Construction and Building Materials 158 (2018) 535–548

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Global perspective on application of controlled low-strength material (CLSM) for trench backfilling – An overview

Tung-Chai Ling [a,b,c], Senthil Kumar Kaliyavaradhan [a], Chi Sun Poon [b,*]

[a] College of Civil Engineering, Hunan University, Changsha 410082, Hunan, China
[b] Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China
[c] Key Laboratory for Green & Advanced Civil Engineering Materials and Application Technology of Hunan Province, China

HIGHLIGHTS

- Recent research developments and applications of CLSM for trench backfilling are overviewed.
- CLSM specifications, practical applications and materials used by different countries are discussed.
- Long-term site experiences and technical limitations of using CLSM are highlighted.
- CLSM could be a beneficial way for recycling waste materials and industrial by-products.

ARTICLE INFO

Article history:
Received 9 August 2017
Received in revised form 3 October 2017
Accepted 10 October 2017

Keywords:
Controlled low-strength material (CLSM)
Trench backfilling
Waste materials
Specification
Flowability
Excavatability

ABSTRACT

Controlled low-strength material (CLSM) is known as a self-leveling and self-compacting cementitious backfill material used for backfilling. The aim of this paper is to give an overview of the research development and practical application of CLSM for trench backfilling. Widespread application of CLSM is found around the world including in the United States of America (USA) as well as in other developed and developing countries. The main specifications and guidelines used in the USA and referenced by most of the other countries are highlighted in this paper. In addition, long-term site performance and technical limitations to be considered before application of CLSM are also discussed. Based on 115 globally sourced literature articles, it is suggested that the materials used for the production of CLSM are varied from country to country which in turn could have a significant influence on the resulting properties and its application in the field. It is also demonstrated that use of high volume by-products or/and waste materials is an effective way to control the low strength requirement of CLSM and minimize the environmental concerns related to the disposal of these waste materials.

Contents

* Corresponding author.
E-mail addresses: tcling@hnu.edu.cn, tcling611@yahoo.com (T.-C. Ling), senthilkumark13@yahoo.com (S.K. Kaliyavaradhan), cecspoon@polyu.edu.hk (C.S. Poon).

https://doi.org/10.1016/j.conbuildmat.2017.10.050
0950-0618/

1. Introduction

Controlled low-strength material (CLSM) is a self-compacting and self-leveling cementitious backfill material used in lieu of conventional compacted fill [1]. The other terms used to describe this backfilling material includes flowable fill, controlled density fill, flowable mortar, self-compacted backfill material, plastic soil-cement or slurry etc. [1–3]. CLSM has a wide range of applications (see Fig. 1) due to its unique characteristics and properties. The principal applications of CLSM include trench backfilling, structural fills, pavement bases, void filling and conduit bedding [4]. Table 1 summarizes the criteria requirements and the essential properties need to be achieved for each different application of CLSM.

In general, CLSM costs slightly higher than the conventional compacted soil or granular backfill materials, however, the potential advantages associated with its use include: less on-site labor and equipment requirement (due to its flowable nature, self-leveling and easy placement with no vibration needed), fast construction speed (from order to the delivery of materials and clean up), ability for use in tight or restricted-access areas (where compacting soil is difficult or even impossible in some cases), safer for labors working in excavated narrow trenches, and could utilize high volume of waste materials in the mixture [4–7]. CLSM usually has a sufficient load-carrying capacity and serve as a strong and durable backfill material for utility conduits, structural fill, and pavement applications. More importantly, it can be designed with sufficient early strength to support traffic loads within several hours after placement [8–11].

A total of 115 research articles are found (for trench backfilling only) in the literature in English dating from 1990 to 2017. Based on this globally sourced literature, an overview of CLSM in terms of specifications, materials adopted in different countries and its influence on the properties for trench backfilling are reviewed. The number of articles published in country-wise and year is presented in Figs. 2 and 3. It can be seen that about one-third of the studies were conducted and published by the USA, and an average of 5 articles are published globally per year for the past 25 years.

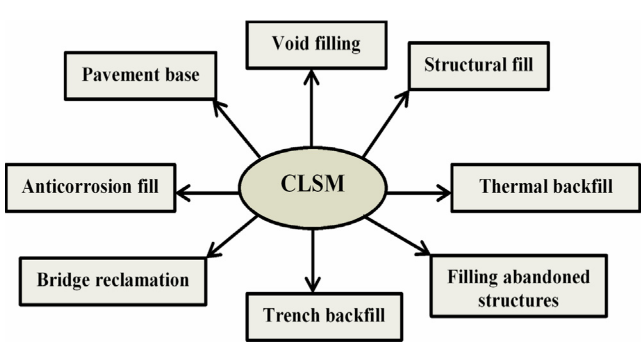

Fig. 1. Different applications of CLSM.

2. Mix design, properties, and specifications of CLSM

In 1985, the ACI Committee 229 was set up with the aim of establishing a comprehensive report covering the applications, proportioning, handling, placement, and performance (i.e. sampling, fresh properties, in-service properties) of CLSM for various applications. The ACI Committee 229 report was first published in 1994 and became effective on April 26, 1999.

2.1. Mix design of CLSM

Generally, the mix design of CLSM was established based on past experience or trial and error. Mostly, it was designed for high flowability (>200 mm spread) and low compressive strength ≤2.1 MPa that allows for re-excavation in future, yet strong enough for backfilling needs [1,4,8,12]. Fig. 4 shows a mix proportion (% of total mass) and typical materials being used in CLSM for trench backfilling [13]. As it can be seen, it is usually a mixture of fly ash, fine aggregate (or other waste materials), water, and a small amount of Portland cement (25–59 kg/m^3) and chemical admixtures. According to American Concrete Institute (ACI 229), the upper and lower limits 28 days unconfined compressive strength of CLSM are limited to 8.3 MPa and 0.3 MPa respectively [1,4,12].

2.2. Key properties of CLSM

CLSM offers a number of advantages over compacted soils in burying underground utilities or pipelines. The key properties of CLSM include the flowability/self-compacting ability, re-excavatability (unconfined compressive strength), chemical stability (corrosion) and other properties are discussed in the following sub-sections.

2.2.1. Flowability of CLSM

High flowability with a slump flow value more than 200 mm is usually required for CLSM to achieve self-flowable characteristic for placement and backfilling. Due to its self-leveling and high flowability, no compaction is required at the bottom of the trench, making it easier to maintain the pipe alignment as well as less chance for settlement [10,11,15]. In addition, it minimizes the working area required within the trench and perhaps, more importantly, improves labor safety [11]. Depending on the type and location of the trench to be filled, it can be placed by a chute, a conveyor, a pump or buckets, and thereby can speed up the