Valorization of Road Construction Waste: Case of the Mboro–Diogo Road Section (Senegal)

Abstract

Given the growing scarcity of high-quality road construction materials and persistent budgetary constraints, recycling materials from road demolition represents a relevant technical and economic alternative in Senegal. This study assesses the feasibility of separately recycling lateritic gravels from the base and sub-base layers of a pavement to be rehabilitated, with a view to reusing them as a sub-base layer in a context of expanding transport infrastructure.

The materials were sampled at three boreholes (S1, S2, S3) on the Mboro–Diogo road in Senegal and blended with raw lateritic gravels from the Keur Samba Kane (KSK) quarry at three incorporation rates: 30%, 50%, and 70%. A comprehensive set of identification tests was carried out, including particle-size distribution analysis, Atterberg limits, the Proctor test, and CBR measurement.

The results show that incorporating KSK lateritic gravels significantly improves the mechanical performance of the blends. The fines content decreases progressively as the incorporation rate increases, while the CBR index improves steadily, reaching up to 77 for S1 at 70% incorporation rate.

With respect to the specifications required for a sub-base layer, the blend with 50% raw lateritic gravels (KSK) appears to be the most suitable. It offers an optimal compromise between mechanical performance and plasticity stability, and thus constitutes a viable solution for reusing reclaimed pavement materials.

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Key words:

Mboro-Diogo road section, road waste, CBR, lateritic gravels, Recycling

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Introduction:-

For several years, Senegal has made a sustained effort to develop and modernize its road network. The classified paved road network grew from 5,304 km in 2013 to 6,569 km in 2021, reflecting a significant expansion of transport infrastructure [1], [2]. This growth in the road asset base inevitably generates an increase in rehabilitation needs.

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However, this momentum faces two major constraints: first, the progressive scarcity of good-quality road materials, a non-renewable resource subject to increasing extraction pressure; and second, the limited financial resources available for rehabilitation works in a constrained budgetary context. In this setting, the reuse of materials from the dismantling of existing pavements emerges as an unavoidable avenue, from both environmental and economic standpoints.

This approach is thus consistent with a circular economy logic applied to the road sector, by promoting the reuse of materials from dismantled pavements, reducing the extraction of natural resources, and decreasing waste, in line with the Sustainable Development Goals (SDGs), notably SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 12 (Responsible Consumption and Production).

Lateritic gravels can be defined as loose soils formed in tropical environments, comprising a granular fraction made of pisoliths or ferruginous nodules embedded in a fine silty-clayey matrix [3]. They are the road construction material of choice throughout sub-Saharan Africa and are widely used for base and sub-base layers [4], [5]. In Senegal, recycling operations essentially consist of in-place reprocessing of the pavement, combining the base and

sub-base layers of treated or untreated lateritic gravels with the asphalt concrete wearing course. However, this approach has the drawback of using high-grade materials in the sub-base when they could be reserved for the wearing course.

The present study proposes an alternative approach: recycling the lateritic gravels from the base and sub-base layers separately, without mixing them with asphalt concrete, so that they can be reused directly as a sub-base layer. In parallel, this approach would allow the asphalt concrete to be directed to a dedicated recycling stream. To assess the technical feasibility of this approach, blends of lateritic gravels from the dismantled Mboro–Diogo road and raw lateritic gravels from the Keur Samba Kane quarry were prepared at three different incorporation rates and then subjected to a comprehensive series of geotechnical identification tests. The objective is to verify the compliance of these blends with the technical specifications required for use as a road sub-base layer, and to determine the incorporation rate that satisfies these requirements while maximizing the proportion of recovered materials.

Materials and methods :-

The study is based on samples taken at three points, S1, S2, and S3 (Figure 1), located between chainage (PK) 3+440 and 3+690, from the 20-cm-thick base layer of cement-treated lateritic gravels of the Mboro–Diogo road, as well as on raw lateritic gravels from the Keur Samba Kane (KSK) quarry. The Mboro–Diogo road section is located approximately 117 km from the Dakar region in Senegal. Data on the age of the pavement or the cement content used in the base layer are not available; however, visual observation shows a superposition of several layers of double-layer surface dressing and, in places, asphalt concrete, attesting to the multiple maintenance operations carried out on this road. The cumulative traffic class established in the studies for the rehabilitation of this road is class C6 [6]. This road plays an essential economic role in the transport of horticultural products from the Niayes zone.

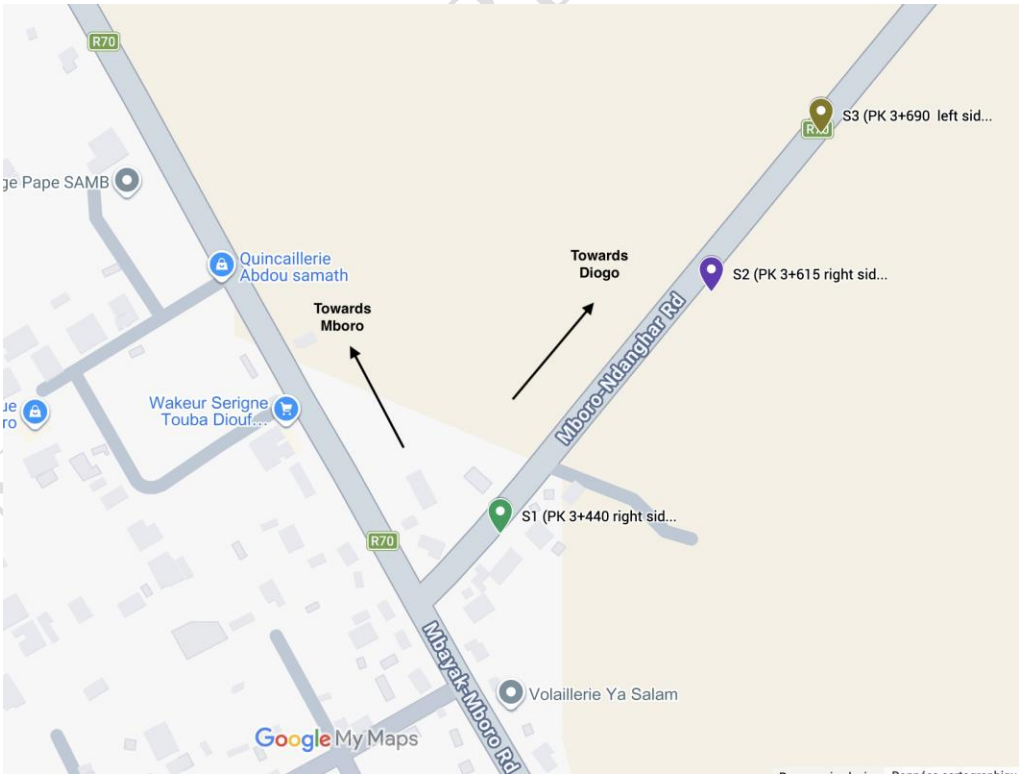


Figure 1: Location of the three survey points

The village of Keur Samba Kane (KSK) is located approximately 107 km from Dakar. The blends studied were prepared by incorporating KSK lateritic gravels at rates of 30%, 50%, and 70%. A comprehensive series of identification tests, in accordance with the applicable specifications [7], was carried out. It includes particle-size distribution analysis [8], determination of Atterberg limits [9], the Proctor compaction test [10], and CBR index measurement [11].

Figure 2 outlines the methodology adopted for the study.

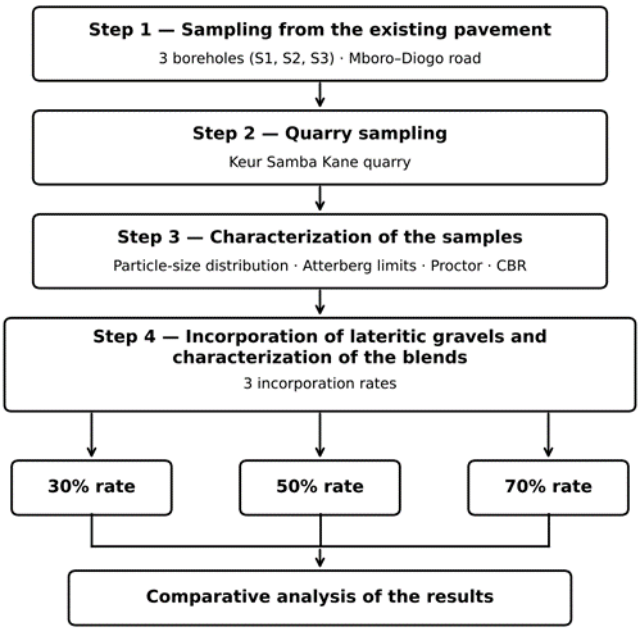


Figure 2: Study procedure

Figure 3 shows photographs of survey point S1 as well as the blends and sample preparation for testing at a 70% KSK incorporation rate.







Figure 3: Sampling, blending and material testing

Results and discussion:-

The following tables report the characterization of the base materials and then of the different blends. The fines content is defined as the percentage passing the 80 µm sieve. It should be noted that, in these tables, there is no direct correlation between the fines content and the plasticity index on the one hand, nor between the fines content and the CBR index on the other.

Table 1 presents the results obtained for the samples from S1, S2, and S3 and for the Keur Samba Kane (KSK) quarry lateritic gravels.

Table 1: Results for the initial materials

Origin	**S1**	**S2**	**S3**	**KSK**
Fines content (%)	28.9	25.7	37	11.3
Liquid limit (%)	36.5	51	42.3	31.6
Plastic limit (%)	15.8	28.1	21.7	16.8
Plasticity index (%)	20.7	22.9	20.6	14.7
Maximum dry density (g/cm³)	1.96	1.91	1.94	2.165
Optimum moisture content (%)	11.61	11.36	11.36	7.6
CBR (95% OPM)	17	12	14	70

The mixture incorporating 30%, 50% and 70% of lateritic gravels from Keur Samba Kane (KSK) into the sample from survey point S1 along the Mboro–Diogo road corridor yield the results presented in Table 2.

Table 2: Results for the S1–KSK mixtures

Ratio	**100% S1** **0% KSK**	**70% S1** **30% KSK**	**50% S1** **50% KSK**	**30% S1** **70% KSK**

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Parameters				
Fines content (%)	28.9	19.5	19.7	14.1
Liquid limit (%)	36.5	45.8	40.3	42.1
Plastic limit (%)	15.8	24.4	19.1	22.8
Plasticity index (%)	20.7	21.4	21.2	19.3
Maximum dry density (g/cm³)	1.96	2.077	2.177	2.156
Optimum moisture content (%)	11.61	9.5	9	7.5
CBR (95% OPM)	17	49	52	77

Figure 4 shows the evolution of the particle-size distribution of S1 as a function of the KSK lateritic gravel incorporation rate.

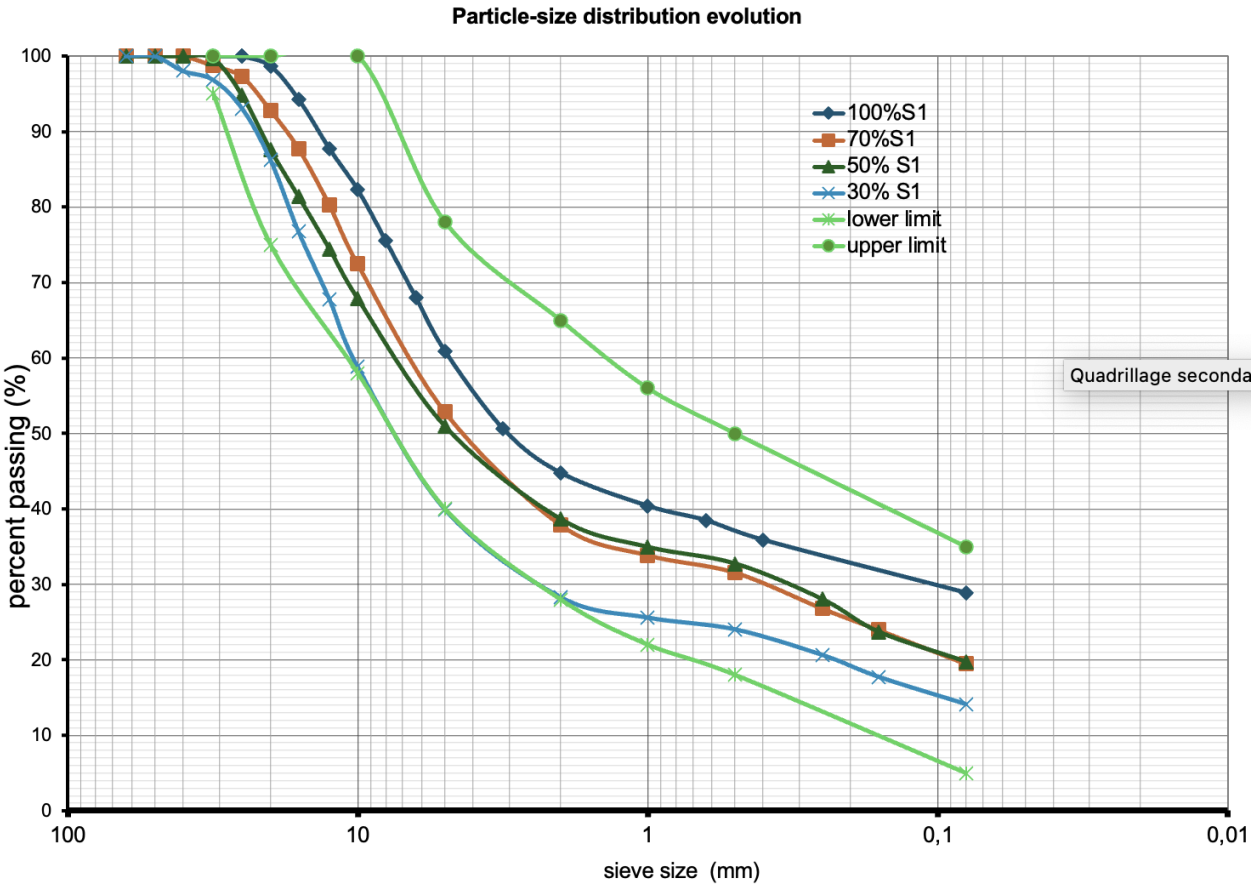


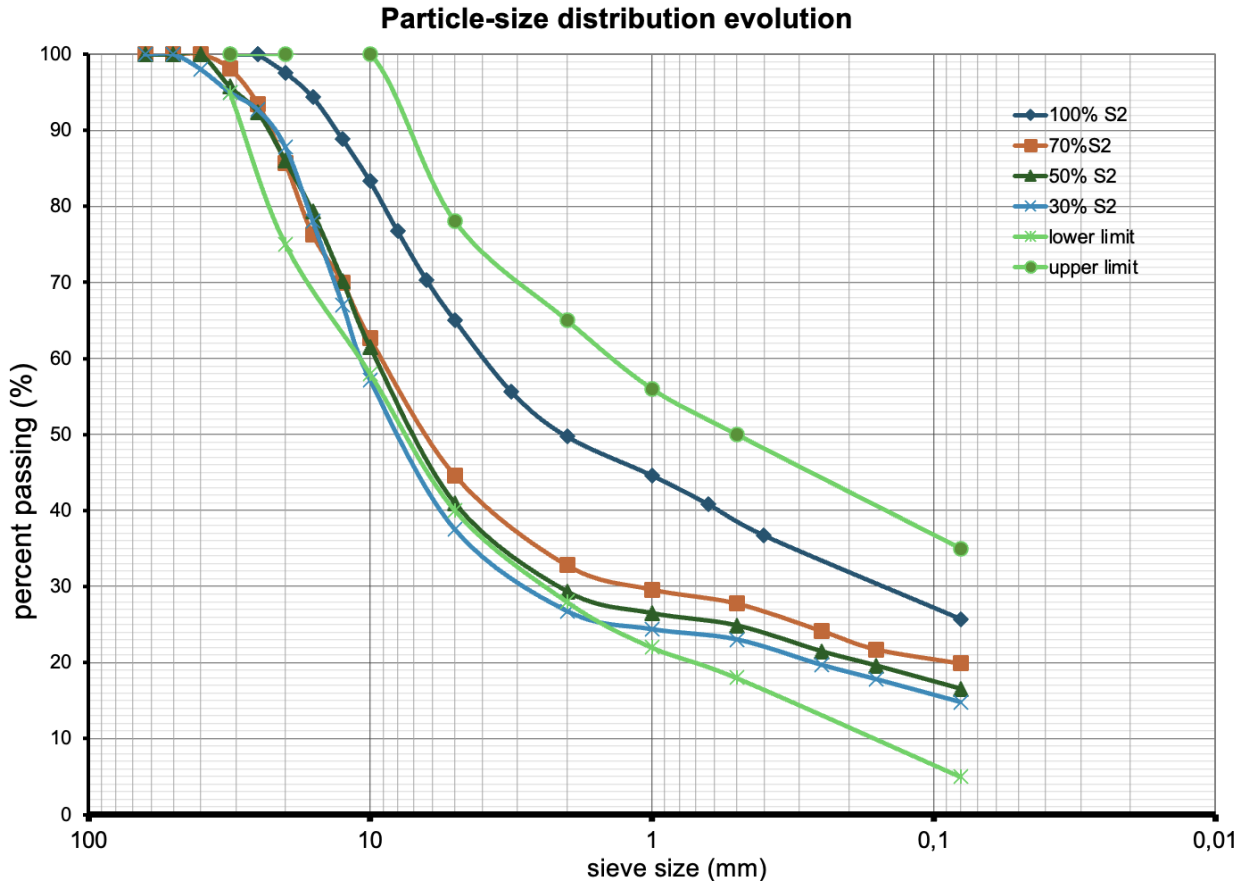
Figure 4: Evolution of the particle-size distribution with incorporation rate for S1

The mixtures of the S2 sample from the Mboro–Diogo road with 30%, 50%, and 70% of lateritic gravels from Keur Samba Kane (KSK) quarry yield the results presented in Table 3.

Table 3: Results for the S2–KSK mixtures

Ratio / Parameters	100% S2 0% KSK	70% S2 30% KSK	50% S2 50% KSK	30% S2 70% KSK
Fines content (%)	25.7	19	16.5	14.8
Liquid limit (%)	51	51.5	37	40.4
Plastic limit (%)	28.1	24.5	21	20.7
Plasticity index (%)	22.9	27	16	19.7
Maximum dry density (g/cm³)	1.91	1.999	2.064	2.14
Optimum moisture content (%)	11.36	10	11.2	9.2
CBR (95% OPM)	12	45	52	59

Figure 5 shows the evolution of the particle-size distribution of S2 as a function of the KSK lateritic gravel incorporation rate.



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Figure 5: Evolution of the particle-size distribution with incorporation rate for S2

The mixtures of the S3 sample from the Mboro–Diogo road with 30%, 50%, and 70% of lateritic gravels from Keur Samba Kane (KSK) quarry yield the results presented in Table 4.

Table 4: Results for the S3–KSK mixtures

Ratio / Parameters	100% S3 0% KSK	70% S3 30% KSK	50% S3 50% KSK	30% S3 70%KSK
Fines content (%)	37	22.7	18.1	16.5
Liquid limit (%)	42.3	51.1	33.9	40.2
Plastic limit (%)	21.7	20.7	17.5	21.8
Plasticity index (%)	20.6	20.4	16.4	18.4
Maximum dry density (g/cm^3)	1.94	2.04	2.076	2.122
Optimum moisture content (%)	11.36	12.8	10.4	9
CBR (95% OPM)	14	46	40	57

Figure 6 shows the evolution of the particle-size distribution of S3 as a function of the KSK lateritic gravel incorporation rate.

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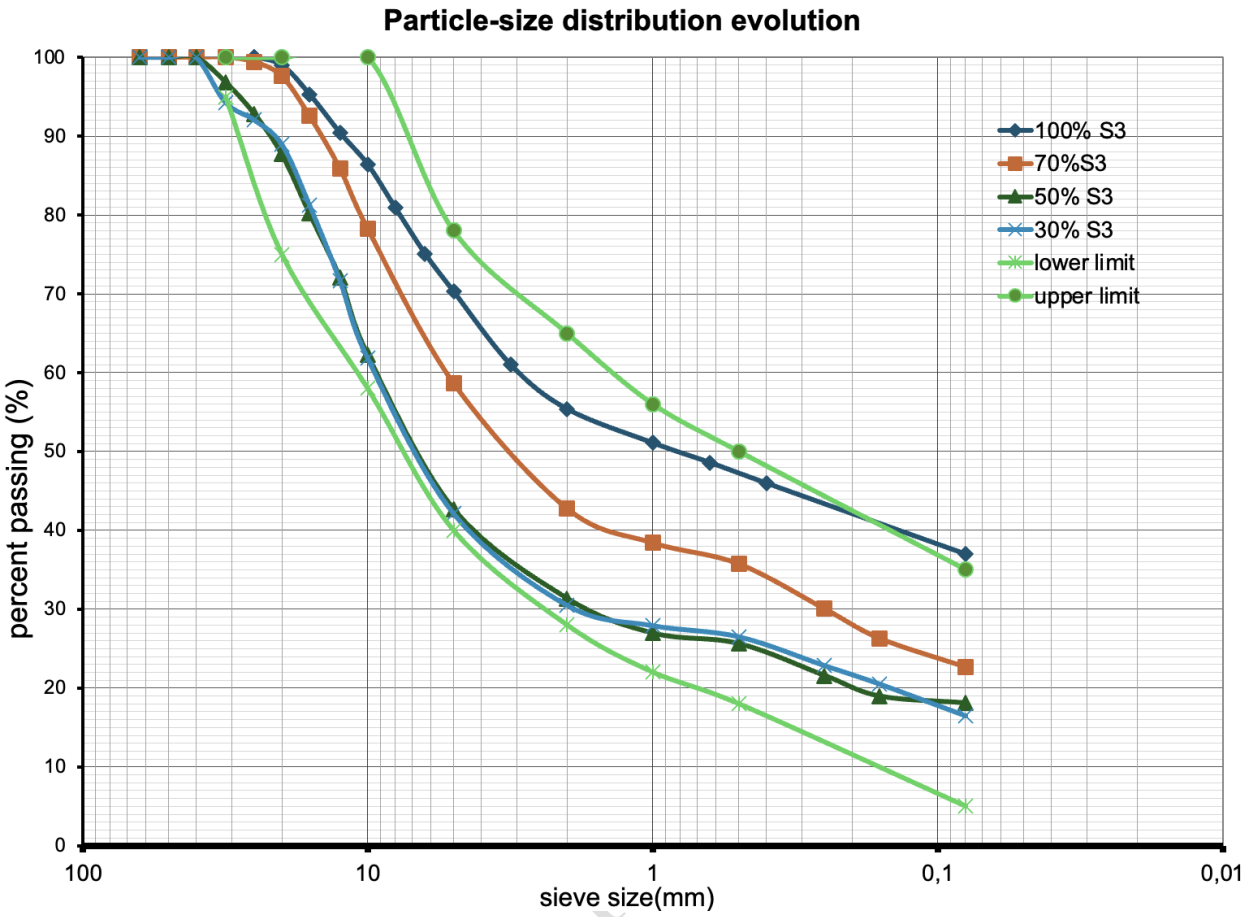


Figure 6: Evolution of the particle-size distribution with incorporation rate for S3

Figures 4, 5, and 6 show that the particle-size distribution curves fall within the limits of the standard grading envelope defined by the AGEROUTE design catalogue, with the exception of the 30% curves for S1 and S2.

Figure 7 shows a progressive and consistent decrease in the fines content across the three boreholes as the incorporation rate of raw material from Keur Samba Kane increases (with the exception of the 50% value for S1, which can be regarded as an outlier). This indicates an improvement in the particle-size distribution.

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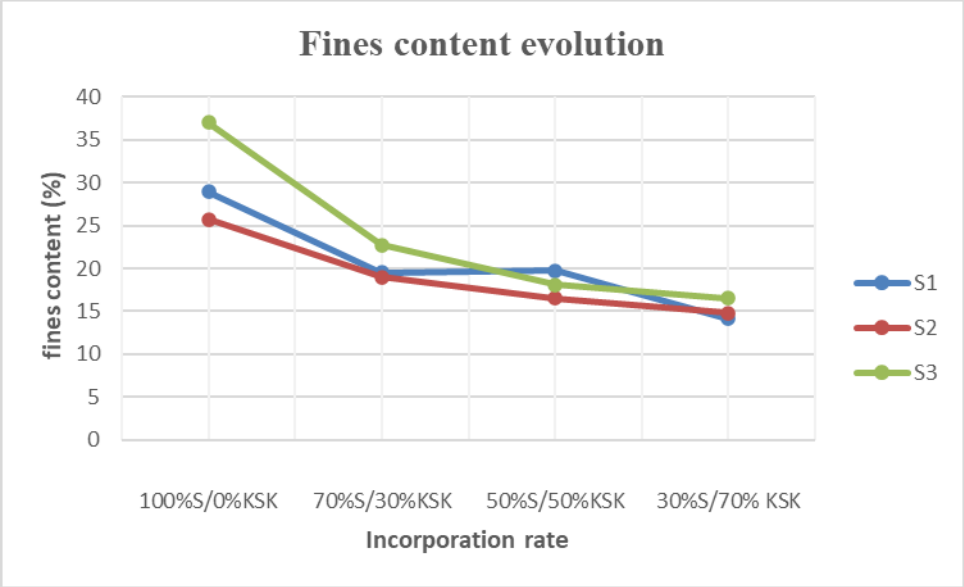


Figure 7: Evolution of the fines content

A less linear trend is observed for the plasticity index, which, after decreasing from the 50% incorporation rate onwards, rises again at 70% incorporation, despite the continued reduction in fines content, however, all PI values are below 25.

A consistent and steady improvement in the CBR index is observed (Figure 8). At survey point S1, the CBR rises from 17 for the untreated material to 77 at 70% KSK incorporation. A similar trend is recorded for S2 and S3, with CBR values reaching 59 and 57 respectively at the maximum incorporation rate. Mixtures with 70% KSK lateritic gravels systematically yield the best bearing capacity.

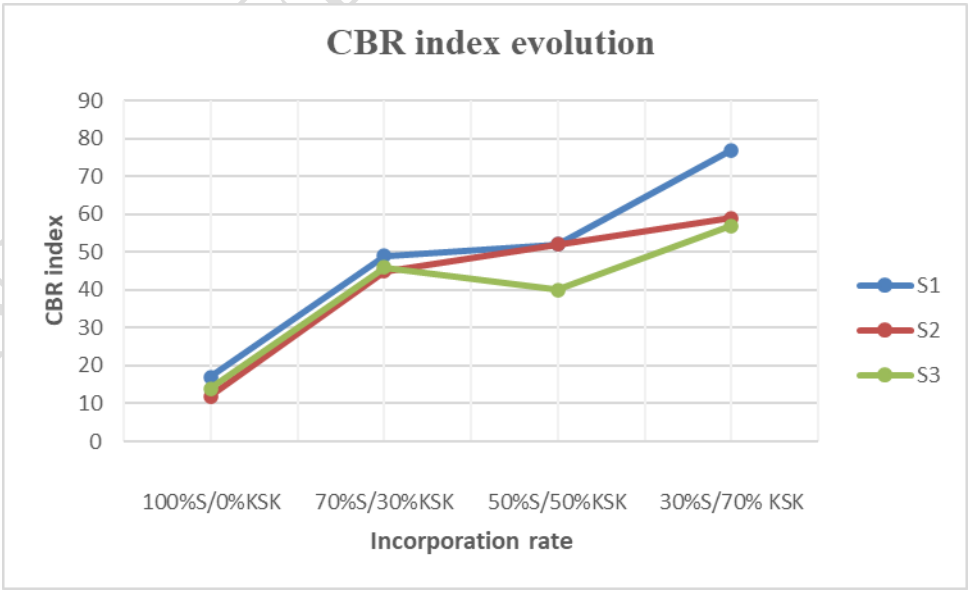


Figure 8: Evolution of the CBR index

For all the materials, the experimental evaluations didn't record swelling values.

Thus, except for a few outliers, we observe a favorable evolution of key parameters such as the fines content, plasticity index, and CBR index. We also note that, except for the 30% incorporation blends, the particle-size distribution curves fall within the standard grading envelope of the AGEROUTE design catalogue.

Overall, the analysis of the particle-size distribution curves shows a clear and progressive reduction of the fines fraction with increasing incorporation of Keur Samba Kane lateritic gravels. This effect is weaker on the coarse fraction at low incorporation rates but becomes more pronounced when the rate reaches 70%. For the materials from borehole S1, going from 30% to 70% incorporation reduces the fines by approximately 50% relative to the initial state (28.9% to 14.1%). The curves of the S2 blends show a clear separation, which confirms the significant effect of the particle-size correction provided by the Keur Samba Kane lateritic gravels, with a marginal impact above 50% addition. For S3, the curves almost overlap at 50% and 70% addition. This means that increasing the incorporation rate beyond 50% has almost no further effect on the reduction of residual fines.

We also note a notable improvement in the CBR index, which is due to the combined effect of the following factors:

- The materials from the dismantled existing pavement (S1, S2, S3) have initial fines contents of 25.7 to 37%. The raw Keur Samba Kane lateritic gravel, with only 11.3% fines, acts as a particle-size corrector. Increasing the incorporation rate dilutes the fine fraction, thereby attenuating its adverse effect on the bearing capacity of the material. This is confirmed by the increase in the CBR index with the progressive and regular decrease in fines content across the three boreholes.
- The Keur Samba Kane (KSK) lateritic gravels densify and optimize the solid skeleton of the blend. This is reflected in an increase in the maximum dry density in the Proctor test, rising, for example, for S2 from approximately 1.91 g/cm³ (without addition) to 2.14 g/cm³ at 70% incorporation. A skeleton densified in this way means considerably greater intergranular contact, which results in higher penetration resistance.

For use as a sub-base layer, the minimum requirements are a CBR value of 30 and PI values between 20 and 25 [3]. The material must also have a particle-size distribution curve within the standard envelope. This is the case for these materials from 50% incorporation onward.

Conclusion:-

In light of the results, the materials from the existing pavement are usable as a sub-base layer from the incorporation of 50% raw KSK lateritic gravels onward. The incorporation rate giving the best mechanical performance is 70%, with fines content, PI, and CBR values ranging respectively from 14.1 to 16.5%, from 18.4 to 19.7%, and from 57 to 77%. Although the 30% incorporation gives acceptable mechanical performance, its particle-size distribution falls outside the standard envelope for at least two samples. However, the 50% blend offers a more stable PI and more robust compliance with the specifications, at the cost of a slight reduction in bearing capacity that remains within the required technical thresholds.

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Ultimately, the blend with 50% raw lateritic gravels (KSK) is recommended in view of the results obtained from these tests, as it offers an optimal compromise between mechanical performance, plasticity, and the quantity of recovered material.

Recycling the base and sub-base layers, excluding the asphalt concrete wearing course, from samples taken during the rehabilitation of the Mboro–Diogo road yields satisfactory performance for a sub-base layer. As prospects for future work, it would be worthwhile (i) to study the behavior of these materials and the evolution of their performance after cement treatment, and (ii) beyond the technical study, to analyze the economic and environmental impacts.

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