

CHALLENGES OF NEW CEMENT-BASED TECHNOLOGIES IN HUMID ENVIRONMENT OF EQUATORIAL AFRICA: LIBREVILLE EXAMPLE

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ABSTRACT

The program for the construction of new urban infrastructure in the capital of Gabon, Libreville, which started in 2017-2018, involved the design and execution of numerous public buildings at several urban locations. However, at the beginning of 2020, due to the pandemic, all plans changed. During the COVID-19 pandemic strict restrictions on the movement of people and goods, especially on an interstate and intercontinental scale, led to the slowing down and halting of a large number of projects.

The paper will present the challenges faced in the construction and execution of works with newly developed high-performance polymer-cement based material and casting technique, on the completion of the Central archive building project in Libreville. The complete ban on movement during the pandemic led to a disruption of works, and the continuation faced serious restrictions, with almost four years passing between the delivery of materials, the start of works, and their resumption. During the pandemic, the conditions for storing materials were far from the prescribed standards, and the works were unprotected. All materials and works went out of warranty. Given the importance of the facility, the prescribed quality of the works had to be achieved. Replacing the unapproved materials and removing unfinished works was not an option due to high costs, unacceptable delays and environmental issues. Since there was no previous experience with this new type of material that has been stored so long, new technology of application and testing methodology were developed. Through the application of supplementary design measures and adjustments, as well as on-site material testing and production site assessments, it was achieved that all works were carried out with the existing materials and required properties achieved.

KEYWORDS _ *Cement-based materials, new construction technology, humid environment, COVID 19*

INTRODUCTION

The Republic of Gabon is located in Central Africa, straddling the Equator along the western coast of the continent. Bordered by Equatorial Guinea to the northwest, Cameroon to the north, and the Republic of the Congo to the east and south, its western edge is defined by the Atlantic Ocean, where its capital city, Libreville, is situated.

Due to its equatorial position, Gabon experiences a tropical rainforest climate, marked by two distinct seasons: Rainy season – prolonged period of heavy rainfall (typically October–May), with coastal regions such as Libreville receiving extremely high precipitation (2,500–3,000 mm annually); Dry season – a shorter, relatively drier interval (June–September), though humidity remains elevated and sporadic showers still occur. Temperatures are consistently hot, averaging 25–30°C, with humidity levels often exceeding 70–90%. The climate's uniformity reflects Gabon's proximity to the Equator, where seasonal temperature shifts are minimal (*source: World Bank Group 2020, 2021*). Among all equatorial African countries, Gabon is the wettest, with average monthly precipitation of approximately 160 mm. It had a general average rainfall/10 year's increase from 1901 to 2015." (*Twumasi et al*).

Gabon's equatorial climate—marked by intense humidity, heavy rainfall, and consistently high temperatures—poses significant challenges for storing and working with cement-based materials. Moisture from the air and rain can prematurely degrade cement binders, alter curing processes, and weaken structural integrity, while prolonged heat exacerbates material handling risks. These factors demand rigorous moisture control, climate-adapted storage protocols, and precise timing of construction activities to mitigate delays and ensure durability.

Unfortunately, COVID-19 lockdowns worsen Gabon's already challenging climatic and logistical conditions for construction. Movement restrictions disrupted supply chains, delaying the delivery of cement-based materials and equipment, while prolonged storage periods under suboptimal conditions (e.g., high humidity, unprotected sites) accelerated material degradation. Lockdowns also halted the works, hindered on-site inspections and quality control, compounding risks of improper curing or compromised structural performance. The overlap of pandemic delays with Gabon's heavy rainy season further strained timelines, as outdoor work faced extended interruptions. These compounded pressures—climatic vulnerabilities amplified by pandemic constraints—made adherence to project specifications and warranties even more complex.

DESIGN AND CONSTRUCTION OF THE CENTRAL ARCHIVE BUILDING

Launched in 2017–2018, Libreville's urban infrastructure development program aimed to design and construct numerous public buildings across strategic locations in Gabon's capital. One of them, the building of the Central Archive of the DGDI (Direction Générale De La Documentation Et De L'immigration), represents an object of special significance for the administration of the Republic of Gabon. It has been designed as the central building for the DGDI administration with the necessary official premises, offices, and spaces for the central archive, where a large number of important documents in various media are stored, under strict requirements concerning the quality of the materials, equipment, and workmanship used. The building has two floors (ground floor + first floor) and is divided into two functional units: a section for employee work (central hall, meeting rooms, offices for employee work and client interactions, and accompanying service rooms), and a section for document archiving (digital and analogue archives with special storage and access arrangements). The building's structure is made of reinforced concrete, consisting of load-bearing columns and walls, with the arrangement of structural elements in accordance with architectural requirements (see Figure 1). The finishing materials have been selected according to the importance of the building: the façade is designed as a modern curtain wall, while the interior finishes are defined by the significance and representativeness of the building. Special attention has been given to the flooring due to high durability and resilience requirements on one hand, and representativeness and

aesthetics on the other. Due to these complex and sometimes conflicting requirements, new type of polymer-cement marble flooring were developed and applied through a modified casting and grinding process, for the majority of the building, particularly in the public and archival areas.



Figure 1: Central archive building – 3D view

The execution of works in Gabon requires particularly careful planning and timely delivery of materials and equipment. All materials are shipped via the Port of Libreville and are delivered to the construction site after inspection and customs clearance. Due to the specific location of Libreville, shipping can take from a few weeks to a few months, depending on the place from which the materials are sent. According to the dynamics of construction works on-site, the flooring materials were delivered in 2019, and the flooring work began in early 2020. However, the onset of the COVID-19 pandemic in early 2020 forced a dramatic re-evaluation of all project plans. Designers and contractors faced unprecedented challenges, as strict interstate and intercontinental travel bans severely disrupted the movement of labour and materials, leading to widespread delays and suspensions of construction activities. The sudden imposition of lockdowns also derailed standard protocols for preserving partially completed structures, leaving the project vulnerable to environmental degradation and material decay.

After the declaration of the end of the pandemic, activities to resume work on the building were undertaken (see Figure 2). Due to the three-year halt, all warranty periods for materials and equipment had long expired. A significant challenge was assessing the condition of the initiated but unfinished flooring work, particularly regarding the materials used for it. Since the materials are based on cement and polymers that are highly sensitive to moisture, there was a real risk that, after three years of inactivity, the materials had become unusable. Replacing all the materials with new ones would be very expensive. An even greater challenge was transporting the materials from Serbia to Gabon, as shipping was dramatically reduced and slowed down due to the pandemic. Uncertainty in transportation could lead to months of delays in work and jeopardize the completion of the building. It was proposed to check the condition of the materials stored on-site and to assess their usability. Regardless of the assessment results, due to the significance of the building, there could not be a compromise on quality, and it was required that all applied materials come with the same warranties as if they were new.



Figure 2: Central archive building during construction

The uncertainties were not only about the condition of the materials and completed work, but also regarding the possibility of keeping the local workforce, specially trained for executing this type of specialized flooring work, on-site until operations could resume. After considering several different options from the perspectives of quality, costs, and the necessary time for implementation, the decision was made. The only rational solution was to subject the existing materials stored on-site to rigorous testing and inspection, so that they could be utilized to the greatest extent possible, provided that the required quality guarantees for the work performed could be offered. In this way, work could soon resume, while any potentially missing materials would be delivered as soon as shipping conditions allowed.

CHALLENGES OF QUALITY CONTROL OF CEMENT-POLYMER MATERIALS

From the very first step in the assessment process, many uncertainties arose. The conditions for storing materials at the construction site over the three-year period were far from ideal. Due to restrictions on the movement of people, it was not possible to monitor the storage conditions, reorganize, or further protect the materials during the pandemic. Predicting the properties of cement-based materials over time is always filled with uncertainties, especially when the conditions under which the components were stored are unfavourable, inappropriate, and largely unknown.

The first step was to define the most adverse scenarios for the storage conditions of the materials and their impact on quality, both during the execution of the work—with consideration for setting time, workability, and installability—and for the finished floor in terms of strength, avoidance of micro-cracking, wear resistance, and durability under long-term use conditions. An extensive literature review was conducted regarding the impact of hot and humid equatorial climates on cement materials and the execution of their installation. Based on the experiences of numerous authors (*Ramge et al., Cieri et al., Ahmad et al., Mota et al.*), testing methods and the necessary properties that the stored materials should possess were established in order to evaluate their usability. Any potentially necessary adjustments in the technology of execution were controlled based on recommendations from the literature (*Tim, T.C., Das S. & Sarkar K., Sarkar K. & Bhattacharjee B., Abbas et al.*) combined with personal experiences from previous projects (Okolassi school).

The biggest challenge was assessing all the preceding factors on the properties of the finished floor. The flooring, based on polymer-cement binders and specially selected marble aggregates and mineral additives, was chosen not only for its solidity and durability but also for its exceptional aesthetic

characteristics. The properties of solidity and durability could be assessed based on the experiences of others (Valdes *et al.*, Vu *et al.*, Sun *et al.*, Bisschop, J., & Wittel, F. K., De Sa *et al.*, Hossain, A. B., & Weiss, J., Megid, W. A., & Khayat, K. H., etc.), but the properties necessary to achieve the desired aesthetic qualities (colour tone stability, uniformity of surface without cracks) needed to be verified on test samples from materials on site. Since it was easier to travel to Libreville than to transport materials, the testing of materials from the construction site was carried out on location.

Examination of material properties after three years of storage on construction site

Tests necessary for executing the work (consistency, setting time, workability, and cast ability) were conducted on-site. The particle size analysis of the material was examined through sieving. Based on the obtained results, the particle size analysis specifications for the usable material were defined. Any material that did not meet the specified particle size analysis had to be removed. For each batch of produced material, there was a control sample at the production site, which was kept under controlled conditions. Therefore, it was possible to conduct a comparative study of the material stored under recommended conditions (room temperature $20 \pm 2^\circ\text{C}$, humidity $< 60\%$) and that in unknown tropical climate conditions. Based on previous research and literature review, compressive strength, flexural strength, adhesion to the substrate, and wear resistance were adopted as key properties for the long-term quality of the material. The comparative results of the tests conducted are presented in Table 1.

Table 1: Designed, delivered, and achieving quality of floor material after three years of storage

Properties (mean values)	Designed	Delivered	Achieved* (after 3 years)
Compressive strength	$> 60 \text{ MPa}$	67.5 MPa	62.5 MPa
Bending strength	$> 8 \text{ MPa}$	9.9 MPa	8.4 MPa
Adhesion to surface	$> 2 \text{ MPa}$	2.7 MPa	2.6 MPa
Abrasion resistance	$< 50 \text{ cm}^3/\text{cm}^2$	$37.8 \text{ cm}^3/50\text{cm}^2$	$39.2 \text{ cm}^3/\text{cm}^2$

* Material selected for casting

Test results and recommendations

Based on the results obtained from testing on-site (Gabon) and at the production site (Serbia), it was noted that the properties of the material changed only slightly, allowing the requested quality to be guaranteed. Tests on cast ability and workability showed that the material could be installed as recommended. The gradation test through sieving was adopted as a method to separate the already set material. Fortunately, the quantities of such material were minimal ($< 6\%$, mostly from damaged packaging). Thanks to the reserve in the delivered quantities, there was no need to supply new quantities of material, which expedited the execution of the work and significantly reduced costs. Casting technology were adapted according to the obtained testing results.

The greatest concern was the assessment of the long-term properties of the material and the durability of its aesthetic characteristics. In order to obtain the necessary data on the behaviour of the material, tests were conducted (both on-site and at the production site) on samples obtained by casting and processing various complex shapes in special moulds. The samples were subsequently finished and subjected to tests simulating the environment in which the material would be placed. Conditions in public spaces, as well as conditions in archival rooms, were simulated. The material did not show any hidden defects or tendencies towards colour loss, smoothness, cracking, and similar issues. Based on the obtained results, it was concluded that the stored material could be used without any restrictions. This enabled the execution of all designed complex shapes in the floor (see Figure 3).



Figure 3: Main hall emblem

CONCLUSIONS

Executing work in remote areas relative to the location from which materials are supplied and organizing the work is always full of challenges and uncertainties. However, the COVID-19 pandemic led to a unique situation that practically suspended numerous activities for several years and reduced almost all others to a minimum.

Work that began on an important national project in Libreville, Gabon, had to be completely halted. Due to the complete travel ban, it was impossible to protect the completed work and stored materials from the effects of the tropical climate, high temperatures and humidity, as well as the intense and heavy tropical rains. Resuming work after the pandemic was a real challenge, not only because of the disrupted supply and communication chains but also because the warranty period for the materials and equipment had long expired, along with the inability to simply and economically replace materials and equipment with new ones.

Thanks to the experiences gained and the extensive tests conducted on the stored materials, it was possible to guarantee the quality of the work despite the inadequate conditions and the expiration of the warranty period.

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