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Research Paper

Improvement of Pambal Laterite by Adding Fly Ash for High-Performance Pavement Design

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ABSTRACT

In the context of improving the overall service level of communications in Senegal through the construction of next-generation transport infrastructure, this study focuses on methods for upgrading road materials to contribute to the design of high-performance pavements. The objective is to improve the quality of low-bearing lateritic soils for their use in road construction.
The methodology involves a geotechnical characterization of laterite from the Pambal quarry (Tivaouane Department, Thiès Region, in western Senegal), followed by experimental testing of mixtures treated with fly ash from the Senegal Chemical Industries (ICS) in Mboro. Laboratory tests revealed a significant improvement in mechanical properties, with the California Bearing Ratio (CBR) increasing from 77 to 153 at a 4% fly ash content.
These findings confirm the technical feasibility of this approach and highlight a sustainable, cost-effective, and eco-friendly alternative to traditional stabilization methods. The combined use of local laterite and industrial by-products opens new perspectives for the development of the national road network.

Keywords: CBR index, improvement, fly ash from ICS Mboro, high-performance pavement, Pambal laterite

INTRODUCTION

The Government of Senegal has launched a large-scale program aimed at improving the overall service level of communications through the construction of next-generation transport infrastructure. The road network represents one of the country's most important common assets, belonging essentially to the State. It is a heritage that must be maintained, operated, improved, and preserved. Pavement maintenance remains a major challenge in Senegal, particularly for roads with heavy traffic. Extending the service life of pavements is a key concern in the road sector and depends largely on their high performance.

Fly ash is a by-product of coal combustion in thermal power plants [1]. Rich in silica and alumina, it exhibits pozzolanic properties that enable it to react to form stronger compounds. This reaction contributes to the improvement of the physical and mechanical characteristics of lateritic soils, such as bearing capacity, compressive strength, and durability.
This study demonstrates that the incorporation of fly ash into lateritic soils significantly enhances their geotechnical performance [9]. The results generally depend on the percentage of fly ash added. With 4% fly ash, the CBR index increased from 77 to 153. This improvement opens promising perspectives for the construction

of roads, embankments, and civil engineering structures at lower cost in developing countries [2].
Thus, the enhancement of laterite with fly ash constitutes an effective and sustainable alternative for strengthening construction soils while contributing to the management of industrial waste.

MATERIALS & METHODS

The fly ash used in this study was obtained from the Senegalese Chemical Industry plant in Mboro, a town located 119 km from Dakar (Senegal).
The laterite was sourced from the Pambal quarry, a village situated 100 km from Dakar (Senegal).
Table 1 and Figure 1 show the location of the Pambal quarry.

Table 1: Limit coordinates of the Pambal quarry

N° Limite	Coordonnées	
	X(m)	Y(m)
L1	295652.61	1651866.86
L2	296390.43	1652176.10
L3	296262.41	1652481.55
L4	295524.59	1652172.32

Fig 1: Location plan of the Pambal quarry

The laterite samples collected were analyzed in the laboratory according to the following testing program:

- Particle size analysis (by sieving) [3] ;
- Modified Proctor test [4] ;
- Atterberg limits [5] ;
- CBR test [6].

Subsequently, a series of samples was treated with different dosages of fly ash to determine the most effective proportion. Each CBR value was obtained at the optimum moisture content and maximum dry density, after 3 days of air curing followed by 4 days of water immersion [7–11].

RESULT

The tests carried out made it possible to identify the characteristics of both the untreated and the improved laterite at percentages from 1% to 5%. The results obtained are summarized in Table 2 and Figure 2.

Table 2: Summary of results on the enhancement of Pambal laterite

STUDY OF PAMBAL LATERITE + ASH						
PERCENTAGE	% of fines on the 0.080 mm sieve	A.L.		δd max	w%	CBR
		WL	IP			
UNTRETED LATERITE	15.0	43	20	1.925	9.6	77
LATERITE + 1% ASH	12.8	40	19	1.931	9.2	88
LATERITE + 2% ASH	15.2	42	19	1.908	10.3	92
LATERITE + 3% ASH	17.6	40	17	1.944	10.6	136
LATERITE + 4% ASH	20.0	39	16	1.923	11.0	153
LATERITE + 5% ASH	22.6	39	15	1.928	10.7	91

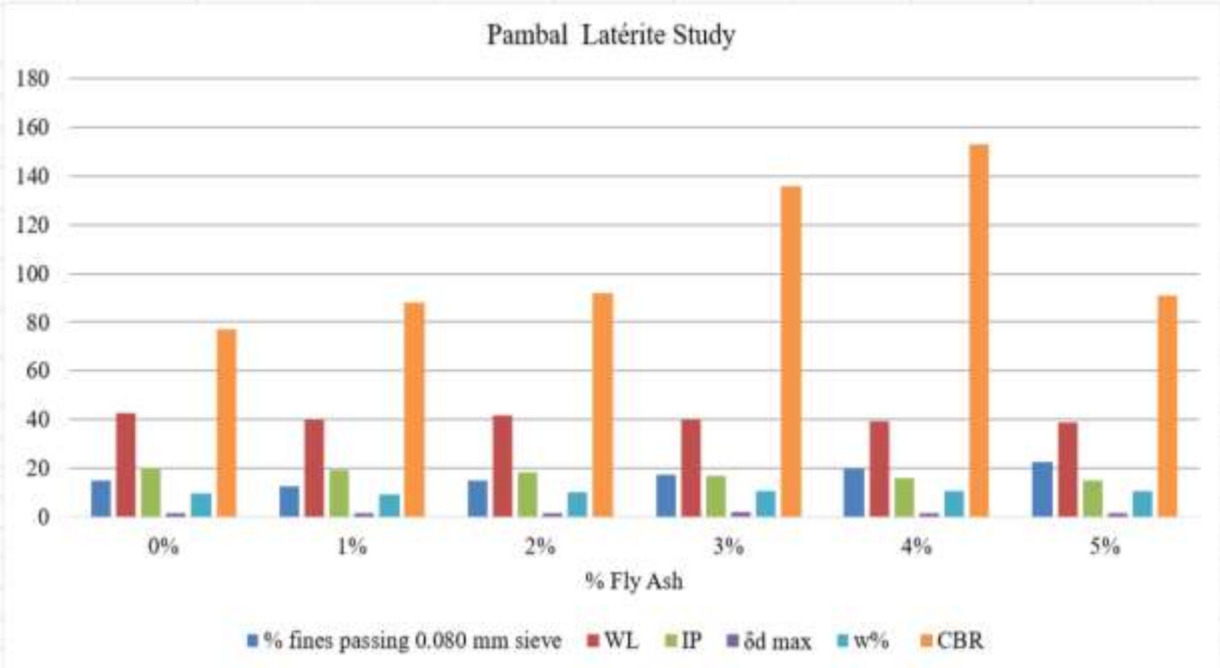

Fig 2: Study of the improved Pambal laterite

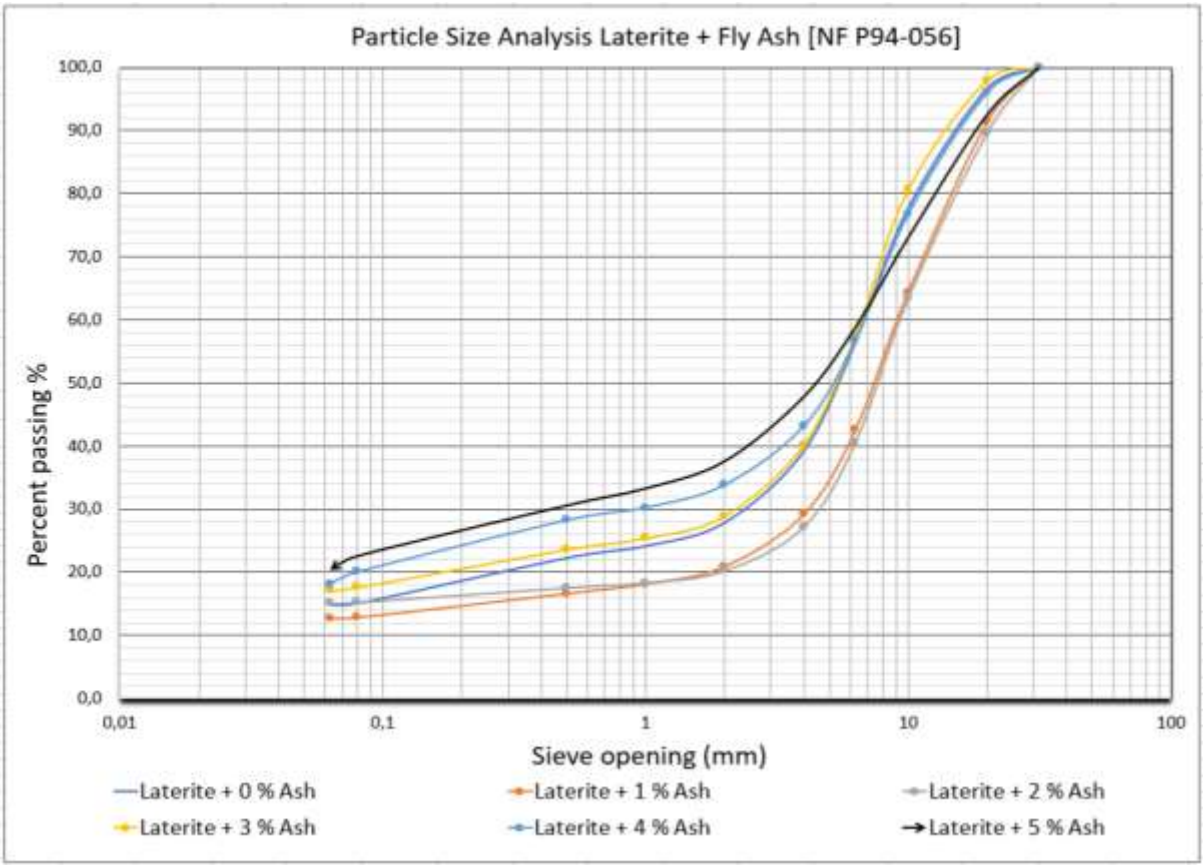

Fig 3: Particle size analysis of the Pambal laterite with different ash percentages

The Figure 4 shows the Proctor curves.

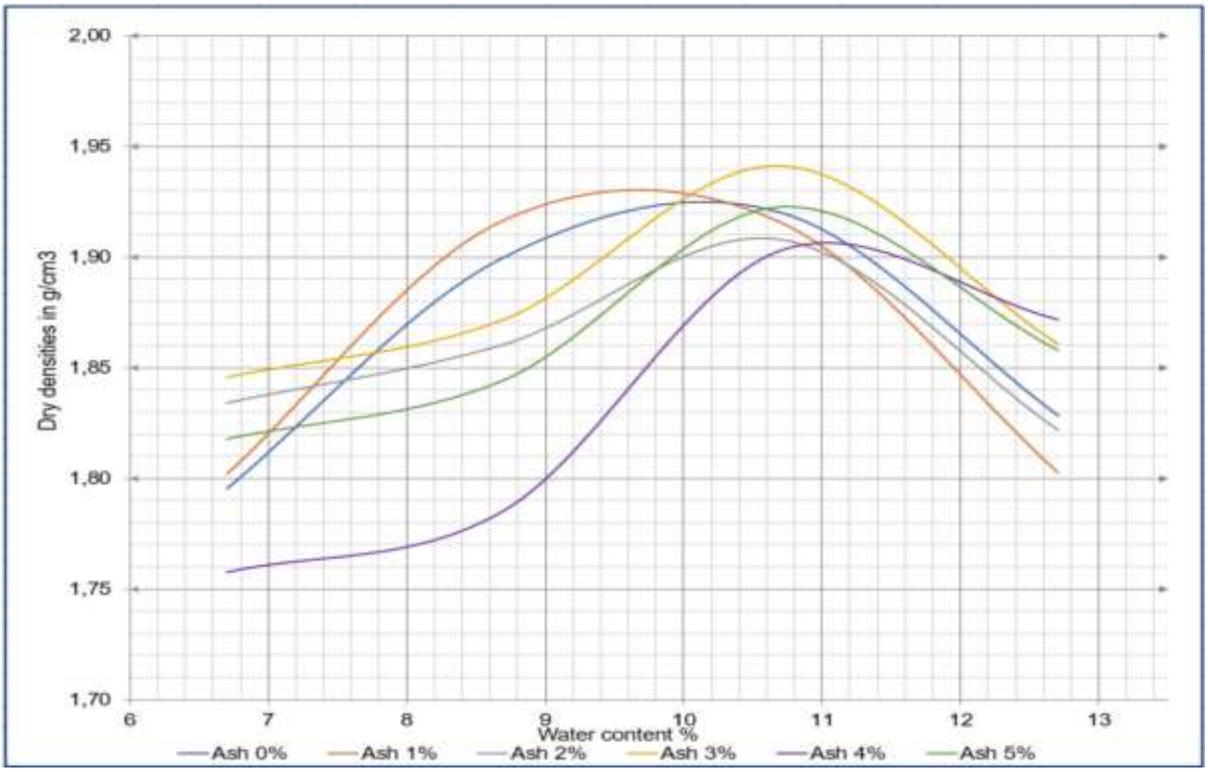

Fig 4: Proctor curves of fly ash-improved laterite

The Figure 5 shows the bearing capacity of each sample, i.e., ifs resistance to failure, determined by the CBR test (California Bearing Ratio), also referred to as the California bearing capacity test.

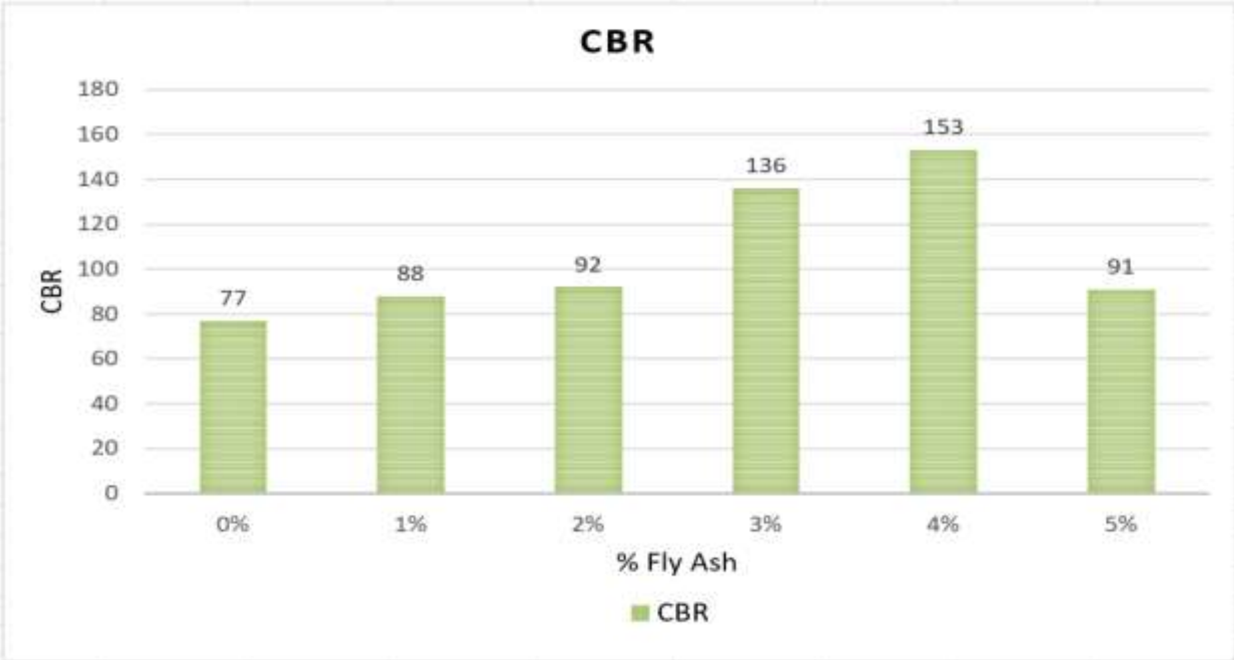

Fig 5: CBR of fly ash-improved laterite

We observe that the CBR index evolves as follows:

- 77 for natural laterite;
- 88 with 1% ash;
- 92 with 2% ash;
- 136 with 3% ash;
- 153 avec with 4% ash;
- 91 with 5% ash;

DISCUSSION

This evolution shows a significant improvement in bearing capacity up to 4% fly ash, the dosage at which the maximum strength is obtained with a CBR value of 153 [6]. Beyond this content, the excess fly ash causes a decrease in strength, dropping to 91 for a dosage of 5%.
The incorporation of fly ash significantly enhances the mechanical performance of laterite up to an optimal threshold. The optimal dosage is 4% fly ash, as it provides:

- Improved bearing capacity (CBR = 153);
- Good stability;
- Satisfactory compaction;
- Overall enhancement of geotechnical properties.

CONCLUSION

At the end of our work, we note that the CBR increases from 77 for the natural laterite to a maximum value of 153 with a 4% ash content, indicating a significant improvement in the material's strength and stability. Conversely, adding 5% leads to a decrease in the CBR, revealing an overdosing effect detrimental to geotechnical performance.
Therefore, the optimal dosage is determined to be 4% ash, which offers the best compromise between compaction and mechanical strength. This mixture can be recommended for use in pavement layers, particularly as a foundation layer for high-performance pavements.

Declaration by Authors
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