International Journal of Research and Review
Vol. 11; Issue: 1; January 2024
Website: www.ijrrjournal.com
Research Paper *E-ISSN: 2349-9788; P-ISSN: 2454-2237*

Geotechnical Properties of Sand-Asphalt for Use in Road Base Layer Instead of Conventional Materials

Makhaly Ba[1], Ibrahima Tine[2], Oustasse Abdoulaye Sall[1], Oumar Kamara[3]

[1]Laboratoire de Mécanique et de Modélisation (L2M), University Iba Der Thiam, Thies, Senegal.
[2] IDEV - Dakar, Sénégal
[3] Consultant en Géotechnique - Dakar, Sénégal

Corresponding Author: Makhaly Ba, makhaly.ba@univ-thies.sn

DOI: https://doi.org/10.52403/ijrr.20240113

ABSTRACT

The study of the geotechnical properties of sand-asphalt for use in road base layer instead of conventional materials, for low to moderate traffic volume, is based on standardized laboratory tests. Sand samples were taken from Kayar, Darou Alpha and Keur Morry (Thies region, Senegal). Identification tests (particle size distribution and sand equivalent) made it possible to select Kayar and Darou Alpha sands which have respective sand equivalent (ES) values of 92 % and 62 %. These values are higher than the minimum required (40 %), for sand-asphalt, with different 35/50 bitumen dosages. The results of the Hubbard-Field test carried out showed that Darou Alpha sands are suitable, with an optimum dosage of 7 % bitumen : the stability at 18 °C, at dry conditions, is 2 732 kg and is greater than the minimum required value of 2 300 kg; the immersion/compression ratio is 85 % and is greater than the minimum required limit of 75 %; water absorption reaches 5.4 % and remains below the maximum required limit of 7 %; the volumetric swelling is 2.6 % and is below the maximum required limit of 5 %. The compactness is 84 % and is acceptable because it exceeds the minimum required limit of 80 %. The sizing carried out with the Alizé©3 software gives deformation values lower than the permissible values. The pavement structure that is placed on a PF3 type platform is therefore correctly sized to support a traffic of 150 heavy vehicles per day for a service life of 15 years. This roadway structure, which is devoid of a foundation layer, includes a 23 cm thick sand-asphalt base layer on which rests a 5 cm thick asphalt concrete.

Keywords: sand-asphalt, Hubbard-Field test, Kayar, Darou Alpha, Keur Morry.

1. INTRODUCTION

Roads play an important role in a country's economy. In Senegal, roads occupy a prominent place in the land transport sector, accounting for nearly 99% of domestic passenger movements and more than 95% of goods. The classified road network has grown steadily from 1960 to the present, its total length increased from 6034 km in 1960 to 14958 km in 2011 (Sène 2013). In road technology, the best use should be made of locally available materials. Road construction and reinforcement work require large volumes of materials, and transport distances must be reduced as much as possible to ensure cost-effective supply of the sites. The construction of a 300 m test board with sand-asphalt, as part of the sectoral transport adjustment program, on the Kébémer-St-Louis axis of the RN2, between Guéoul and Baralé, stems from the difficulty of finding lateritic gravelly borrowings along the route. The nearest lateritic material loan is that of Lam-Lam which is located 100 km southwest, in the Thies region. In the vicinity of Guéoul, the only material available is a fine homogeneous sand whose totality passes through a sieve of 0.4 mm opening. The borrowings are quite close, along the Guéoul-Louga section with a length of 17 km. The average transport distance is less than 3 km. The discoveries of the various borrowings never exceed 30 cm to 50 cm (CEBTP, 1967). In 1952, sand-asphalt was used as a road base layer for the construction of the Kaolack-Thiadiaye section. The sand-asphalt layer was demolished about twenty years ago as part of the road reconstruction work. Improved sand with asphalt binder must meet the technical requirements. The objective of this study is to enhance the value of these sands in road technology.

2. MATERIAL PROPERTIES AND TEST PROCEDURES

2.1. Geographical framework of sampling sites

Located to the east of the Dakar region, the Thies region is one of the 14 administrative regions of Senegal. Figure 1 shows the location of the three dune sand sampling sites: Kayar, Darou Alpha, and Keur Morry in the Thies region (figure 2). The sands sampled are of dune type. It should be noted that the Thies region is characterized by Quaternary sedimentary formations which rest on older formations (Maastrichtian, Lower Paleocene, Lower Eocene, Lower and Upper Lutetian). The dune formations date from the Quaternary and are made up of sandy materials that cover most of the region.

Figure 1 Location map of sand sampling sites

Figure 2 View of Kayar, Darou Alpha and keur Morry borrows

The formation of these dunes is explained by variations in sea level and climate change and can be of different ages, textures and colors. The Kayar loan is characterized by coastal dunes or white dunes which date from the 2000 to 1800 years. These dunes are constantly picked up by the wind, hence the name "live dunes". The Darou Alpha borrow pit is made up of yellow dunes which are located in the background of the coastal dunes and are interrupted in places by lakes or temporary ponds. That of Keur Morry is characterized by continental red dunes or interior dunes. They are made up of red soils commonly called "Dior soils" and date from the Ogolian (15,000 to 20,000 years). These dunes form an important erg from the south-west of Mauritania to the west of Senegal.

The sand borrowings from Kayar, Darou Alpha and Keur Morry are therefore of different ages and colors but are not very far from the town of Thies. They are used to supply materials to worksites, particularly roads. The study of the properties of these sands in their natural state and mixed with other products such as bitumen is useful for precisely defining their conditions of use and thus contributing to their valorization.

2.2. Geotechnical Characteristics and Test Procedures

The identification tests related to the particle size analysis (NF EN 933-1), the sand equivalent test (EN 933-8), the penetrability of the bitumen (EN 1426), the softening point (Ring and Ball method) (EN 1427), and the Hubbard-Field test (NFP 98-251-3). Tables 1 and 2 show the physical properties of sand and bitumen. The elements constituting the Kayar borrow pit have a diameter between 0.4 mm and 0.08 mm (figure 3). The percentage of fines (Ø < 80µm) is low (2%). The value of the uniformity coefficient Cu is 1.7 and indicates a uniform granularity; the coefficient of gradation Cc is 0.98 and attests to a porly-graded sand. Those constituting the Darou Alpha borrow pit are distributed in the grain size range between 0.4 mm and 0.08 mm (figure 3). The fines content of this sand is low (8%). The value of the uniformity coefficient Cu is 2.21 and the coefficient of gradation Cc is 1.01 and corresponds to a well-graded sand. The Keur Morry material also contains elements with dimensions between 0.4 mm and 0.08 mm (Figure 3). The fines content is high and is equal to 17.5%. The uniformity coefficient Cu is 5.25 and attests to a semi-spread granularity. The coefficient of gradation Cc is equal to 1.07 and attests to a well-graded sand. Sand samples from Kayar, Darou Alpha and Keur Morry have sand equivalents of 92, 62 and 19 respectively. So, Kayar and Darou Alpha sands are well suited to being treated with asphalt binder unlike that of Keur Morry.

Table 1 Physical proprieties of sands

	Type of sample	Sand		
	Borrow pit	Kayar	Darou alpha	Keur Morry
Particle size distribution	Fines (% < 0.08 mm)	2	8	17,5
	Uniformity coefficient (Cu)	1,7	2,21	5,25
	Coefficient of gradation (Cc)	0,98	1,01	1,07
	Sand Equivalent	92	62	19
	Specific unit weight of particles (g/cm^3)	2,69	2,68	2,6
	Angle of internal friction (°)	26,5	31,5	31

Table 2 Physical proprieties of the asphalt binder

Penetrability (1/10 mm)		39
Class		35/50
Softening point	Time	19 min 47s et 21min 20s
	Average Temperature	50
Specific unit weight (g/cm^3)		1,03

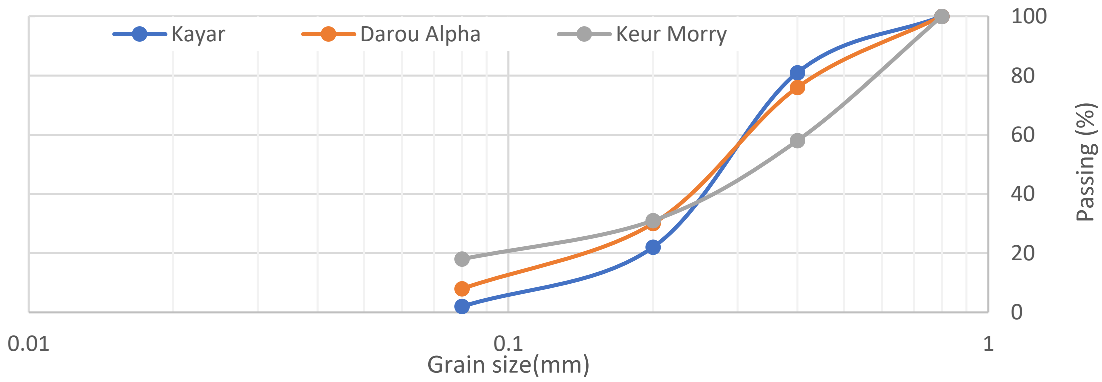

Figure 3 Granulometric curve of the natural sand samples

The asphalt binder used is 35/50 class of penetrability with a relative density of 1.03 g/cm^3. This hard bitumen is well suited because it allows the highest stability to be obtained. Thanks to its specific qualities, it offers better resistance to road rutting and creep, increased resistance to bad weather, flexibility of use and gives to the road a long service life. The average value of the softening temperature obtained is 50 °C.

The Hubbard-Field test is a method of measuring the conventional stability of a fine material whose maximum particle diameter is less than 4 mm, bonded with a bituminous binder, at a temperature and according to a given mode of compaction. The binder is a pure or modified bitumen which can be liquefied or emulsified. Its main objectives are to:

- Highlight the variation in the performance of the mixtures according to the variation in the percentage of binder;
- Choose the optimal formula that best satisfies the required conditions;
- Characterize the resistance to water by the ratio of the stability of the specimens with immersion to the stability of the specimens without immersion;
- Determine the percentage of voids and compactness.

The specimens are kept under defined conditions, with immersion for some or without immersion for others. Conventional stability (at 18 °C or 60 °C) is the maximum force required to cause the specimen to extrude through a calibrated ring. The mass of the test specimens is 100 g, compaction is carried out using a piston with a load of 42 kN. This charge must be reached in 60 seconds and maintained for 5 minutes, then the discharge takes place slowly. The specimens can be stored either at 18°C or at 60 °C depending on the climatic conditions of the environment and the objectives targeted. For the test at 18 °C, seven specimens are made, one of which is for measuring the apparent density. The other six specimens are stored for 24 hours at 18 °C; after this time, a lot of three is kept dry for 7 days under these conditions and the other lot is subjected to the action of water at 18 °C for the same time. The action of water is evaluated according to one of two modes: total immersion or imbibition at the base. At the end of this storage period, the specimens having undergone the water resistance test are again weighed and measured. For the test at 60 °C, the six specimens intended for the test as well as the test apparatus and the compression piston are placed in an oven whose temperature near the specimen is 60 °C for 60 mins. The specimen is then introduced into a water bath at 60 °C, such that the specimen is completely submerged. Once the storage time has been reached, at 18 °C as well as at 60 °C, the test specimen surmounted by the compression piston is carried between the platens of the press. The speed is set to 1 mm/s. The extrusion of the specimen is stopped when the load has passed through a maximum. This value is called Hubbard-Field stability.

RESULT AND DISCUSSION

3.1. Hubbard-Field Test

The extremely rare use of sand-asphalt as a base course explains why there are no precise indications regarding the performance to be achieved. However, the projects and studies already carried out have made it possible to identify certain criteria for assessing this technique. These criteria are essentially based on the Hubbard-Field test:

- Minimum Hubbard-Field stability at 18 °C, at dry condition: 2300 kg (Capdesus et Chauvin, 1973);
- Minimum water resistance: 75% (CEBTP, 1984);
- Minimum Hubbard-Field compactness: 80% (CEBTP, 1984);
- Maximum water absorption: 7% (Chauvin, 1987);
- Maximum volumetric swelling: 5% (Chauvin, 1987).

Kayar sand

Table 3 shows the results of Hubbard-Field tests of Kayar sand mixed with 35/50 bitumen. From the values obtained, it will be possible to plot the curves of variation of the dry Hubbard-Field stability and the Hubbard-Field stability after immersion for 7 days, as a function of the percentage of bitumen. They will allow us to appreciate the optimal stability and water resistance. The variation curves of the other parameters (compactness, imbibition, swelling) are also plotted as a function of the bitumen content in order to better understand the behavior of the sand-bitumen. Figure 4 shows that the stability optimum at 18 °C and at dry condition is equal to 2361 kg, obtained for 7% bitumen. A bitumen content below this value results in a less stable mixture and a higher content causes a drop in stability. This optimal stability obtained is greater than that recommended which is 2300 kg. The water resistance at optimum stability is 43%, while the minimum recommended value is 75%. A correction must be made to this mixture to improve its water resistance.

Table 3 Results of Hubbard-Field tests of Kayar sand mixed with 35/50 bitumen

Binder content (%)		4	5	6	7	8
Sample	Mass (g)	104.2	105.6	106.1	107.5	108.5
	Height (cm)	2.75	2.7	2.8	2.8	2.85
	Diameter (cm)	5	5	5	5	5
Hubbard Field Stability (kg)	18°C with total immersion in water	594	749	842	1005	948
	18°C at dry condition	1374	1691	2109	2361	1658
Water absorption (%)		10	8.5	7.5	6.8	5.8
Volumetric swelling (%)		5	4.9	3.4	3.4	3.3
Stability ratio : wet/dry (%)		43	44	40	43	57
Bulk unit weight (g/cm^3)		1.69	1.73	1.78	1.78	1.88
Specific(reel) unit weight (*g/cm^3*)		2.43	2.37	2.32	2.27	2.22
Compactness (%)		70	73	77	78	85
Voids (%)		30	27	23	22	15

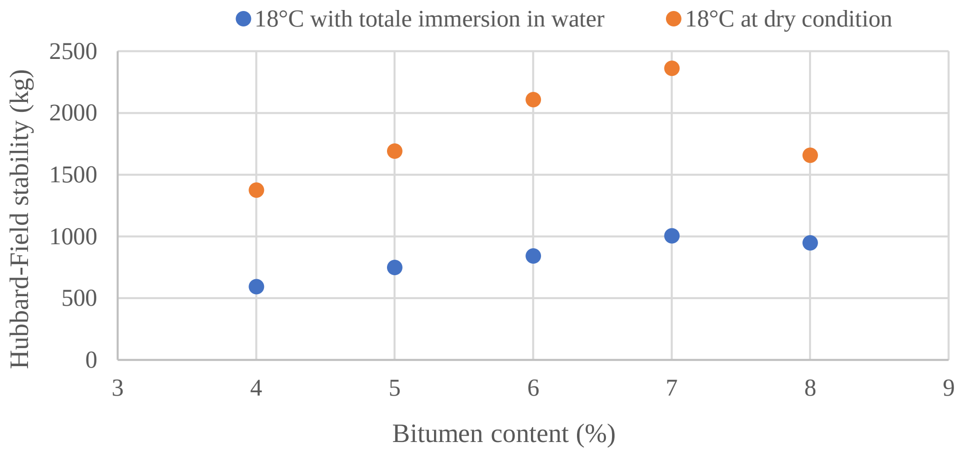

Figure 4 Variation of Hubbard-Field stability (at 18 °C, dry and immersed) as a function of bitumen content (Kayar sand mixed with 35/50 bitumen).

Compactness increases with increasing bitumen content (Figure 5). It varies from 70 to 85% for binder content between 4 and 8%. Compactness at the optimum stability binder content (7%) gives 78%. This mixture must therefore be improved to satisfy the minimum required compactness value which is equal to 80%. The water absorption rate decreases with increasing bitumen content (Figure 6). It varies between 6 and 10% for bitumen contents between 4 and 8%. At 7% of bitumen, which represents the optimum binder content for stability, water absorption gives 6.8% and remains below the maximum value (7%) prescribed. Volumetric swelling decreases with increasing bitumen content (Figure 7). Its values are between 3.3 and 5% for bitumen content varying between 4 and 8%. At the Hubbard-Field stability optimum (7% bitumen), the volumetric swelling (3.4%) is less than the specified maximum value (5%).

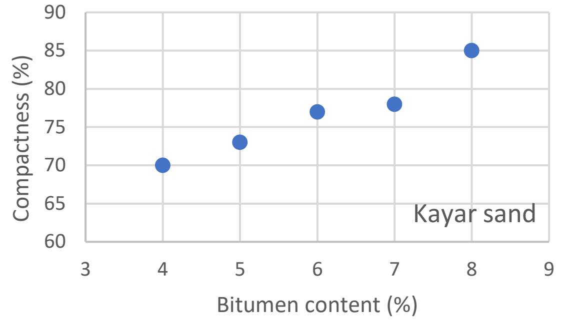

Figure 5 Variation in compactness as a function of bitumen content (Kayar sand mixed with 35/50 bitumen)

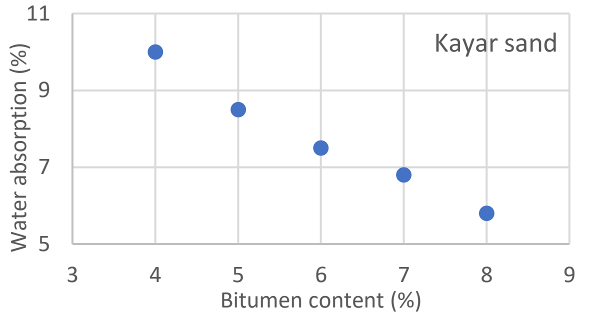

Figure 6 Variation of the water absorption rate according to the bitumen content (Kayar sand mixed with 35/50 bitumen)

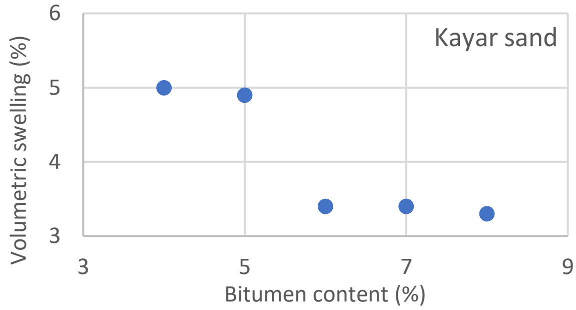

Figure 7 Variation in volumetric swelling as a function of bitumen content (Kayar sand mixed with 35/50 bitumen)

Darou Alpha sand

The Hubbard-Field tests carried out on test specimens of sand samples from Darou Alpha, with different bitumen rates, gave the results which are reported in Table 4. its water resistance. The optimum stability at 18°C and dry condition is obtained with 7% of bitumen with a stability of 2732 kg (figure 8). The water resistance with this same percentage of bitumen (7%) gives 85%. In terms of stability and water resistance, the Darou Alpha sand sample mixed with 7% bitumen satisfies the technical requirements which set the minimum stability (at 18°C dry) at 2300 kg and the minimum water resistance at 75%.

Table 4 Results of the Hubbard Field tests obtained with specimens of Darou Alpha dune sand sample mixed with 35/50 bitumen

Binder content (%)		4	5	6	7	8
Sample	Mass (g)	106,2	107,5	107,8	109.6	110,6
	Height (cm)	2,7	2,7	2,7	2,7	2,7
	Diameter (cm)	5	5	5	5	5
Hubbard Field Stability (kg)	18 °C with total immersion in water	1658	2043	2089	2315	2189
	18 °C at dry condition	1990	2480	2537	2732	2348
Water absorption (%)		9,8	8,7	6,2	5,4	4,5
Volumetric swelling (%)		3,7	3,7	3,6	2,6	2,4
Stability ratio : wet/dry (%)		83	82	82	85	93
Bulk unit weight (g/cm^3)		1,72	1,84	1,8	1,89	1,94
Specific(reel) unit weight (*g/cm*^{3})		2,42	2,37	2,31	2,26	2,21
compactness (%)		71	78	78	84	88
Voids (%)		29	22	22	16	12

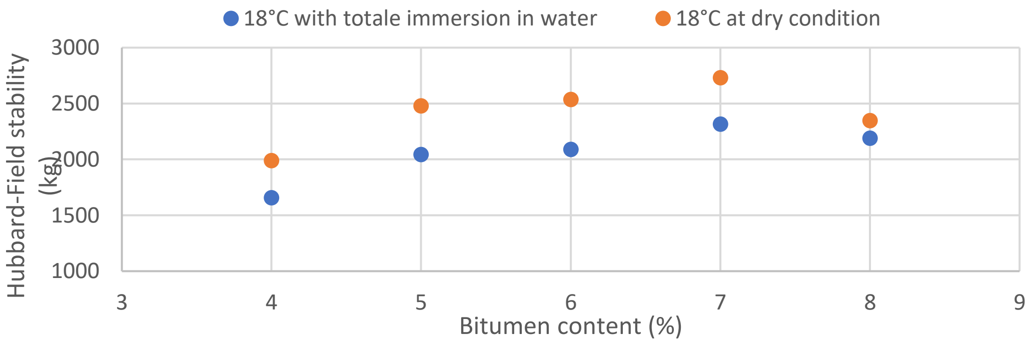

Figure 8 Variation of Hubbard-Field stability (at 18°C, dry and immersed) as a function of bitumen content (Darou Alpha mixed with 35/50 bitumen)

The higher the bitumen content, the higher the compactness (Figure 9). This varies from 71 to 88% for bitumen content between 4 and 8%. The compactness (84%) of this optimum mixture (7% bitumen) is greater than the specified minimum value (80%). The water absorption rate decreases with increasing bitumen content (Figure 10). It varies from 4.5 to 9% for bitumen rates between 4 and 8%. At 7% bitumen, the water absorption rate is 5.4%, which is less than 7% and satisfies the technical requirements. Volumetric swelling decreases with increasing bitumen content (Figure 11). It thus varies from 2.4 to 3.7% for bitumen contents of between 4 and 8%. At 7% of bitumen, the swelling (2.6%) is less than 5% and thus meets the technical requirements.

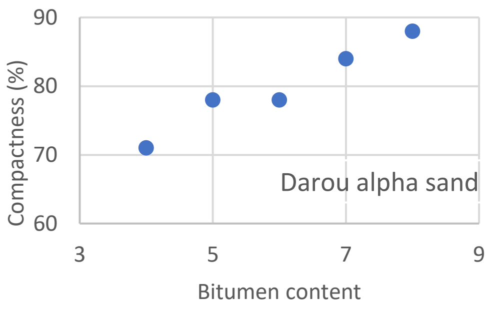

Figure 9 Variation in compactness as a function of bitumen content (Darou Alpha sand)

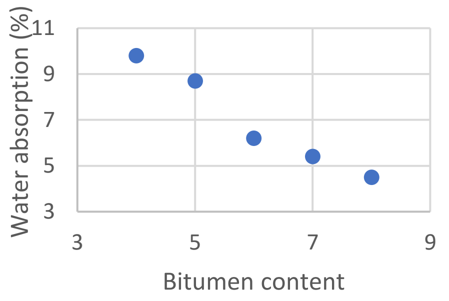

Figure 10 Variation in water absorption as a function of bitumen content (Darou Alpha sand)

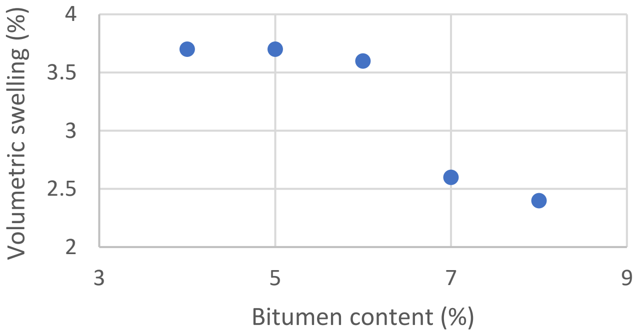

Figure 11 Variation in volumetric swelling as a function of bitumen content (Darou Alpha sand)

3.2. Interpretation of experimental results

The main results of the laboratory tests carried out on the sand samples from the Kayar, Darou Alpha and Keur Morry borrow pits are summarized in Table 5, as well as the results of the Hubbard-Field test on the sand-asphalt specimens.

For hot mix, the sand used must have a sand equivalent greater than 40; the binder used must be a pure bitumen with low penetration (hard bitumen) suitable for light to moderate traffic. The quality of sand-asphalt is evaluated by the Hubbard-Field test. The bonded material must meet the technical specifications for use as a road base course.

Table 5 Summary of geotechnical test results

Type of sample	**Sands**		**Requirements**
Borrow pit	**Kayar**	**Darou Alpha**	
Characteristics of sand-asphalt specimens			
Optimum binder content (%)	7	7	-
Optimum Hubbard-Field stability at 18°C and dry (kg)	2361	2732	≥ 2300
Water resistance (%)	43	85	≤ 75
Water absorption (%)	6,8	5,4	≤ 7

Volumetric swelling (%)	3,4	2,6	≤ 5
Compactness (%)	78	84	≥ 80
Voids (%)	22	16	-

3.2.1 Quality of sand samples

For hot mix, the granularity of the sand has no restriction. The assessment criterion is the sand equivalent which must be greater than 40. Under these conditions, the sands from the borrowings of Kayar and Darou Alpha can be retained initially because the respective sand equivalents are 92 and 62. The Keur Morry sand sample has a low ES value of 19 with 17.5% fines and is unsuitable.

3.2.2 Quality of sand-bitumen specimens

For a dosage of 7% of 35/50 bitumen (optimum dosage), the results of the Hubbard-Field test (Table 5) show that the sand-asphalt specimens made with Kayar sand do not meet all the technical requirements.

- the stability has a value of 2361 kg which is greater than the required minimum value of 2300 kg at 18°C and at dry condition;
- the water resistance is 43% and is below the required minimum limit of 75%;
- water absorption is 6.8% and remains below the maximum recommended limit of 7%;
- the volumetric swelling is 3.4% and is below the maximum recommended limit of 5%;
- Compactness is 78% and is below the required minimum limit of 80%.

For a dosage of 7% of 35/50 bitumen (optimum dosage), the results of the Hubbard-Field test show that the sand-asphalt specimens made with Darou Alpha sand meet the technical specifications:

- Stability at 18 °C, at dry condition, is 2732 kg and is greater than the minimum required value of 2300 kg;
- the water resistance is 85% and is above the minimum required limit of 75%;
- water absorption reaches 5.4% but remains below the required maximum limit of 7%;
- the volumetric swelling is 2.6% and is below the required maximum limit of 5%;
- the compactness is 84% and is acceptable because it exceeds the required minimum limit of 80%;

In the end, the borrowed sand from Darou Alpha can be exploited to produce sand-asphalt that can be used as a road base layer, for light to moderate traffic.

The results of the experimental study therefore show that the sand from the Darou Alpha borrow pit can be enhanced in road technology. The results of the Hubbard-Field test carried out on the specimens are satisfactory and comply with the technical requirements. With an optimum dosage of 7% of 35/50 bitumen, the hot mix of Darou Alpha sand is likely to give a sand-asphalt that can be used as a road base course, in the Senegalese context, for light to moderate traffic level.

3.3. Sizing of a pavement structure with sand-asphalt as base layer

The design is done according to the French guide for the design and dimensioning of new pavements (SETRA-LCPC, 1994). The pavement considered (Table 6) consists of a 5 cm thick asphalt concrete wearing course with a Young's modulus (E) of 2450 MPa, a base layer of sand-asphalt with a thickness (e) of 23 cm with a modulus of 400 MPa and a PF3 type platform (CBR=24) whose modulus is 120 MPa. For traffic, the assumptions to be taken into account are as follows:

- T2- or T3+ type traffic with an annual daily average of 150 heavy vehicles per day;
- annual growth rate of 3%;
- 15-year service life.

The values resulting from the calculation with Alizé 3 are recorded in table 7. The values of the horizontal deformation (ε_t) at the base of the coating, of the horizontal deformation (ε_t) at the base of the base layer as well as the vertical strain (ε_z) on the top of the subgrade are all lower than the admissible values. The pavement structure is correctly sized for the envisaged traffic of 150 heavy vehicles per day.

Table 6 Model considered for the dimensioning of the structure

Layer	Materials	e (m)	E (MPa) at 25 °C	υ
wearing course	Asphalt Concrete	0.05	2450	0.35
Base	Sand-Asphalt at 7 % of bitumen	0.23	400	0.35
Subgrade (PF3)	Sand	-	120	0.35

Table 7 Sizing Results

Layer	wearing course	Base	Subgrade
Types of strain	ε_t (10^{-6})	ε_t (10^{-6})	ε_z (10^{-6})
Allowable values	250	525	784
Values obtained	65	346	780

The strain values obtained with Alizé 3 being lower than the admissible values, the sand-asphalt can be used for the realization of a base layer 23 cm thick surmounted by a surface layer in asphalt concrete 5 cm thick. This structure must support T3+ type traffic with an annual daily average of 150 heavy vehicles per day. And this for a service life of 15 years with an annual increase of 3%. The sand-asphalt base layer is laid directly on a PF3 type subgrade.

CONCLUSION

The main objective of this study was to see to what extent it is possible to use sand-asphalt as a road base layer, given that the scarcity of lateritic gravel in certain regions of Senegal. To carry out this study, sand samples were taken from the Kayar, Darou Alpha and Keur Morry borrow pits and subjected to the usual identification tests (particle size, sand equivalent). For hot mix, the granularity of the sand has no restriction. The criterion for assessing the quality of the sand is the sand Equivalent, which must be greater than 40. On the other hand, the Keur Morry sand sample has a low ES value of 19 with 17.5% of fines and is not suitable. The quality of sand-asphalt is evaluated by the Hubbard-Field test. The bituminous binder treated material must meet the technical specifications for use as a road base course. The experimental results obtained show that the sand-asphalt specimens made with Kayar sand and 7% of 35/50 bitumen (optimum dosage) do not meet all the technical specifications. For a dosage of 7% of 35/50 bitumen, the results of the Hubbard-Field test show that the sand-asphalt specimens made with Darou Alpha sand meet the technical requirements. Stability at 18°C, at dry condition, is 2732 kg. The water resistance is adequate with 85% which is above the minimum required limit of 75%. The water absorption is 5.4% and is less than 7%. The volumetric swelling is 2.6% and is less than 5%. Finally, the compactness is 84% and is above the minimum required limit of 80%. The hot mix of sand from the Darou Alpha borrow pit is likely to produce a sand-asphalt that can be used as a road base course, for light to moderate traffic. The dimensioning of a pavement structure with Alizé 3, gives strain values lower than the admissible values, the pavement is therefore correctly dimensioned. It is placed on a PF3 type subgrade on which directly rests a 23 cm thick sand-asphalt base layer and a 5 cm thick bituminous concrete coating. Its service life is 15 years for traffic of 150 heavy vehicles per day.

At the end of this study, the following recommendations are made:

- complete the inventory of sand borrowings and the estimation of reserves;
- complete the study of the properties of the sand samples, by determining the organic matter content and the acidity-basicity;

- study the properties of sand-asphalt, in the case of cold mix, with different types of hydrocarbon binders (cut-back, bitumen emulsion) suitable for low traffic.

Declaration by Authors

Acknowledgement: None
Source of Funding: None
Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Sène F. (2013). Caractérisation géotechnique du matériau latéritique de Sindia traité au ciment pour son utilisation en construction routière. Mémoire de fin d'études pour l'obtention du grade d'ingénieur géologue de conception, IST, n° 279, UCAD, Dakar, 44 pages.
2. CEBTP (1967). Etude des chaussées économiques en Afrique. Rapport général, rapport de synthèse, annexes. Paris, 408 pages.
3. Capdesus H. et Chauvin J.J. (1973). Traitement des sables des Landes. Laboratoire régional de Bordeaux, 19 pages.
4. CEBTP (1980). Guide pratique de dimensionnement des chaussées pour les pays tropicaux. Ministère de la coopération française, 117 pages.
5. Chauvin J.J. (1987). Les sables, guide pratique d'utilisation routière, ISTED, Paris, 76 pages.
6. LCPC-SETRA (1994). Conception et dimensionnement des chaussées. Paris, 260 pages.

How to cite this article: Makhaly Ba., Ibrahima Tine, Oustasse Abdoulaye Sall, Oumar Kamara. Geotechnical properties of sand-asphalt for use in road base layer instead of conventional materials. *International Journal of Research and Review*. 2024; 11(1): 117-126.
DOI: *https://doi.org/10.52403/ijrr.20240113*

******