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Review Study on Stabilized fly ash Type C as Admixture in Sub-Grade of Pavement

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Abstract: Fly ash, also known as the residues of fine particles that formed with flue gases is a by-product which can be found at thermal power stations. There are two types of fly ash, which are Type C and Type F. This material can be used in construction of buildings or infrastructures as a new alternative to reduce material costs if the material can achieve an adequate performance as a construction material. With the use of fly ash, Portland cement usage can be reduced hence it promotes sustainable development. The aim of this study are to evaluate the engineering properties and adequacy of stabilized fly ash Type C as an admixture to stabilize sub-grade soil. Several past researches are reviewed to study the chemical and physical properties of stabilized fly ash Type C and they conducted various tests such as unconfined compression test, California Bearing Ratio (CBR) test, and resilient modulus test on the soil specimens containing stabilized fly ash Type C material. It was found that fly ash Type C with almost optimum water content (less than 5%) significantly increase the compressive strength, CBR value and resilient modulus of stabilized soil when mixed. Therefore, these researches showed that fly ash-stabilized material (FASM) significantly improve bearing resistance and stiffness of sub-grade in a road pavement.

Keywords: Fly Ash, Compressive Strength, Resilient Modulus, California Bearing Ratio, Pavement, Fly Ash-stabilized Material.

1. Introduction

In modern-day society, roads and highways are undeniably important as they have become one of our basic necessities, especially with the rise of technologies along with the modernization and transformation of lifestyle for future generations. Roads and highways are like networks which are used to connect cities and states all around the globe, therefore it is considered very important for people to enable a safe passage to their destination whether it is their workplace, educational complex, and residential area. It is a crucial component for the growth of a city or even a country in terms of economy

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and development. Over the past few decades, the need for additional roads and highway networks and improvements in several regions had drastically increased [1].

Pavement is one of the main component in the process of road design and construction works. Better quality of pavement is equivalent to better quality of transportation, which has been an essential element of technology in modern-day. Pavement is the durable surfacing of a road, airstrip, or similar area. The main function of a pavement is to transmit loads to the sub-base and the soil beneath it [2]. Nowadays, modern flexible pavements are consist of sand and gravel or crushed rocks compacted with a binder of bituminous material, such as tar, asphalt, or asphaltic oil. In order to absorb shock, the pavement are designed to have enough plasticity properties. Another type of pavement which is the rigid pavement, is made of concrete, composed of coarse aggregate, fine aggregate, and Portland cement. It is usually reinforced with steel rod or mesh.

In highway engineering, subgrade layer or formation level is the native material underneath a constructed road, pavement or railway tracks. A subgrade is very important to withstand repeated load that applied by the traffic [3]. The next layer is sub-base that refers to the layer of aggregate material laid on the subgrade, on which the base course layer is located. The materials used in making sub-base layer may be either granular, or cement-bound [4]. Base course is the layer directly constructed on sub-base layer or subgrade, if sub-base layer is not applied. This layer provides a stable foundation needed to support either additional layers of aggregates or the placement of an asphalt concrete wearing course which is applied directly on it [5]. However, it is suggested that poor mix proportioning practices and a high variability in aggregate gradation directly influenced the constructability of pavements [6].

Fly ash, a waste by-product is produced when coal is consumed to generate electric energy in power generating plants [7]. This material is primarily composed of alumina, silica, and calcium contents [8]. It has two different types, which are Type C and Type F. Fly ash is proved to have similar physical and chemical properties as cement [9]. Fly ash also can be used as land filler which improves soil properties and also acts as stabilizer [10]. It is found that Type C fly ash does not require any other activator to improve the engineering properties of a soft subgrade soil [11]. Fly ash-stabilized soil also can enhance engineering properties according to the study conducted [12].

2. Research Methodology Process

Peer-reviewed academic papers written with the associated keywords were found using the search engines "Scopus" and "Google Scholar," which are known as the most extensive citation and abstract collection of peer-reviewed literature, scholarly journals, conference proceedings, and books. The first steps of the analysis. A study was undertaken to allow the formulation of the keywords used in performing searches. Figure 2.1 shows the diagrammatic representation of the methodology process. A comprehensive and systematic search is conducted under the title, abstract and keyword fields in both datasets utilizing the Boolean search technique and keywords. Boolean operators AND, OR and NOT are used to find perfect search criteria by merging or limiting terms. The combination of the following keywords and the Boolean operators will be used for the first stage of the review: 'Bitumen AND fly ash' OR 'pavement' OR 'construction AND pavement' OR 'bitumen AND asphalt'.

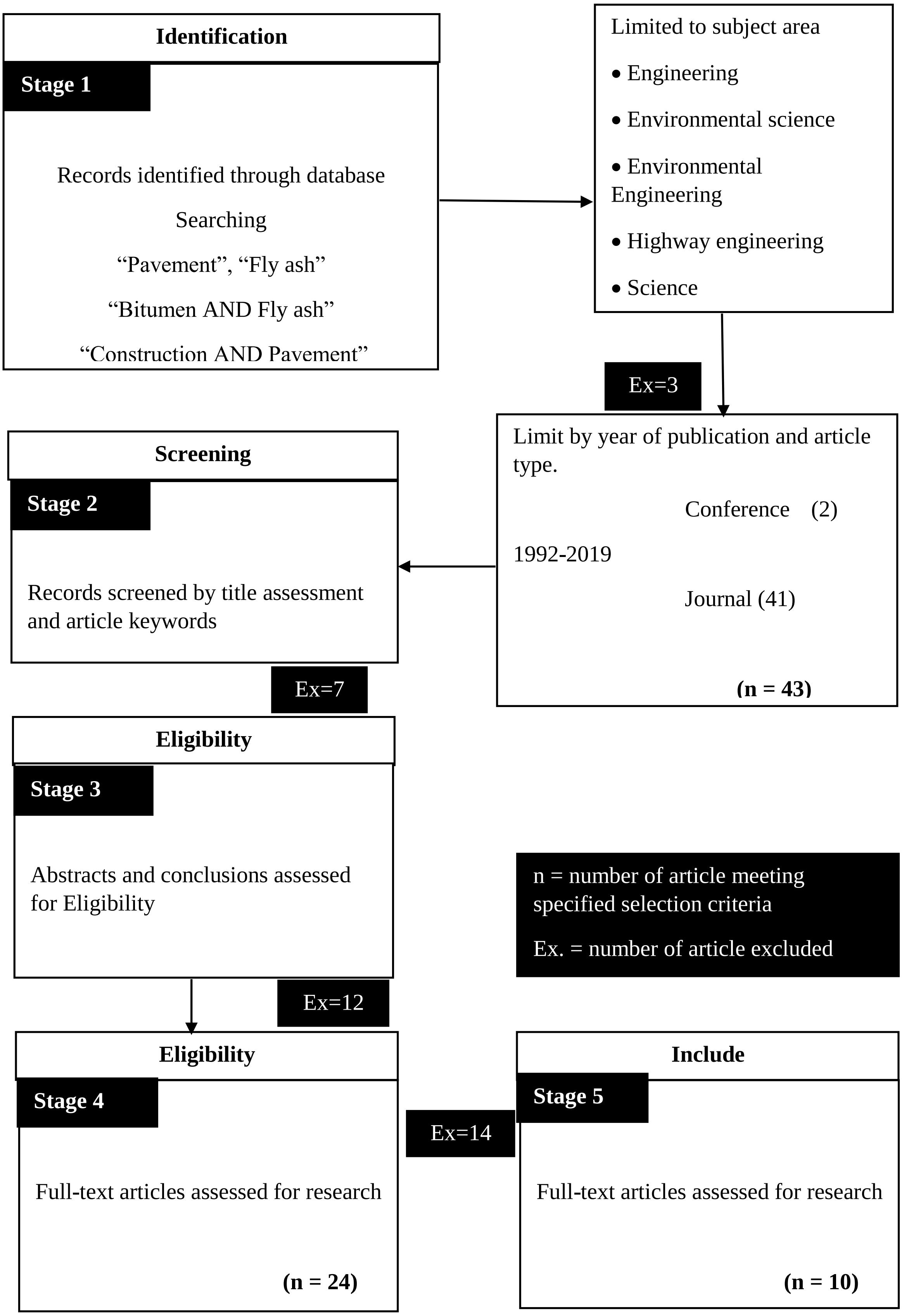

Figure 2.1: The procedure of methodology

A total of 52 papers were returned to the first step of the Journal Review Process. It is important to make the error of collecting too many articles that may potentially be filtered out rather than collecting too few, which could result in certain articles being lost. The findings were then filtered by topic field and restricted to infrastructure, agricultural science, environmental engineering, highway engineering and technology. The subject areas used for the first stage of filtering were determined based on the observation that most of the search results initially returned 52 papers were written in the subject areas, contributing to the withdrawal of 6 articles. The findings were also filtered by a form of text, e.g., conference and journal articles, and the year of release (e.g., 1990-2020), which lead to the elimination of three documents, leaving 43 papers to progress to the next level.

The second stage of the systematic analysis phase included screening the search results by reviewing the titles and keywords of the publications and evaluating their eligibility for inclusion by determining the titles and keywords' appropriateness. This process contributed to the elimination of 7 papers, leaving 36 to proceed to the next level. In the third stage of the systematic review, the articles' abstracts and conclusions were read in detail to assess their eligibility for inclusion; this led to removing 12 documents, leaving 24 documents to proceed to the next stage. The fourth stage of the review entailed reading the full texts of all the selected papers. The introduction section's main aim, the methodology adopted, the gaps identified, and the papers' main contributions were given to the introduction section. This led to eliminating 14 articles, leaving only 10 articles in the fifth stage to do a final review and comparison among the research.

3. Results and Discussion

Based on the previous research papers that are reviewed and assessed in this research, unconfined compression tests are carried out to observe the relationship of moisture content and unconfined compressive strength (UCS) of soil [11]. The test is also conducted to investigate the impact of delay in soil compaction. As for the result, it is found that by adding fly ash Type C for soil stabilization significantly heighten the strength of soil. The maximum strength also proportionally increased when more fly ash Type C content is added. Optimum strength of soil is achieved at almost optimum moisture content (1% wetter). Due to 2 hours compaction delay, the maximum strength decreased by approximately 20% [11]. Another study also conducted unconfined compressive test on organic soil samples which compared both fly ash Type C (also known as Type I) and Type F (also known as Type II) [13]. In that test, it is found that the UCS of both organic soil specimens which contain Type C and Type F contents increases with the increment in fly ash contents. However, it is determined that Type C is slightly better than Type F when the UCS of soil added with Type C contents is slightly higher than the UCS of soil with Type F contents. UCS of both samples also improved with the increment of curing period [13]. Figure 3.1 and 3.2 shows the results of the unconfined compressive tests.

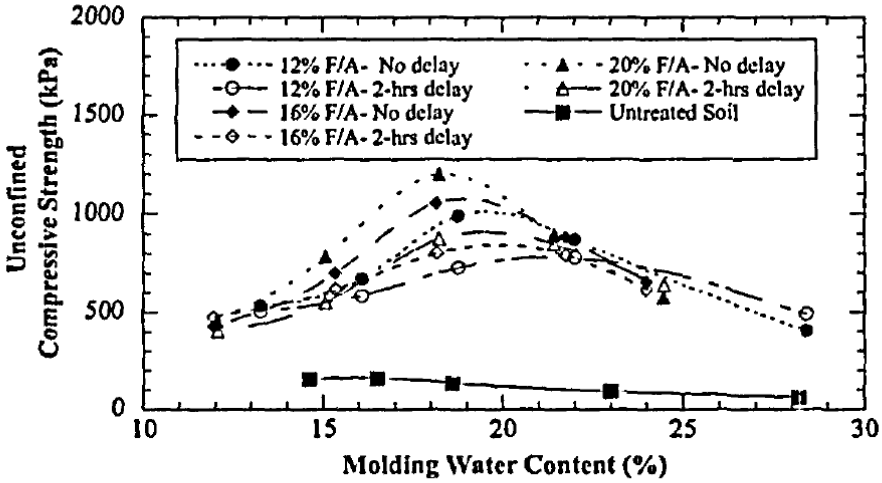

Figure 3.1: UCS of stabilized soil with fly ash content at different moulding moisture contents [11]

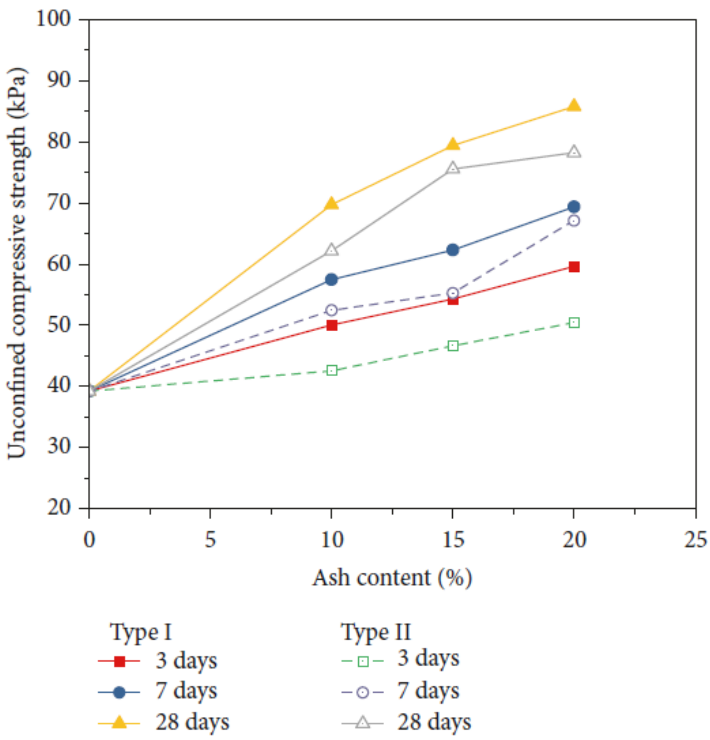

Figure 3.2: Relationship of UCS with ash content [13]

A California Bearing Ratio (CBR) test is conducted on sub-grade soil which is soft clay soil to be mixed with fly ash Type C contents [14]. They added fly ash-stabilized material (FASM) and found that the CBR value of the stabilized sub-grade soil sample is slightly higher than the sub-grade soil sample without FASM. However, there are a huge difference of CBR value between laboratory-mix and field-mix. Another research also carried out CBR test in accordance with ASTM D 1883-87 for stabilized soil samples with different contents of fly ash Type C at optimum moulding moisture content (1% wet), based on the maximum UCS of sample [11]. In this test, they found that with the increment of fly ash content, the CBR value of stabilized soil also increased. However, the CBR value decreases by approximately 18% with 2 hours delay of soil compaction. Figure 3.3 and 3.4 shows the results of this test.

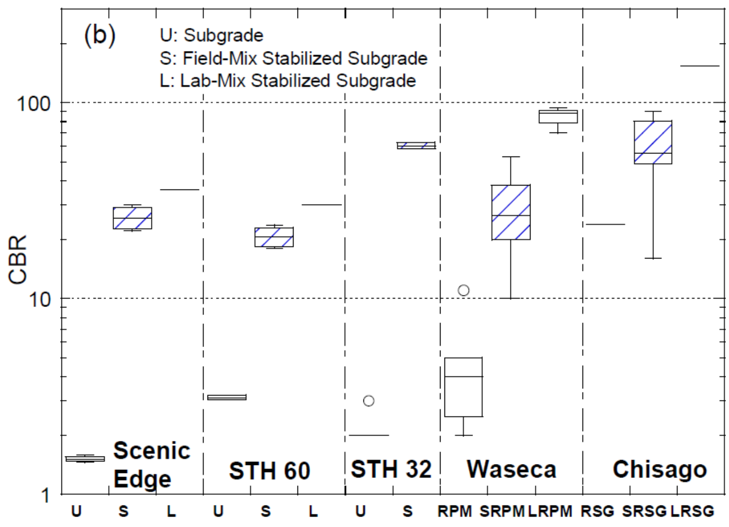

Figure 3.3: Box plot of CBR of sub-grade soil with FASM of both mix after curing of 7 days [14]

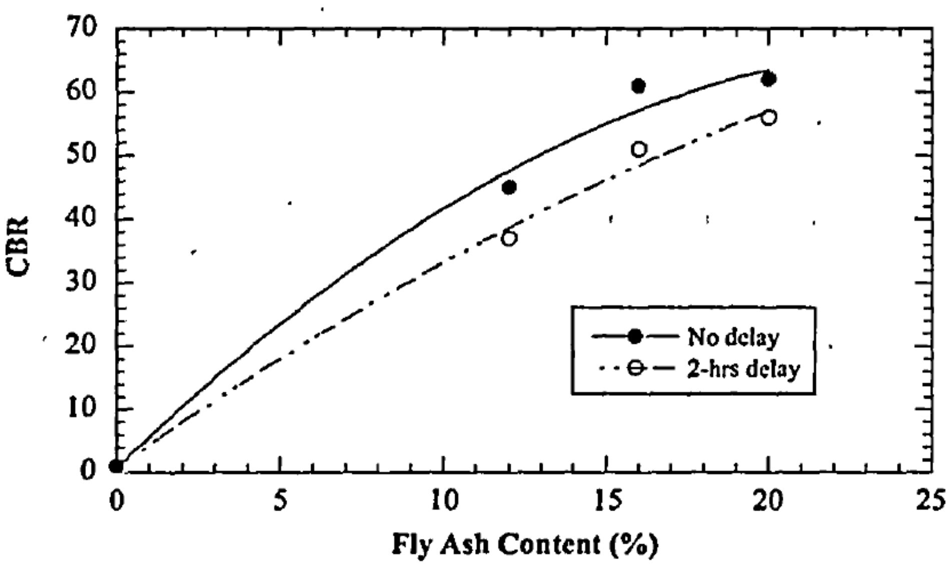

Figure 3.4: CBR of stabilized soil at different contents of fly ash [11]

Resilient modulus test on sub-grade soil is also conducted [14]. These resilient moduli reacted to 21 kPA deviator stress that depicting a common state within a base course of pavement [15]. The results showed that resilient modulus increased slightly when fly ash contents are added to the soil. Another study also carried out a resilient modulus test as well. They followed AASHTO Standard T 294-94, because fly-ash stabilized soil is considered as a cohesive soil [11]. It is conducted using soil samples which contain different content of fly ash percentage while keeping the moisture content the same as they used in CBR test. This test however, is applied only to the samples that experience 2 hours delay in compaction. The results yielded that the modulus of resilient also shows an increment if more content of fly ash are added to the soil samples. Figure 3.5 and 3.6 shows the results obtained through the tests.

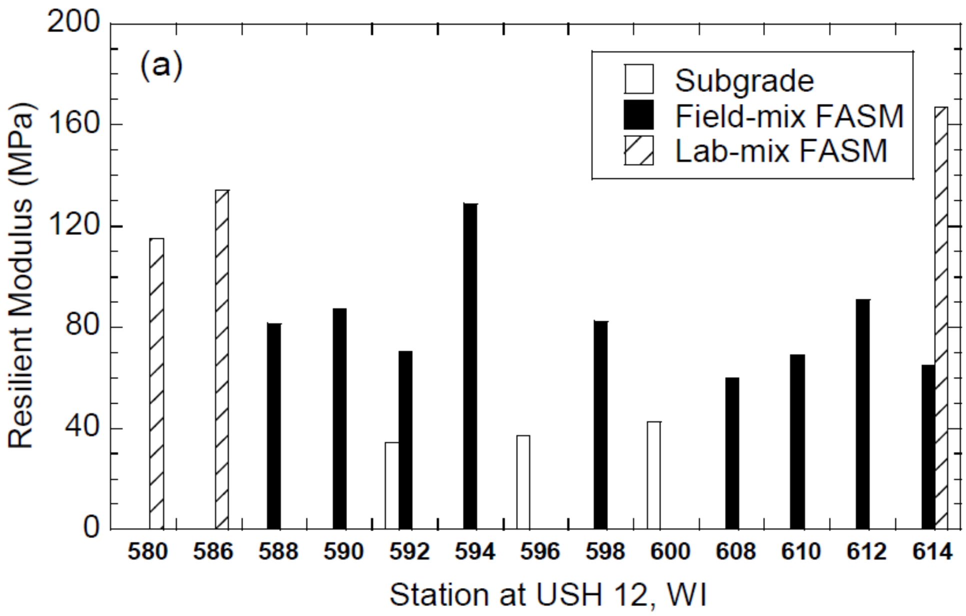

Figure 3.5: Resilient modulus of stabilized sub-grade soil with fly ash contents after curing for 14 days [14]

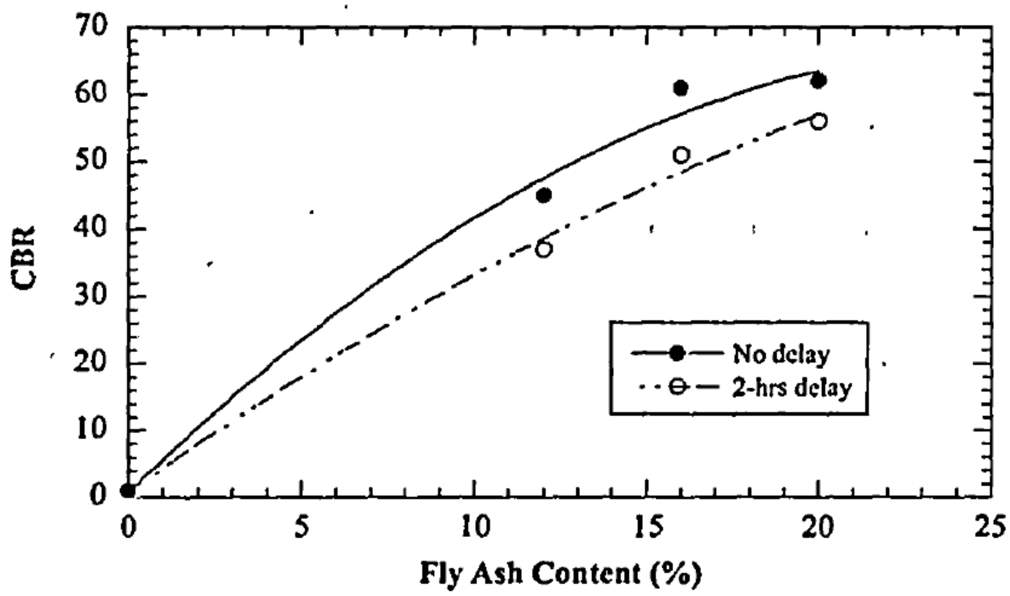

Figure 3.6: CBR value of stabilized soil at different percentage of fly ash content [11]

In this research, it is found that fly ash Type C content with almost optimum water content (1% wetter) significantly affects the compressive strength, CBR value, and resilient modulus of stabilized soil when mixed. By increasing the fly ash content in the stabilized soil, the compressive strength, CBR value, and resilient modulus will increase as well (Senol et al., 2002). Research by Li et al. (2009) also showed the same information in CBR test and resilient modulus test. However, they found that there is a significant difference with the results obtained from laboratorial tests and field tests. It is concluded that FASM significantly improve the bearing resistance and stiffness of sub-grade soil.

Conclusion

In a nutshell, all of the objectives of this research were achieved. Based on the findings, it can be concluded by mixing fly ash-stabilized material (FASM) with subgrade soil or base, the engineering properties such as unconfined compressive strength, resilient modulus, and CBR value will improve significantly hence increasing the bearing resistance, stiffness, and service life of the pavement. A strict control of water content during stabilization process is required in order to maximize the compressive strength. However, a delay in compaction of fly ash-stabilized soil mix can hugely reduce the compressive strength. These aspects must be considered thoroughly in design and construction to avoid the loss of strength during construction works.

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