GIS mapping of geo-materials for road construction in Cameroon case of the sections YAOUNDE – BONIS, D'ESSE – EDZENDOUN and OVENG – GABON BORDERS

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Abstract: Context: The State of Cameroon has initiated various projects to develop road, motorway and port infrastructure. The quality of the materials used is of paramount importance to ensure the durability of these works. Detailed and accurate mapping of the geo-materials used in road construction in Cameroon plays a key role in enabling effective and sustainable infrastructure planning while preserving natural resources.

Objective: The main objective of this work was to use the possibilities offered by Geographic Information Systems (GIS) to map and quantify the borrowing areas and quarries along three major road sections: Yaoundé-Bonis, Esse-Edzendouan, and Oveng-border of Gabon, located in the Central and Southern regions.

Material and method: To achieve this objective, the methodology was based on the identification of road sections, the in situ visit of quarries as well as the sites of borrowing on these sections, the materials, mapping of borrowing areas and development of a database.

Results: The main results achieved were the mapping of the borrowing and career areas along the N10 and N15 National Highway in the Central region and along the N17B National Highway in the Southern region. During this study, the residual quantities of geo-materials were determined for each extraction area.

Conclusion: These maps should help optimize the use of geo-materials in road construction, which can help reduce costs, improve road sustainability and promote regional economic development.

Keywords: Cartography, Geographic Information System, Geo-materials, Road construction

List of abbreviation

GNSS: Global Navigation Satellite System.

GIS: Geographic Information System.

N: National.

SQL: Structured Query Language.

Introduction

Cameroon's road network is a vital part of its infrastructure, playing a crucial role in the national economy and territorial cohesion. In the Central and Southern regions, geo-materials are of strategic importance both economically and geologically. These areas are rich in various mineral resources and geotechnical materials essential to several sectors, including road infrastructure. Geo-materials include a variety of substances such as rocks, minerals, sands and soils, each with distinct properties that directly influence road design and sustainability in these regions. However, their precise location, quantity and quality are often not well documented, which is a major challenge for the development and effective management of these projects.

Indeed, the availability of good quality geo-materials is of paramount importance in the design, construction and maintenance phases of roads. Detailed and accurate mapping of the geo-materials used in road construction in Cameroon would ensure sustainable and efficient infrastructure planning while preserving natural resources. However, due to the scarcity of accurate geo-spatial data on these materials, it is difficult to make informed decisions regarding road infrastructure planning and management.

Existing studies on geo-materials used in road construction in Cameroon often run into gaps due to the lack of accurate spatial data and a fragmented approach to mapping natural resources. Despite efforts to integrate GIS technologies into their assessment, their potential for providing detailed and up-to-date information is not fully exploited.

This research is of particular interest in proposing to remedy these shortcomings through the creation of maps using Geographic Information System (GIS) of geo-materials used in road construction. Its objective is also to develop a comprehensive spatial data to effectively support planning and road infrastructure decisions in the South and Central regions of the Cameroon. The specific objectives of this study include identifying the main types of geo-materials, as well as the evaluation of the quality of these materials, and the establishment of a geo-spatial database accessible to stakeholders involved in the road infrastructure planning and management.

This work is organized in three distinct parts. First, a literature review will be undertaken to synthesize the existing knowledge on geo-materials used in road construction in Cameroon. Then, a methodology will be developed for data collection and analysis by Geographic Information System (GIS), with the aim of mapping geo-materials in the southern and central regions of the country. Finally, thematic maps will be developed and a geo-spatial database will be set up to consolidate the results of this study.

1. Methodology

1.1 General site survey

The general recognition of sites was achieved through documentary research with the Ministry of Public Works; the objective being to determine precisely the sites suitable for the collection of geo-materials along road sections connecting Yaoundé to Bonis, from Essé-Edzendouan and Oveng to the Gabonese border. This approach was followed by a field visit in two distinct phases: the first phase consisted of a careful observation of the road section in order to identify precisely the borrowing areas and potential quarries and the second phase involved interviews with the local population using a questionnaire to have a correct itinerary to join the site.

1.2. Data collection

The objective of collecting data is to provide information on different borrowing areas along the different sites and the location of each activity using a GNSS receiver. Once the information is collected, it will be submitted to the Excel administrator for processing.

1.3. Data processing and analysis

In order to process and analyse the collected data the following steps were followed.

-Export of data: after the information for each borrowing zone is collected, it is transferred to the deposit files. They should then be exported in XLS format, compatible with the Excel spreadsheet.

- Data cleaning: each information collected is separated into an Excel sheet to realize the operations that will allow for data analysis.

- Data analysis: to analyze information gathered in the field, calculations will be made to determine the remaining volumes of each borrowing areas along each section

1.4. Database creation

The creation of a database has been done using Microsoft SQL Server. A database was created by defining its name and storage settings. Then the structure was designed by defining tables, columns, and data types, while establishing relationships using foreign keys. Indexes, constraints, stored procedures and views can also be added to optimize performance and data management. This method ensures efficient and secure information organization.

2. Results

It is to be notes that the collected data considered two cases: the case of the Central region and the case of the Southern region.

2.1. Case of the Central region

Tables 2.1 and 2.2 illustrate the different characteristics of the Esse-Edzendouan site in the central region. These tables will provide us with extensive information on the location of the loan areas and quarries; nature; distance from the project; area; the average thickness; cubature; remaining volume.

Table 2.1. The following table shows the different borrowings identified on the Esse-Edzendouan road section

Location Borrowing areas	PK	Rental Borrowing areas	nature	Size (m^2)	Average thickness (m)		Cubature (m^3)		Remaining volume (m^3)
					Stripping	Feat	Discovery	Feat	
Ehan	0+515 D	4	Coloured clay lateritic grave	4000	0.10	4	400	16000	15 787.375
Ehan	0+650 G	2	Coloured clay lateritic grave	3500	0.15	5	525	17500	13 803.475
Efouda	5+209 D	15	Coloured clay lateritic grave	4000	0.4	4	1600	16000	8 941.6375
Ebogo 4	9+613 G	10	Coloured clay lateritic grave	3500	0.0	4	0	14000	7 462.9625
Enkonda	13+510 G	11	Coloured clay lateritic grave	3500	0.10	4	300	12000	6 421.35
Enkonda	16+697 G	22	Coloured clay lateritic grave	2500	0.15	5	360	12500	6 869.375
Edzendouan	20+660 G	5	Coloured clay lateritic grave	2500	0.00	5	0	12500	2 566.475
Total borrowing anticipated (m^3)							100 500		
Need for the project (m^3)							84 046		

Table 2.2. The following table shows the mechanical characteristics obtained for each site

Location of Quarries	Nature of the rock	PK	Distance from project (Km)	Cubature (m3)	Remaining volume (m3)
LOUM	Gneiss	16+500	1	4 000 000	3 983 659.375
NKOLESSONI	Gneiss	2+000	2	60 000	47 006.25
AKOKFULENA	Gneiss	0+000	9.5	28 000 000	27 996 850
MONGOSSA	Gneiss	2+000	26	1 800 000	1 787 006.25
NKOL-NGOK	Gneiss	22+750	2.5	1 200 000	1 195 041.9
Estimated Volume of Career Sites (m^3)				35 060 000	
Need for the project (m3)				75 679	

- Yaoundé – Ayos, Ayos- Bonis road section

Tables 2.3 and 2.4 illustrate the different characteristics of the Yaoundé – Ayos site, Ayos-Bonis in the Central region. These tables provide us with extensive information on the location of loan areas and quarries; the nature of the geo-materials; the distance from the project; the area; the average thickness; the cubature and remaining volume.

Table 2.3. Summary of the characteristics of the loans of Siberian Downy located on the Yaoundé – Ayos, Ayos – Bonis section.

Location Borrowing areas	PK	Distance from project (m)	Thickness of the discovery (m)	Nature	Exploitable thickness (m)	Area (m^2)	Cubature (m^3)	Remaining volume (m^3)
Ekoumgat	37+700 G	25	0,10	Coloured clay lateritic grave	1,5	3500	5250	1520
Zili	47+400 D	400	0,10	Reddish lateritic clay	1,5	4900	7350	4 95.68
Otto-Messane	53+325 D	700	0,20	Coloured clay lateritic grave	1,5	5500	8250	274.6875
Ebolowa	58+225 G	300	0,20	Coloured clay lateritic grave	1,5	4500	6750	3704.06
Kakportgentil	66+600 D	1000	0,20	Coloured clay lateritic grave	1,5	6500	9750	1 489.2
Nkol-Ntop	72+500 G	400	0,20	Coloured clay lateritic grave	1,5	7500	11250	3 022.2
Mengang	77+050 G	0	0,20	Coloured clay lateritic grave	1,5	4500	6750	222.5
Mefoubi	81+100 D	50	0,20	Coloured clay lateritic	1,5	5200	7800	43.125

				grave				
Koundou	86+900 G	550	0,20	Coloured clay lateritic grave	1,5	9000	13500	128504
Mfoumassi	89+350 G	200	0,00	Coloured clay lateritic grave	2,00	7800	15600	12 056.25
Ndele	91+400 D	1000	0,30	Coloured clay lateritic grave	1,5	6500	9750	4 335.93
Akak Otonme-long	96+225 G	600	0,20	Coloured clay lateritic grave	1,5	4500	6 750	2 970
Ekoum-douma	101+000	10	0,20	Coloured clay lateritic grave	1,5	2500	3 750	1 152.8
Miende	108+800	700	0,00	Coloured clay lateritic grave	2,00	5400	10 800	11.25
Veminko	114+700	0	0,10	Coloured clay lateritic grave	1,5	5000	7 500	1 922.92
Ecole Publique d'Adoua	115+882	600	0,00	Coloured clay lateritic grave	2,00	3600	7 200	10 361
cubature totale (m^3)							138 000	

Table 2.4. The following table shows the mechanical characteristics obtained for each site investigated

Location of Quarries	Nature of the rock	PK	Distance from the project (Km)	Cubature (m3)	remaining volume (m^3)
d'Elat	Gneiss	35+900	2,50	34 550	_
Nkol-Ntop	Gneiss	72+500	2,00	16 50	_

2.2. Case of the Southern Region

Tables 3.5 and 3.6 show the areas of mining and quarrying; the nature of the geomaterials; the distance from the project; the area; the average thickness; the cubature; the volume remaining of the Oveng- Gabon border road section in the southern region. They provide us with valuable data of the site.

Table 2.5. Summary of the characteristics of the loans of Serious Lateritic located on the section of road Oveng-border Gabon.

Location Borrowing areas	PK	Rental Borrowing areas	nature	Size (m^2)	Average thickness (m)		Cubature (m^3)		Remaining volume (m^3)
					Stripping	Feat	Discovery	Exploit	

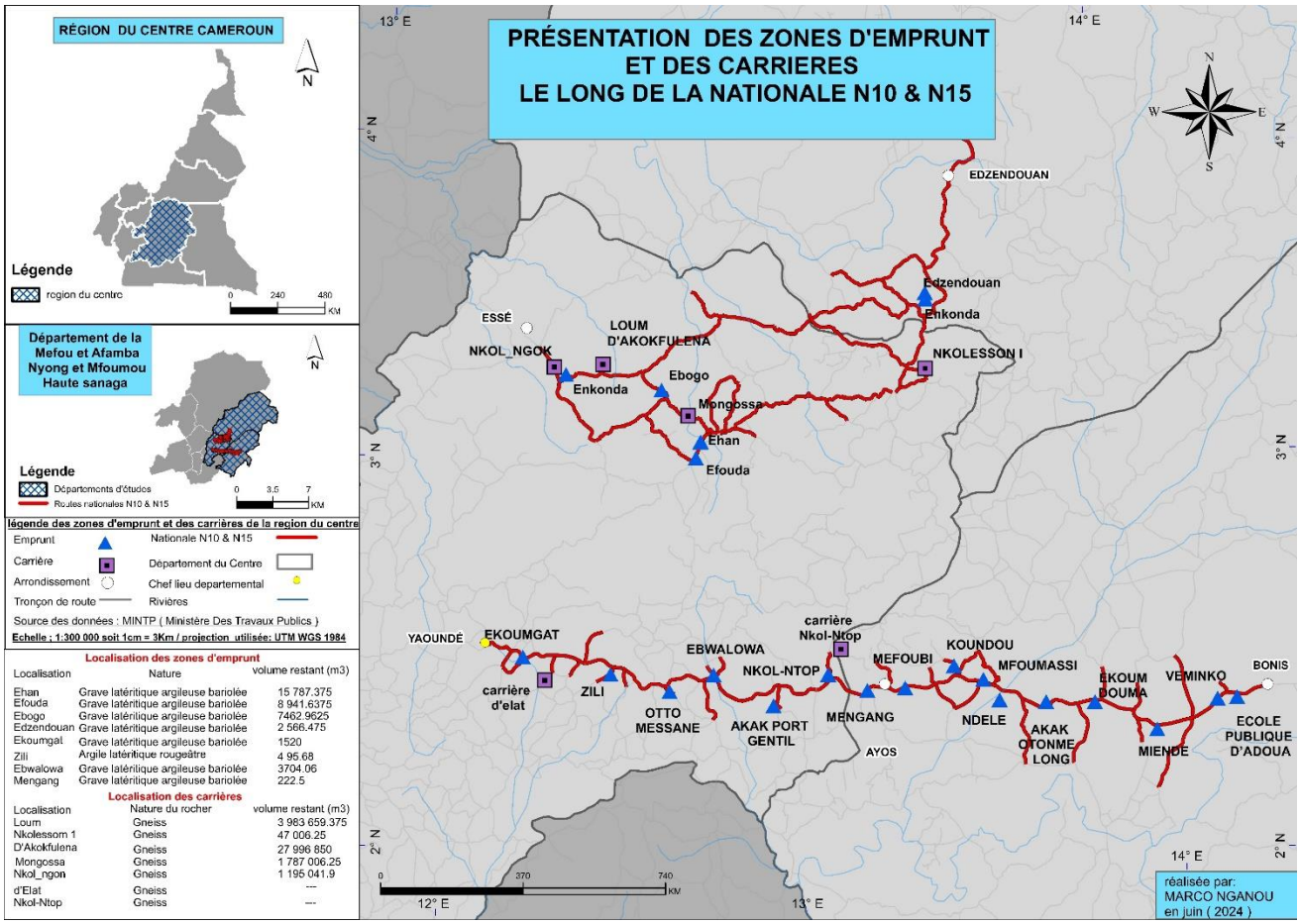
Mvan 2	6+676	4	Coloured clay lateritic grave	18750	0.05 0.70	4	937.5 13125	75000	49 837.8
D'End one	12+573	12	Coloured clay lateritic grave	11900	0.10 0.05	3.5	1190 595	41650	36 027.25
D'Ebo man	16+440	8	Coloured clay lateritic grave	16500	0.40	4	6600	57750	45239.775
Meka'a	20+516	18	Coloured clay lateritic grave	12000	0.60	6	7200	72000	68 015.25
D'Akoa bass	21+500	15	Coloured clay lateritic grave	8360	1.5	3	12540	25080	21 029.1
D'Akoa bass	25+660	11	Coloured clay lateritic grave	10000	0.05	2	500	20000	13 800.8
Mebang 1	29+372	20	Coloured clay lateritic grave	11400	0.05	2.5	570	28500	22 109.4375
Mebang 2	33+775	9	Coloured clay lateritic grave	8800	0.10	2.5	880	24000	10 410.9
AFANE-VAM	9+300 Côté droit	9	Coloured clay lateritic grave	15 000	0.10	2.5	880	37500	32 856.1125
AFANE-VAM	9+300 Côté gauche	9	Reddish lateritic clay	15 000	0.10	2.5	880	37 500	32 856.1125
Total Volume in (m3)							45897.5		
Estimated Project Needs (m^3)							241 650		

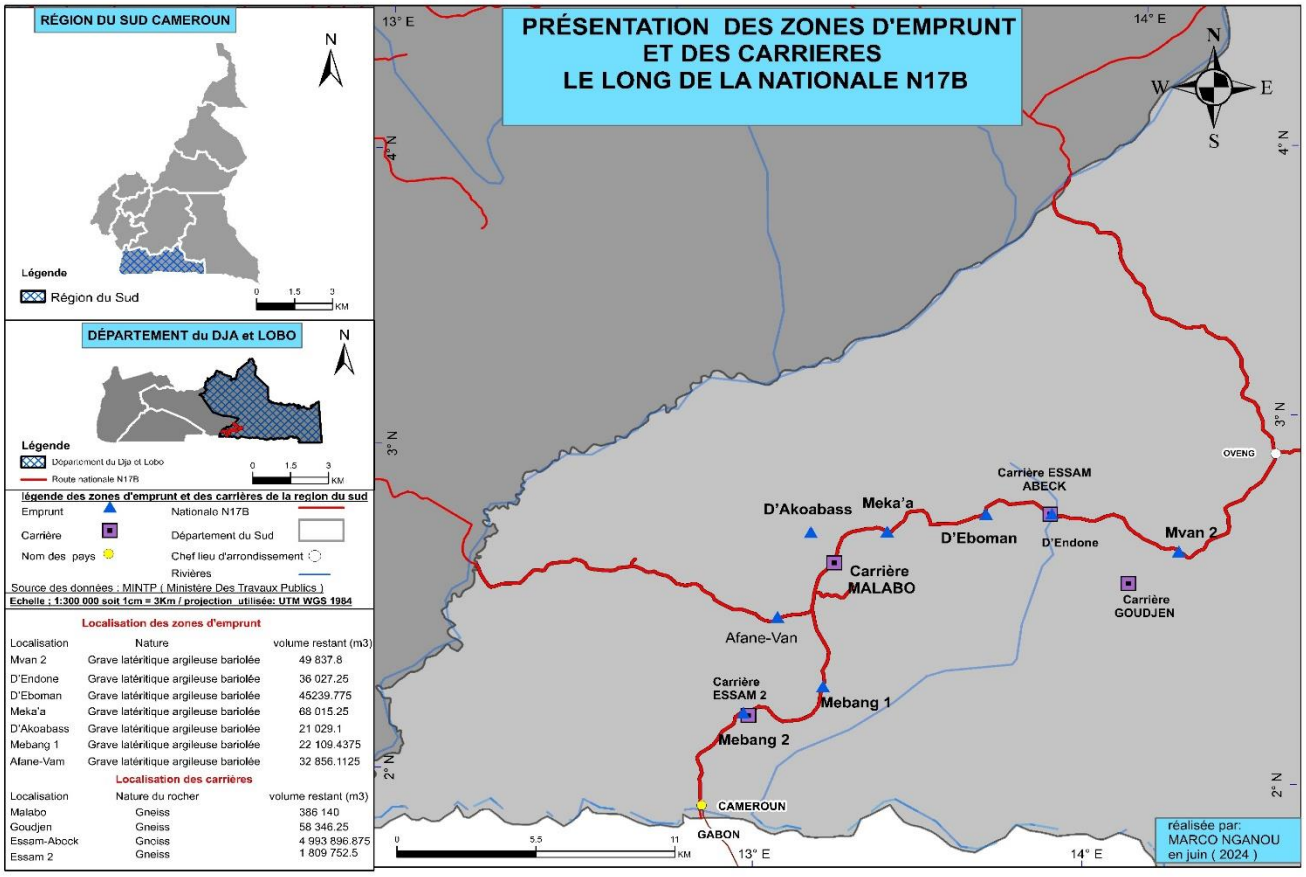
Table 2.6. The following table shows the mechanical characteristics obtained for each site investigated.

Location of Quarry	**Nature of the rock**	**PK**	**Distance from project (Km)**	**Cubature (m^3)**	**Volume remaining (m^3)**
ESSAM – ABECK	Gneiss	4+100	5	400 000	386 140
ESSAM II	Gneiss	4+750	2	60 000	58 346.25
MALABO	Gneiss	6+200	15	5 000 000	4 993 896.875
GOUDJEN	Gneiss	12+500	0.94	1 900 000	1 809 752.5
Estimated Volume of Quarry Sites (m3)				7 360 000	
Estimated Project Requirements (m3)				198 647	

2.2.2. Project mapping data

Some geographical data which have been produced on the ArcGIS mapping software are shown in figure 1.1 and 1.2





Conclusion

The road network in the central and southern regions of Cameroon is of crucial importance for regional and national connectivity. The main objective of this work was to use the possibilities offered by Geographic Information Systems (GIS) to map and quantify the borrowing areas and quarries along three major road sections: Yaoundé-Bonis, Esse-Edzendouan, located in the Central region, and Oveng-border of Gabon, located in the South region of the country. To achieve this objective, a literature review was conducted to collect existing knowledge on geo-materials in the regions. Then, a methodology was established to describe the process adopted to carry out this study. This method consisted first of an analysis of the geo-materials and then the creation of a database.

The results of this study include the creation of detailed thematic maps of geo-materials on the sections of roads: Yaoundé-Bonis, Esse – Edzendouan, Oveng- border of Gabon in the regions of the South and the Centre. In addition, a geo-spatial database was developed to consolidate the results of the quality assessment of the geo-materials available, and provide easy access to information for those involved in road infrastructure planning and management.

However, it should be noted that this work has some limitations, including the lack of data on the quality of geo-materials in certain areas, as well as the need for field validation of GIS results.

On the other hand, this study has given important information and location in the knowledge of geological resources for road construction in both the South and Central regions. The use of GIS technologies has provided accurate and up-to-date spatial information to improve road infrastructure planning and management. For the future, additional research could include field validation of GIS results, as well as exploration of the use of drones and other emerging technologies for spatial geo-data collection.

Ultimately, this study paves the way for a better understanding and use of geological resources for road construction in Cameroon, thus contributing to sustainable development and economic growth in the regions.

Declarations

Conflicts of interest

The authors declare no conflict of interest.

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Administrative authorization

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Author contributions

WOUNBA Jean François, contributed to the design of the study
NGANOU Marco Jessie, contributed to the collection, analysis, data processing and writing of the manuscript
MVONDO FANGA Aubin Loïc contributed to the critical reading and improvement
All authors have read and approved the final version of the manuscript.

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What we know about this subject

What webGeo brings

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