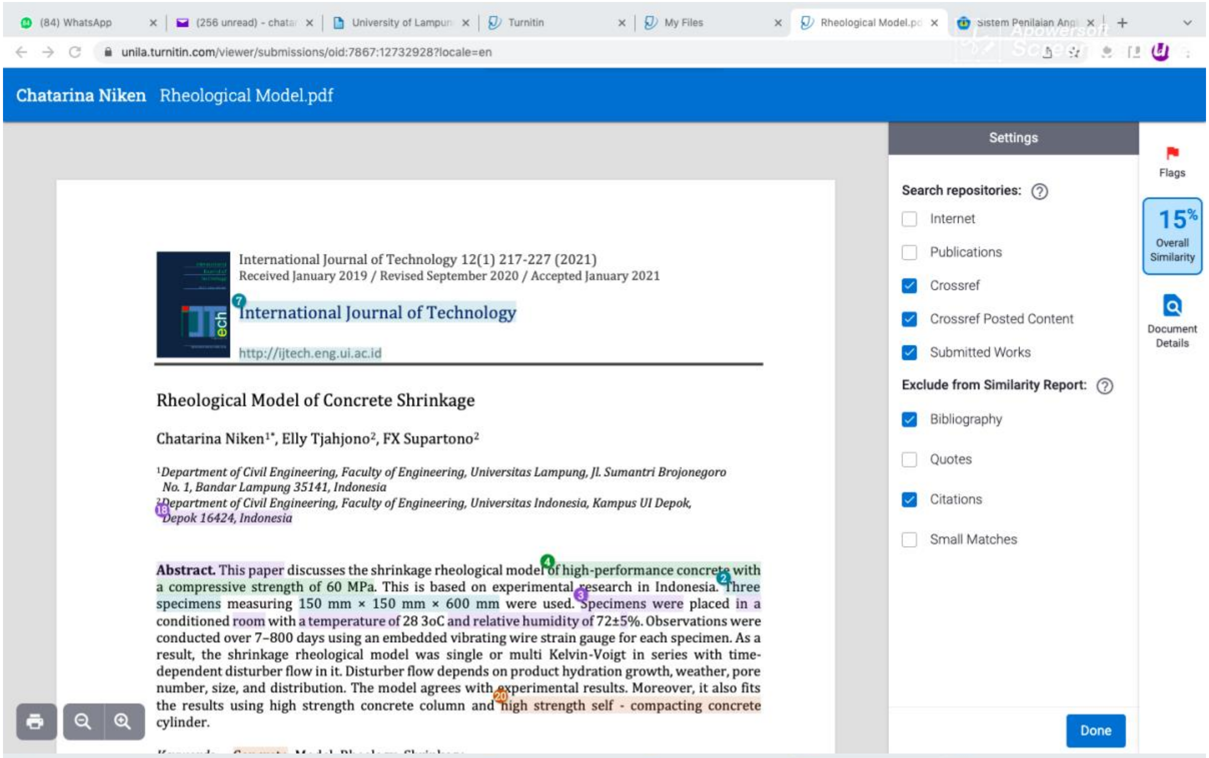

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Rheological Model of Concrete Shrinkage

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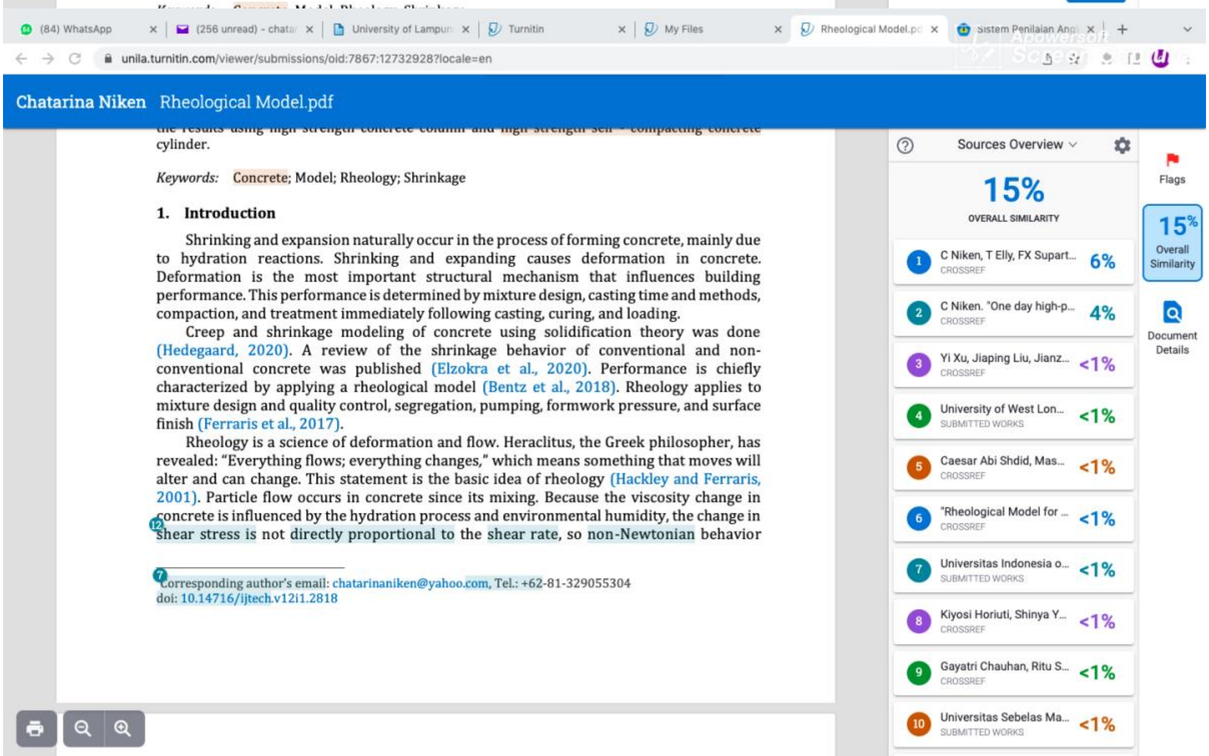
Abstract. This paper discusses the shrinkage rheological model of high-performance concrete with a compressive strength of 60 MPa. This is based on experimental research in Indonesia. Three specimens measuring 150 mm × 150 mm × 600 mm were used. Specimens were placed in a conditioned room with a temperature of 28 3oC and relative humidity of 72±5%. Observations were conducted over 7–800 days using an embedded vibrating wire strain gauge for each specimen. As a result, the shrinkage rheological model was single or multi Kelvin-Voigt in series with time-dependent disturber flow in it. Disturber flow depends on product hydration growth, weather, pore number, size, and distribution. The model agrees with experimental results. Moreover, it also fits the results using high strength concrete column and high strength self - compacting concrete cylinder.



cylinder.

Keywords: Concrete; Model; Rheology; Shrinkage

1. Introduction

Shrinking and expansion naturally occur in the process of forming concrete, mainly due to hydration reactions. Shrinking and expanding causes deformation in concrete. Deformation is the most important structural mechanism that influences building performance. This performance is determined by mixture design, casting time and methods, compaction, and treatment immediately following casting, curing, and loading.

Creep and shrinkage modeling of concrete using solidification theory was done (Hedegaard, 2020). A review of the shrinkage behavior of conventional and non-conventional concrete was published (Elzokra et al., 2020). Performance is chiefly characterized by applying a rheological model (Bentz et al., 2018). Rheology applies to mixture design and quality control, segregation, pumping, formwork pressure, and surface finish (Ferraris et al., 2017).

Rheology is a science of deformation and flow. Heraclitus, the Greek philosopher, has revealed: "Everything flows; everything changes," which means something that moves will alter and can change. This statement is the basic idea of rheology (Hackley and Ferraris, 2001). Particle flow occurs in concrete since its mixing. Because the viscosity change in concrete is influenced by the hydration process and environmental humidity, the change in shear stress is not directly proportional to the shear rate, so non-Newtonian behavior

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occurs. Non-Newtonian particle-laden fluids are more complex due to various factors (Mau et al., 2020).

Shrinkage can be defined as a time-dependent decrease in concrete volume (American Concrete Institute, 1992). In fresh conditions, the paste rheological model is useful in designing SCC mixtures and reducing the extent of laboratory work, testing time, and materials used. For hard concrete, a long-term deformation rheological model was mentioned by Sobotka (1962) as H-StV | N-H | N | StV = H-B- (K | StV) (H: Hooke, StV: St Venant, N: Newton liquid, B: Bingham, K: Kelvin solid). Sobotka (1984) and Ferraris (1999) also stated that the long-term deformation of concrete fits well with the Bingham model (H-StV l N). Because the first model as described above is Hooke (H), it means that the increase in load is directly proportional to the rate of strain. This means that the sample is under external load, so what is happening is creep. Until now, concrete rheological models were only for creep. This matter is based on deformation and particle flow caused by the applied load. In fact, without an applied load, there are microscopic flows in the concrete due to microprestresses-solidification. In rheology, there is no clear border between solid and liquid. Based on this condition, shrinkage can be modeled rheologically. By seeing the rheological model, concrete behavior can be understood quickly and easily.

Shrinkage is a natural phenomenon that is also due to moving particles and water. After curing, concrete starts to deform with environmental influences; thus, shrinkage is influenced by external supply water, so the climate plays an important role. Because the hydration process may occur for a long time, shrinkage occurs simultaneously with hydration, causing the shrinkage mechanism to become complex. A full understanding of long-term shrinkage behavior is needed for concrete design with good performance. A full understanding of long-term shrinkage behavior is needed for concrete design to reach good performance.

The objective of this research is to create a shrinkage rheological model to illustrate the deformation behavior of concrete under the influence of hydration and climate.

2. Methods

This research was conducted in Jakarta, Indonesia, within humid, tropical weather. This study was performed experimentally using three specimens of 150 mm × 150 mm × 600 mm, according to ASTM C78-08, with one embedded vibrating wire strain gauge (SG) for each specimen. The position of the SG can be seen in Figure 1a (i.e., five cm from the end of the

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