Collège Amadou Hampaté Bâ, Niamey, Niger: structural design in an international development context

SYNOPSIS

Collège Amadou Hampaté Bâ, a school in Niamey, Niger, was MHA Structural Design's winning entry to the Structural Awards 2023. The project won an award for its use of sustainable local materials and for enabling positive social impact. For this article, the IStructE's Humanitarian and International Development Panel spoke to the firm's structural engineering design lead for the project, Marco Conti. The case study explores key considerations and appropriate technological approaches to structural design in humanitarian and international development contexts.

Background

Collège Hampaté Bâ utilised a range of innovative engineering solutions and construction techniques to create a functional, yet inspiring, space for learning. The design team, composed of MHA, Article 25 and Max Fordham, had to overcome various challenges posed by the extreme Sahelian weather conditions, the lack of advanced construction technologies, the limited availability of building materials, and the absence of local building codes.

The design of the classroom blocks incorporates a double roof system that provides shading and forms an air curtain to reduce the temperature of the vaulted ceiling **(Figure 1)**. A series of mono-pitch steel trusses spans along the short edge of the buildings, overhanging beyond the walls **(Figure 2)**. The geometry of the trusses has been designed to maximise the shaded area during the day and to protect the walls and ceiling from the heavy summer rains. The orientation of the buildings and the slope of the roofs are designed to follow the mean wind direction, improving the cooling of the ceiling structure thanks to the air flow. The lower chord of the steel trusses supports the base of the barrel vaults. The reinforced concrete ring beams resist the thrust of the vaults and redistribute the lateral actions to the laterite shear walls and piers. The superstructure and slab sit on a raised plinth over reinforced concrete ground beams.

Cement stabilised earth blocks (CSEBs) were chosen for the vaults across the trusses due to their light weight and small size, simplifying the

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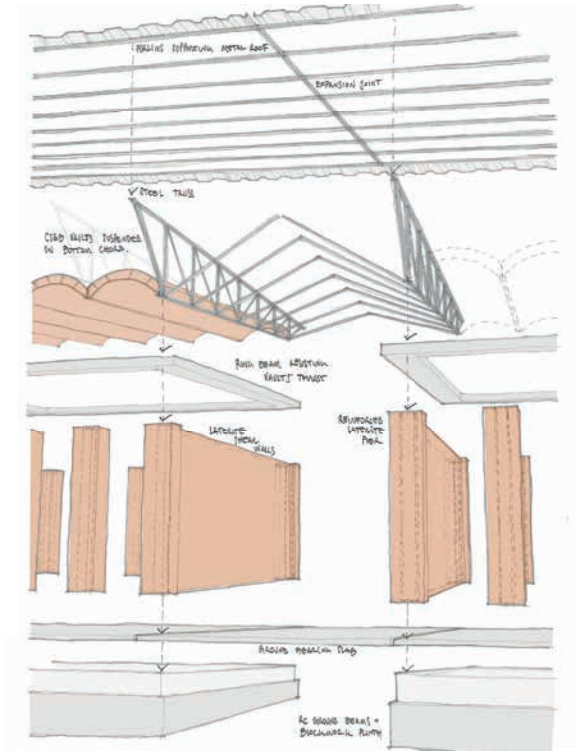
↑FIGURE 1: Double roof system provides shading and forms air curtain to reduce temperature of vaulted ceiling

Project team

Structural engineer	MHA Structural Design (pro bono)
Architect	Article 25 (low bono)
MEP engineer	Max Fordham LLP (pro bono)
Contractor	Afrique Universe



construction and improving the site accuracy. Prototypes were built on the ground and tested before installation, giving further reassurance on the strength of the structure and providing a useful opportunity for the workers to familiarise themselves with the construction method. The secondary buildings have a different roof construction, with a thick laterite vault, rendered and finished with a whitewash paint.

The emphasis on sustainability and use of locally sourced materials also provides social and economic benefits to the surrounding area.

The project has had a significant positive impact on the local education sector, where it is helping to address the high drop-out rate among primary school children.

↖FIGURE 2: Exploded view of structure

Q&A

Talk us briefly through your design process and thinking, and how you ended up with the final design.
Our design process for Collège Amadou Hampaté Bâ drew from successful precedents set by our design team in the region, emphasising cross-disciplinary collaboration. The integration of local materials, particularly laterite, and collaborative experiences from previous projects provided the foundation for the innovative and context-specific design, ensuring sustainability and functionality.

How did you ensure that local construction knowledge and skills were incorporated into the design and the construction process?
Our design process prioritised an exchange with local professionals and craftspeople. Through on-site training programmes, we collaborated closely with local masons, sharing expertise on working with laterite and CSEBs. This exchange not only enhanced construction skills but also fostered meaningful collaboration, enriching the project with traditional craftsmanship and promoting vernacular architecture.

How did you incorporate the unique needs and desires of the children and the teachers into the design?
The team engaged in collaborative workshops with staff and pupils to understand their needs. This participatory approach directed the design, ensuring the space is not only functional but also addresses the critical requirement for a cooler and more comfortable environment for studying during the day. Additionally, we incorporated specific facilities to meet the needs of female students, promoting inclusivity.

Could you expand on the structural characteristics of the local laterite? How strong is it, and why does it harden with time? How does it perform in a sustained flood?
The mechanical properties of local laterite vary significantly across extraction sites. However, we observed a noteworthy increase of approx. 50% in compressive strength after six months of air curing. Its hardening results from chemical weathering of iron- and aluminium-rich soils under high temperatures. While laterite provides good structural performance in normal conditions, its performance in a sustained flood is mitigated by using a reinforced concrete raised plinth, ensuring durability.

What were the challenges of working with the local laterite and using it for structural columns and walls? Did you select a lime- or cement-based mortar for bonding, and why?
Working with local laterite for walls presented challenges tied to the variability in mechanical properties, compounded by the scarcity of local data. To address this, we developed a testing regime and used steel-reinforced masonry walls. Opting for a lateritic lime-based mortar not only aligned with laterite's characteristics and sustainability, but also ensured better accommodation of movements, given its flexibility. This choice proved crucial, especially considering the unreliable supply of cement from neighbouring countries.

At end of life, how can laterite be disposed of or reused? Does it remain solid or, if buried, does it return to a softer form?
Based on our recently constructed projects and similar examples, the laterite has demonstrated remarkable durability so far and remains solid. Historical records of laterite used in different regions also attest to its long-lasting qualities, with many structures still in good shape, highlighting its potential even beyond the anticipated lifecycle of this building. At the end of its life, laterite can potentially be crushed and utilised as part of a mortar or render mix, so has potential for reuse. Reusing the blocks is, in principle, feasible if the mortar is not cement-based, although the practicality is currently hindered by the labour-intensive dismantling process, as the proximity of the quarry results in nearly negligible material costs.

Are arches common in the vernacular architecture, and how did you adapt this local knowledge?
The design draws inspiration from traditional arches built with mud bricks, commonly utilised for constructing floors and roofs without the need for formwork. This technique, historically employed in various structures, including residential buildings and community spaces, has deep roots in the region. We opted for shallow barrel vaults that reduced the depth of the steel trusses supporting the corrugated steel roof, while maintaining a similar architectural language that could pay homage to the versatile and enduring construction methods observed in traditional buildings throughout the region. A perimeter reinforced concrete ring beam dealt with the thrust from the short-span barrel vaults, and the long-span barrel vaults were tied.

What tests did you conduct into the durability and strength of the laterite and the CSEBs?
We initiated the process by consulting local specialists to understand the optimal mix design for CSEBs. Subsequently, through a series of compressive strength tests conducted at regular intervals, we gained a comprehensive understanding of the evolving properties of both laterite and CSEBs, including their compressive

strength and durability over time. Additionally, on-site prototyping served as a valuable training session for masons, while load testing further validated the materials' performance.

What is the design life of the building?
The design life is intended to be at least 50 years.

Will the building require much structural maintenance?
In the challenging climate of Niamey, the building will require ordinary maintenance typical for constructions in this environment, including routine measures for masonry upkeep, such as repointing, and regular checks on exposed steelwork. The integrated engineering and architectural design of the building enhances its overall performance, offering a holistic approach to maintenance and longevity in this harsh environment.

How was design, operation and maintenance information transferred to the end user?
Design, operation and maintenance information were effectively communicated to the end user through a comprehensive manual in French. The construction site, running concurrently with school activities, facilitated regular exchanges between site operatives and school personnel. The key emphasis was on a resilient design that inherently requires little maintenance.

How was capacity, inclusion and equality built up in the local construction industry?
Local capacity and inclusion were enhanced through the prioritisation of local materials, architectural choices inspired by vernacular styles, and active engagement with local professionals, fostering sustainable practices and contributing to community development. An additional initiative involved conducting vocational training courses for female students during construction, exposing them to construction skills, architectural principles, and engineering concepts. This effort aimed at encouraging continued education and potential careers in the construction industry, promoting gender inclusivity in the field.

Is the design effective at keeping the interior cool?
The double roof, providing effective shading and complemented by the thermal mass of the building, creates a synergistic effect, contributing significantly to keeping the interior 7–8°C cooler than the exterior even when occupied by 40 students **(Figure 3)**. Striking the right balance between optimising the thermal mass of the ceiling and considering the structural implications on the trusses posed a notable challenge in the design process. There is ongoing exploration of additional measures to enhance thermal performance, marking a core objective for the next phase of the project.

How does the embodied carbon of the final design compare with a typical school in Niger?
The structure demonstrates significantly lower embodied carbon (155kgCO_2e/m^2 for modules A1–A5) compared with typical Nigerien schools (over 300kgCO_2e/m^2). This has mainly been achieved through the use of laterite blocks, sourced just outside the city, and CSEBs, formed on site with a mix including excavation spoil and lateritic sand. With minimal finishes and structural carbon representing around 85% of the whole building, the design outperforms typical UK building targets. Moreover, the building's lower energy consumption, with upfront carbon (A1–A5) accounting for 70–80% of the whole-life carbon (A–C, including operational energy) of the building, further contributes to its sustainability.


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FIGURE 3: Building was designed with users in mind, ensuring effective cooling of interior spaces

What feedback did you get on the design from the end users?
Feedback from end users has been positive, particularly regarding the effective cooling of interior spaces. Additionally, the sports facilities and communal areas have received favourable comments. Importantly, the project has become a landmark for education in the area, instilling a sense of belonging and pride in the school community. It is, however, worth mentioning that while all staff and users appreciated how well laterite can perform, some still have reservations on the appearance due to its social perception as a poor material.

What would you change in the design if you were to build more of these schools?
With more reliable data on laterite's long-term performance, we would consider its broader use, potentially replacing most of the CSEBs in the barrel vaults. This optimised approach aligns with the team's commitment to continual improvement and sustainability, and also reduces dependency on imported cement, making our projects more resilient to external factors such as political relationships with neighbouring countries. Additionally, we would explore further optimisation of the corrugated steel roof to enhance its overall performance.

What were the biggest challenges on the project?
The variable properties of local materials, including laterite, prompted a return to testing and fundamental engineering principles. The scarcity of construction materials, notably cement and steel, posed logistical challenges. Ensuring quality control from a distance added an extra layer of complexity to the project. However, these challenges were successfully overcome, thanks to the expertise and professionalism of the on-site team.