HBRC Journal (2016) 12, 1–12

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

Evaluation of consistency properties of freshly mixed concrete by cone penetration test

Metwally A.A. Abd Elaty, Mariam Farouk Ghazy *

Faculty of Engineering, Structural Engineering Department, Tanta University, Egypt

Received 20 June 2014; accepted 29 September 2014

KEYWORDS

Fresh concrete;
Consistency;
Workability;
Rheology;
Cone penetration

Abstract This study is directed to evaluate the ability of using cone penetration test as a simple method to investigate the consistency level of fresh concrete. A cone of 30° apex angle attached with different load values was used. Eighteen concrete mixes divided into three groups were conducted. Three types of coarse aggregate were tried. Crushed dolomite, round gravel, and crushed basalt all of 20 mm maximum grain size were investigated. For each type of coarse aggregate, six levels of concrete consistency calibrated by standard slump test were tried. For the investigated mixes and at a specified consistency level, the displaced volume values were directly proportional to the applied load. The inclination of this relation is termed as the displaced volume rate (D.V). The results of cone penetration were analyzed and compared to the corresponding slump test values. The displaced volume per unit mass, bearing strength, as well as shear yield strength were the evaluated properties. The results introduce the cone penetration test as a simple instrument that could be adopted either at a laboratory or at site to evaluate fresh concrete workability. Moreover, it is being more sensitive compared to the well known slump test. It can simply and clearly distinguish between stiff mixes as well as floppy ones. Very useful numerical limits for the evaluated properties controlling the workability levels of very low, low, medium, high and very high were proposed.

Introduction

Fresh concrete is being a transit stage. The importance of this stage comes from the fact that the concrete strength is very seriously affected by the degree of its compaction. Moreover, ease of placement, consolidation and durability depend on the flow properties of concrete. Concrete that is not properly consolidated may have defects like honey combs, air voids, and aggregate segregation.

* Corresponding author.
E-mail addresses: drmet2828@yahoo.com (M.A.A. Abd Elaty), dr.mariamghazi@yahoo.com (M.F. Ghazy).
Peer review under responsibility of Housing and Building National Research Center.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.hbrcj.2014.09.001
1687-4048

Historical development of existing workability test methods

The concrete industry has recognized the importance to monitor concrete workability since the early 20th century [1]. The American concrete industry at the beginning of 1900s had no standard test methods to measure workability. Instead, subjective, qualitative descriptions of "consistency" were typically given. While recognizing that concrete consistency was of utmost importance, Taylor and Thompson [2] divided concrete consistency into three simplistic and vague categories: "dry" consistency, "medium" or "quaking" consistency, and "wet a mushy" consistency.

In 1918, the concrete industry took a dramatic step forward as a result of Duff Abrams's [3] work in the field of design concrete mixture, in which he showed that concrete strength was directly related to the ratio of water-to-cement what Abrams called the water ratio. Whereas, other mixture proportioning procedures of that time focused mainly on achieving an optimum packing of aggregates and considered the water content to be subordinate, Abrams showed that the water-to-cement ratio was the most important parameter in developing mixture proportions and that it should be set as low as possible on the condition that proper workability could be achieved.

To define workability, Abrams [3] suggested the slump test method to evaluate the relative consistency of concrete mix. Although the slump test was quickly accepted due to its simplicity, the concrete industry immediately recognized that the slump test was in adequate for fully properly characterizing workability.

Since the introduction of the slump test, a myriad of workability test methods have been developed. Workability tests for concrete workability have attempted to simulate actual field conditions to develop an index expressing particular aspect of workability. On the other hand, rheology-based approaches attempt to measure the fundamental rheological parameters of concrete, which can then be related to practical construction requirements. Workability tests can generally be split into five broad categories, free flow tests, confined flow tests, vibration tests, rotational rheometers, and tests for very dry concrete.

Free flow tests

Common free flow tests include slump test, Kelly ball test, modified slump test etc. [1].

Free flow tests measure either the penetration resistance of concrete or the ability of concrete to flow under its own weight. Such tests are simple to perform and provide a direct result without calculations. The results of free flow test methods are typically closely related to yield stress. The slump test is the best known of the free flow test methods.

In addition to the slump test, several free flow test methods have been improved to also measure plastic viscosity. For instance, the modified slump test [4]. In the Kelly ball test, which is the best known penetration resistance test, the depth of penetration of a ball is measured and then related to slump [1].

Confined flow tests

Common confined flow tests include the compaction factor test beside the free orifice (Orimet) test, L-shaped boxes which are commonly used for self-compacting concrete [1].

In these tests, concrete flows through a narrow orifice either under its own weight or under an applied pressure. Confined flow tests are simple to perform and provide a direct result; however, they do not give a direct indication of yield stress and plastic viscosity [1].

Generally, confined flow tests are not suitable for low to moderate slump concretes, which are not sufficiently fluid to readily flow under confined flow conditions and produce meaningful results.

Vibration tests

Many test methods are used to measure the flow of concrete under vibration due to the wide use of vibration in placing concrete. Vibration tests are important in measuring the flow properties of low to moderate slump concretes that are commonly vibrated in the field. VeBe test and flow table test are examples of vibration tests that measure the ability of concrete to remold from one shape to another under applied vibration [1].

Rotational rheometers

Rotational rheometers for concrete apply shear stress to concrete at different shear rates to measure yield stress and plastic viscosity. Rotational rheometers are typically used exclusively in the laboratory. Although some rotational have been designed to be sufficiently small and rugged for use on jobsites, the limited availability and high cost of these devices made them impractical for regular field use. Different rotational rheometers measure different ranges of workability. Coaxial cylinders, impeller and parallel plate are some common geometries of concrete rotational rheometers [1]. Modified vane shear test was used to measure the shear yield strength of the fresh concrete [5].

Very dry concrete tests

For very dry concrete mixtures, compaction tests are used due to unsuitability of flow and other tests. The proctor test for soils can be used for very dry concrete mixtures. With the exception of the widely used slump test, the few methods that have been studied extensively have generally failed to gain widespread acceptance [1].

Compaction factor test was developed in Britain in the late 1940s and has been standardized as British standard 1881–103. Although this test gives more information than the slump test due its dynamic nature and its large and bulk nature reduce its usefulness in the field moreover, it is not suitable for harsh concrete mixes [1].

The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. An inexpensive test, which measures consistency, is used on job sites to determine rapidly whether a concrete batch should be accepted or rejected. The test method is widely standardized throughout the world, including ASTM C 143 and EN 12350-2. Although this test is the most widely used worldwide, concretes with the same slump can exhibit different behavior when tapped with a tamping rod. Moreover, the slump test is less relevant for newer advanced concrete mixes than for more conventional mixes [1].

The Kelly ball test was developed in the 1950s in the United States as a fast alternative to the slump test. The simple and inexpensive test can be quickly performed on in-place concrete