ISSN: 2347-7431
EPRA International Journal of Climate and Resource Economic Review
-Peer Reviewed Journal
Volume: 11 | Issue: 8 | November 2023 || SJIF Impact Factor (2023): 8.076 || Journal DOI: 10.36713/epra1213

COMPARATIVE STUDY OF CEMENT SOUNDNESS FOR PORTLAND CEMENT IN THE NIGERIA

Osagie, E.K , Idiata, D.J
Department of Civil Engineering, Edo state Polytechnic Usen, Edo state, Nigeria
Department of Civil Engineering Technology, National Institute of Construction Technology & Management Uromi, Edo state, Nigeria.

ABSTRACT--
The Autoclave Expansion Test was performed on six distinct cement types denoted as A, B, C, D, E, and F, exhibiting average expansion values of 5.57%, 3.33%, 6.17%, 2.23%, 3.52%, and 3.52%, correspondingly. The objective of this study was to evaluate the integrity of these cements and derive implications for their utilisation in construction endeavours. The findings demonstrate significant discrepancies in expansion values, which can be attributed to variations in the likelihood of delayed expansion and unsoundness. Type A demonstrated the highest mean expansion, implying a greater susceptibility to unsoundness, whereas Type D displayed the lowest expansion, indicating a higher level of stability and soundness. Types B, E, and F exhibited moderate expansion values, necessitating a judicious assessment of their suitability for particular construction requirements.

The results emphasise the importance of utilising the Autoclave Expansion Test as a means of assessing the integrity of Portland cement. Cements with lower expansion values tend to exhibit improved stability and a decreased likelihood of delayed expansion, rendering them more favourable for applications that require enhanced durability. Nevertheless, it is imperative to exercise caution when dealing with higher expansion values, as they may have significant ramifications on the long-term structural integrity.

This research provides significant contributions to the field of cement selection and application in construction, highlighting the significance of conducting a comprehensive evaluation that takes into account not only the soundness but also other crucial properties. The findings contribute to the facilitation of well-informed decision-making processes, thereby advocating for the utilisation of cement that is tailored to meet the unique demands of various construction endeavours.

KEYWORDS: *Construction Quality, Concrete Performance, Autoclave Expansion Test, Cement Soundness, Portland Cemen*---

INTRODUCTION

The relationship between the durability and longevity of concrete structures is closely tied to the integrity of Portland cement, which serves as a fundamental constituent in the manufacturing of concrete. The concept of cement soundness refers to the capacity of cement to withstand alterations in volume subsequent to its setting process. This characteristic holds significant importance as it directly impacts the performance of concrete under diverse environmental circumstances (Mehta & Monteiro, 2006 & Neville, 2011, Mindess et al., 2003). In the Nigerian construction industry, which is characterised by a variety of climatic and logistical obstacles, it is crucial to comprehend and enhance the soundness of cement.

The increasing demand for infrastructure development in Nigeria necessitates the utilisation of durable and environmentally-friendly construction materials. Cement, as a fundamental component within the construction sector, is required to adhere to rigorous quality criteria in order to guarantee the soundness and dependability of constructed edifices. The examination of the soundness of Portland cement in Nigeria is necessary due to the distinct environmental conditions, storage practises, and transportation challenges that are prevalent in the country (Oyekan & Sani, 2019; Fapohunda & Joshua, 2019; NIOB, 2018; Olusola & Ajibade, 2017).

This study aims to expand upon the current body of knowledge by conducting a thorough comparative analysis of cement soundness within the Nigerian construction industry. This study aims to offer valuable insights into the optimisation of cement soundness for improved construction practises in Nigeria by taking into account factors such as temperature and humidity fluctuations, storage protocols, and transportation techniques.

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LITERATURE REVIEW

The term "soundness" is utilised within the context of cement paste specimens to describe the state in which they exhibit no cracks, disintegration, or other imperfections resulting from excessive volume change. The modification in volume is primarily influenced by the hydration of crystalline magnesia, specifically periclase (MgO), within cement (Qian et al., 1998; Gonnerman et al., 1953; Zheng et al., 1991).

The influence of cement soundness on the quality of Portland cement is significant, yielding extensive implications for the long-term resilience and effectiveness of concrete structures. The integrity of Portland cement is of utmost importance in assessing the resilience and extended functionality of concrete constructions. The term "soundness" pertains to the capacity of cement to withstand volumetric alterations without experiencing significant disruption following the process of setting. According to Mehta and Monteiro (2006), it is crucial to highlight the detrimental effects of unsound cement expansion on concrete, as it can result in the formation of cracks and subsequent deterioration. These consequences pose a significant threat to the structural integrity and overall longevity of the concrete. The ASTM C 151/C 151M-19 standard offers a universally accepted procedure for quantifying the autoclave expansion of hydraulic cement, which serves as a crucial parameter in assessing its susceptibility to unsoundness. The occurrence of excessive autoclave expansion serves as an indication of the existence of unsound cement and can potentially have adverse impacts on the overall quality of concrete, as stated in the ASTM C 151/C 151M-19 standard.

The soundness of cement is directly influenced by environmental factors such as temperature and humidity. The hydration process of cement can be influenced by variations in environmental conditions in regions with diverse climates, such as Nigeria, which can consequently contribute to unsoundness (Oyekan & Sani, 2015). Olusola and Ajibade (2017) conducted a study that delves deeper into the evaluation of cement quality within the Nigerian construction sector, with particular emphasis on the influence of environmental factors. The quality and performance of concrete are directly influenced by the quality of Portland cement. The utilisation of unsound cement in construction can lead to various repercussions, such as the occurrence of cracks, a decrease in compressive strength, and a compromise in durability (Mehta & Monteiro, 2006). Hence, it is crucial to prioritise the establishment of soundness in order to uphold the overall excellence of construction endeavours.

The significance of cement soundness within the Nigerian construction sector is emphasised due to the distinctive environmental circumstances and logistical complexities encountered in the area. The issue of the negative influence of substandard cement on the long-term resilience of concrete structures has led to an increased emphasis on the assurance of cement quality in construction endeavours (Olusola & Ajibade, 2017).

In their study, Oyekan and Sani (2015) investigate the influence of environmental variables, specifically temperature and humidity fluctuations, on the overall quality of Portland cement within the Nigerian setting. It is imperative to comprehend the relationship between these variables and the integrity of cement in order to enhance storage and transportation methodologies. The study conducted by Olusola and Ajibade (2017) presents a thorough evaluation of cement quality within the context of the Nigerian construction industry. The authors provide valuable insights into the various factors that contribute to the soundness of cement. This study assesses the physical and chemical characteristics of cement, highlighting the imperative of thorough examination to guarantee adherence to established quality criteria. Research endeavours in Nigeria have undertaken exploratory measures to augment the integrity of cement soundness. The study conducted by Oyekan and Sani (2015) involved an examination of the effects of transportation on the quality of cement, as well as the identification of potential strategies to overcome the difficulties encountered in Nigerian ports.

FACTORS AFFECTING CEMENT SOUNDNESS

The soundness of cement, which is a crucial characteristic for guaranteeing the long-term resilience of concrete structures, can be impacted by a range of factors. Understanding of these factors is imperative in order to uphold the calibre and efficacy of Portland cement. There are several fundamental factors that have the potential to influence the soundness of cement.

The determination of the percentage expansion of the cement autoclave involves the calculation of the increase in length exhibited by the test bars. An observable rise in the percentage expansion can indicate potential structural instability or delayed expansion, which can be ascribed to several factors, including an excessive quantity of magnesia or the existence of unburnt lime (Certifiedmtp (2023).

1. Existence of Unstable Compounds: The constitution of cement, particularly the existence of compounds such as free lime (CaO) and magnesia (MgO), can exert a substantial influence on the soundness of the material. According to Mehta and Monteiro (2006), increased concentrations of these substances may result in delayed expansion, which can potentially compromise the structural integrity of concrete.

2. Environmental Factors: The impact of climatic fluctuations, encompassing temperature and humidity, is of paramount importance in determining the integrity of cement. The study conducted by Oyekan and Sani (2015) highlights the significance of environmental factors in influencing the quality of Portland cement within the Nigerian setting, which is characterised by a range of climatic conditions.

3. Storage Practices: Inadequate storage practises, such as the presence of moisture, have the potential to cause the formation of hydrates within the cement, which may lead to unsoundness. The significance of maintaining suitable storage conditions for preserving cement quality is underscored in research conducted by Fapohunda and Joshua (2019).

4. Challenges in Transportation: The transportation of cement, especially in areas with logistical difficulties, can have an impact on its integrity. In their study, Oyekan and Sani (2015) examine the impact of transportation on the quality of cement in Nigerian ports. They underscore the importance of cautious handling practises to mitigate potential problems that could undermine the integrity of the cement.

The reactivity and hydration characteristics of cement can be influenced by the fineness of its particles, potentially impacting its soundness. The process of finely grinding cement is crucial; however, an excessive reduction in particle size can lead to the development of unsoundness in the cement (Mehta & Monteiro, 2006).

6. The inclusion of additives or admixtures in cement compositions can have an effect on its integrity. Although the addition of specific additives may potentially improve performance, it is imperative to guarantee that their incorporation does not undermine the overall integrity of the cement.

LABORATORY PROCEDURE FOR CEMENT SOUNDNESS TEST

The cement soundness test, often conducted using the autoclave expansion method (ASTM C 151/C 151M-19), is crucial for assessing the potential for unsoundness in Portland cement. Here is a step-by-step laboratory procedure:

Materials and Equipment

i. Portland cement sample
ii. Mixer
iii. Vibrating table
iv. Molds
v. Vicat apparatus
vi. Autoclave
vii. Balance
viii. Calipers
ix. Graduated cylinder
x. Water

Procedure

1. Sample Preparation:
   a. Weigh the required amount of Portland cement sample (usually 500 grams).
   b. Mix the cement with water to form a homogeneous paste using a mixer.
   c. Fill the molds with the paste and compact using a vibrating table.

2. Initial Length Measurement:
   a. Measure the initial length of the cement specimen using calipers.
   b. Record the initial length.

3. Vicat Needle Test:
a. Perform the Vicat needle test using the Vicat apparatus to ensure the initial setting time has passed.

4. Autoclaving
   a. Place the molded specimens in the autoclave.
   b. Subject the specimens to high-pressure steam at a temperature of 216 ± 3°C for a duration of 3 hours.

5. Final Length Measurement
   a. After autoclaving, remove the specimens and allow them to cool to room temperature.
   b. Measure the final length of the specimens using calipers.
   c. Record the final length.

6. Calculation of Expansion
a. Calculate the expansion percentage using the formula:

$$Expansion\ (\%) = \left(\frac{Final\ length - Initial\ length}{Initial\ length}\right) x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(i)$$

7. Comparison with Standard
   a. Compare the calculated expansion percentage with the maximum allowable expansion specified in relevant standards, such as ASTM C 151/C 151M-19.

8. Interpretation
   a. If the expansion is within the specified limits, the cement is considered sound. If it exceeds the limits, the cement may be unsound.

Note: The mineral composition of the Portland cement was not taken into consideration in this test, as it solely focused on the Autoclave Expansion Test (AET). The correlation between the MgO content and the long-term expansion of cement pastes that have undergone moist curing at room temperature has been established by Gonnerman et al. (1957). The ASTM C150 standards establish limitations on the permissible amount of magnesia (MgO) present in cement, stipulating a maximum threshold of 6.0%. According to the ASTM C150 standards, it is mandated that the autoclave expansion of cement should not surpass 1.0%. If the specified limit is not adhered to, the cement will be rejected due to its unsoundness.

RESULT AND DISCUSSION

Three samples were prepared for each of the seven cement types and the autoclave test carried out on them. The result is presented in figure 1.

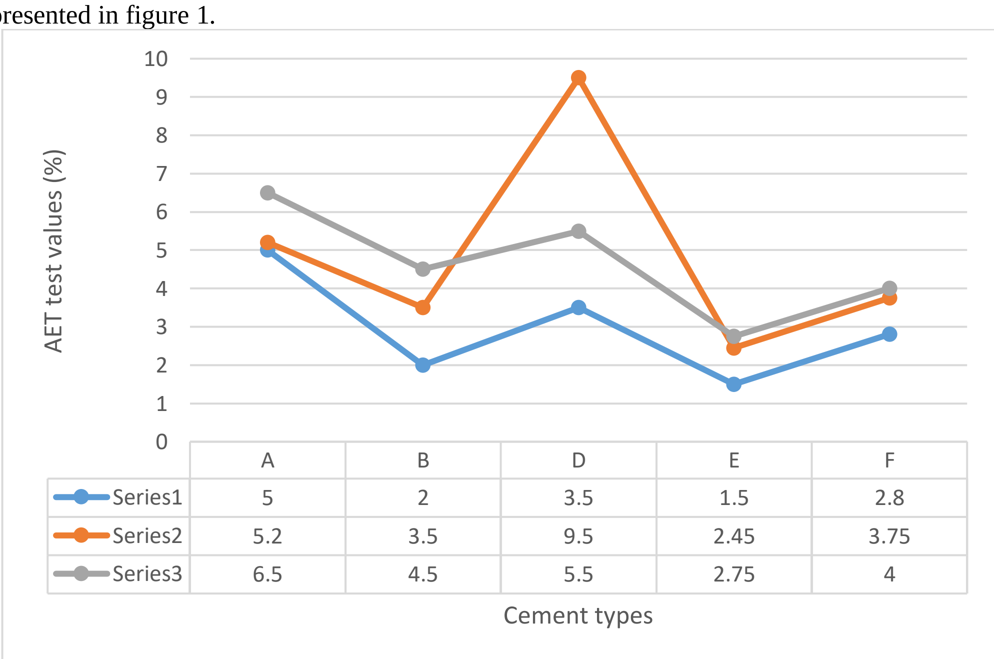

Figure 1. AET values for the samples

The average for the AET values for each cement type are 5.57%, 3.33%, 6.17%, 2.23% and 3.52% for A, B, C, D, E and F.

The Autoclave Expansion Test values offer valuable insights into the structural integrity of various cement types. Lower expansion values are typically associated with improved soundness and reduced risk of delayed expansion, thereby enhancing the overall quality of the cement. Nevertheless, it is crucial to take into account additional factors and specific requirements that are contingent upon the intended utilisation of the cement within construction contexts.

The Autoclave Expansion Test conducted on Type A cement yielded an average expansion rate of 5.57%. The aforementioned percentage denotes the alteration in the dimensions of the cement specimens subsequent to their exposure to the conditions prevailing within the autoclave. A higher percentage of expansion indicates an increased likelihood of structural instability, which can result in problems such as cracking and diminished longevity of concrete.

For Type B cement, the average expansion is 3.33%. Type A exhibits inferior soundness in comparison to Type B, as evidenced by its higher expansion value. The evidence indicates that Type B cement exhibits a reduced susceptibility to delayed expansion, thereby enhancing the overall performance of concrete.
The Autoclave Expansion Test conducted on Type C cement yielded an average expansion of 6.17%. Type C cement exhibits a higher expansion percentage in comparison to Types A and B, indicating a potential elevated susceptibility to unsoundness. This characteristic may have implications for its appropriateness in specific construction applications.

Type D cement demonstrates the least average expansion, with a value of 2.23%. The lower expansion value observed in Type D cement suggests a higher level of stability and integrity, implying that this type of cement is less susceptible to delayed expansion and related complications.

The average expansion of Type E cement is 3.52%. The observed value is situated within the range of expansion values exhibited by Types B and C, suggesting a moderate degree of soundness. The findings indicate that Type E cement exhibits a moderate propensity for delayed expansion in comparison to alternative types.

The average expansion of Type F cement is 3.52%. The observed value aligns with Type E, indicating comparable attributes of soundness. Nevertheless, it is imperative to take into account supplementary variables like compressive strength and setting time in order to conduct a thorough evaluation of cement excellence.

The Implication of the test
A greater degree of expansion indicates a possible susceptibility to unsoundness. The cement exhibits an increased susceptibility to delayed expansion, thereby potentially resulting in the occurrence of cracks and a subsequent decrease in the overall durability of the concrete.

A lower expansion level demonstrates greater soundness in comparison to Type A. Type B cement exhibits a reduced susceptibility to delayed expansion, thereby implying superior performance in various concrete applications.

The type with the highest expansion value. Type C cement presents a potentially elevated susceptibility to unsoundness, thereby prompting apprehensions regarding its appropriateness for specific construction purposes.
A minimal expansion is indicative of soundness. Type D cement exhibits a reduced susceptibility to delayed expansion, rendering it a comparatively more stable alternative for the construction of concrete structures.
The concept of moderate expansion implies a moderate level of vulnerability to instability. Type E cement is characterised by expansion values that lie between those of Types B and C, suggesting a moderate degree of soundness.

Similar to Type E, characterised by a moderate degree of expansion. The cement exhibits a moderate level of soundness, and it is important to consider additional factors such as compressive strength and setting time.

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CONCLUSION

The Autoclave Expansion Test results offer significant insights into the integrity of different cement types (A, B, C, D, E, and F). The implications derived from the mean expansion values present significant factors to be taken into account when choosing and utilising these cements in the field of construction. The selection of cement types is guided by the results of the Autoclave Expansion Test, which assesses their soundness characteristics. A thorough examination of these findings, in conjunction with a comprehensive assessment of other cement characteristics, will enhance the efficacy and longevity of construction endeavours.

The Autoclave Expansion Test is an essential indicator of possible unsoundness, which has a significant impact on the durability and performance of concrete structures. Types B and D typically exhibit lower expansion values, which are associated with improved soundness and stability. Conversely, Types A and C tend to have higher expansion values, indicating a greater likelihood of delayed expansion. In order to conduct a comprehensive evaluation, it is imperative to take into account additional attributes of cement such as compressive strength and setting time, alongside expansion values.

RECOMMENDATIONS

- For applications demanding high durability and reduced risk of unsoundness, Types B and D may be preferable.
- Types A and C, with higher expansion values, should be approached cautiously, considering the potential implications for long-term structural performance.
- Types E and F, with moderate expansion values, may be suitable for applications where a balance between soundness and other properties is essential.

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