Global engineers thinking locally: creating kindergartens for Africa

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This paper reflects on the wider benefits that civil engineers can bring to individual communities when undertaking design services through engaging with local stakeholders and understanding the environment, context and culture in which they work. A sustainable kindergarten complex in Ghana is used as a case study to illustrate the benefits of civil engineers adopting a broader perspective, combining global expertise with local knowledge. The paper explains the design approach taken by the team and the key features of the design and construction, which offers a sustainable solution to the shortfall in facilities for early-years learning in Ghana and potentially throughout Africa.

1. Introduction

Great value is placed on sustainability in today’s built environment with a strong emphasis on low-carbon-dioxide solutions and minimising use of natural resources. However, civil engineers need to move out of their technological comfort zone and develop infrastructure that is also socially sustainable.

Social sustainability comes from understanding and being sensitive to the needs of the local culture, context and environment, and leaving behind skills and enhanced institutional capacity that will support future development. This requires a broader perspective than has typically been required from engineers working in countries in Europe and the USA. Recognising this is particularly important for global engineers working in developing countries, who need to ‘think locally’ if they are to deliver appropriate solutions which have a positive impact.

This paper provides a case study of how engineers have combined their global expertise with local knowledge to develop a prototype for a sustainable kindergarten, part of a programme to address the challenges of inadequate infrastructure for early-years learning in Ghana.

2. Sustainable kindergarten complex

In 2004 the government of Ghana launched a comprehensive early childhood care and development policy to formalise and expand support for the kindergarten sector. Despite great progress in the past 8 years numerous obstacles remain, many of which relate directly to insufficient infrastructure and inadequate learning environments.

Net enrolment for kindergarten in Ghana is currently 60%, meaning that roughly 605,000 four- and five-year-old Ghanaian children are not yet in school. Conservative estimates state that 8000 kindergarten classrooms need to be built and a further 3700 require major repairs (MoE, 2011).

Where classrooms do exist they generally provide spaces that are not conducive to the ‘learning through play’ environment desired at kindergarten level (GES, 2012). Typical government school buildings consist of a three-classroom linear block. These are built from weak concrete blocks with few windows, resulting in classrooms that are dark and poorly ventilated. Over half of the kindergarten schools in Ghana do not have toilet facilities and only 20% have access to drinking water.

The Sabre Charitable Trust is an education charity working in rural Ghana to improve the future of disadvantaged and marginalised children. Its work focuses on improving early-years learning through teacher training, providing teaching materials and building child-friendly learning environments. Its programmes are aligned with the government’s goals and they work closely with the Ghana Educational Service (GES).

In September 2008 Sabre approached Arup for assistance in the design and construction of a prototype sustainable kindergarten complex that was maintainable, replicable, scalable, value for money and child-centred. The project goal is for the prototype to be accepted as a building standard in Ghana and to be rolled out through the national government school-building programme.

Inspired by the charity’s vision Arup agreed to participate and provide engineering and architectural design services, including
sustainability assessment, construction supervision and strategic advice on a pro-bono basis. Arup entered into a three-way partnership with Sabre and Davis Langdon, which provided project management and cost consulting services.

3. Design approach

The approach to planning and designing the kindergarten complex was shaped by local needs, materials, capacity and culture. From the outset the intent was to develop a prototype design and process that could be replicated so as to enable the programme to be scaled up nationally. Building performance, cost and buildability were key design considerations and sustainability was central to the design approach.

In developing countries sustainability embraces much more than ‘green buildings’ or the use of local materials. Maximising social impact and making the most of limited resources is essential, placing greater emphasis on affordability and durability, while also recognising the opportunity that building projects afford to develop skills and capacity within the community.

The success of the project relied on creating ownership locally. This was achieved through extensive liaison with the government and time spent building relationships with local authorities as well as active engagement with the community where the first kindergarten complex was built. The design brief was informed by participatory planning processes. This and regular visits to Ghana ensured that the design team had an appreciation of the local context in terms of capacity, environment and resources.

A further factor in reaching a coherent, appropriate and cost-effective design was the decision to develop the design through a series of workshops. This enabled the multi-disciplinary design team to work collaboratively, resulting in a more integrated approach to design development. The team was led by a structural engineer and included an architect, other structural and civil engineers, a building physicist, lighting engineer and seismic engineer. Design workshops as well as progress meetings were often attended by Sabre and the cost consultant.

4. Stakeholder consultation

The success of this type of project is dependent on the quality of the design process as much as the end product. Stakeholder consultation (Figure 1) is essential to create local ownership of the project and gain an appreciation of the local context that will ensure an appropriate solution.

A needs assessment carried out by Sabre in collaboration with GES had identified Dwabor as the community in the Komenda–Edina–Eguafo–Abrem district that was most in need of a new kindergarten school. The first task was to undertake an analysis of potential stakeholders in the project. Sabre already had a good relationship with the education service and a strategy for coordination and collaboration with various civil society groups. In addition the project team identified additional stakeholders, including local architectural and engineering firms and donor organisations.

Stakeholder consultations were undertaken jointly by Sabre and the design team at several different levels. At a national level meetings were held with the Ministry of Education, Unicef and the World Bank to understand the level of commitment and support for education.
and infrastructure projects in Ghana. At the regional level local consultants and other non-government organisations provided insights and information on local construction methods, availability of skills and materials. At district level the municipal education office (part of the education service) and the municipal assembly made a significant contribution to the design and planning of the project.

There was a particular focus on consultations at the local level with the community, particularly with the village elders. Information was gathered through participatory planning exercises. Timeline mapping (Figure 2) was used to understand how the community conducted their daily lives and whether it was realistic to expect them to contribute to the construction. Village mapping exercises informed the location and orientation of the school and highlighted the resources within the village. Direct observation and focus groups including women and children provided the design team with valuable insights into what they liked and disliked about their environment, as well as their expectations of the project.

Specific consultations were held with the teachers who, as end-users of the kindergarten, were well placed to offer an informed view of what the facility should comprise and to critique the design proposal.
Cardboard blocks representing different types of accommodation space (classrooms, toilets, kitchens, office) were used by the teachers to explore the best layout of the school. They also identified and prioritised other key performance criteria including acoustics, comfort, wall space and storage. The teachers and the education service personnel who were present were delighted when, several months later, the design team presented the final design and it was self-evident their input had been taken seriously.

The design team also invested significant time in visiting other schools in the district and in Accra to consult with teachers and pupils, research different architectural styles and building technologies, analyse what has and has not worked in the past and identify potential material suppliers, standard component sizes and costs. The intent was to use local materials and suppliers wherever possible so as to contribute to the local economy and to reduce wastage, part of an overall strategy towards creating a sustainable and economic facility.

Procurement and transport of materials and opportunities to promote new building technologies, create local employment and up-skill local labour were further considerations. Sabre employed a local Ghanaian site manager whose local knowledge was integral to design development and decisions about the construction process. Input was also sought from local architects and engineers before finalising the construction details.

5. The design

5.1 Layout

The kindergarten has been conceived as a complex since the classrooms are complemented by external teaching areas, a staff room, toilets and a kitchen, which collectively provide a self-contained educational environment (Figure 3).

The various facilities are organised around a central spine which acts as the core circulation route and extends from the kitchen past the three staggered classrooms to the toilets. This arrangement facilitates monitoring of pupils and promotes interaction. Additional shaded external teaching areas – reported by GES as being highly beneficial in a tropical climate – are accessed from each classroom through large pivoting doors.

Colour, scale and layout are used to create a child-centred design that provides a hub of playful exploration and promotes a learning environment unprecedented among government schools in Ghana. A typical government primary classroom is 44.7 m² while the kindergarten complex classroom is 103 m². Each child has 2.4 m² of space which is in line with international standards. The complex also meets Unicef standards for ‘child-friendly’ schools (Unicef, 2011).

5.2 Environment

The classrooms were designed to provide a high-quality learning environment in terms of daylight, temperature and acoustics (Figure 4). Performance-based criteria relevant to a kindergarten in a tropical environment were developed based on international guidelines for teaching spaces. Electricity is hard to come by in rural Ghana and is often prohibitively expensive, therefore it was important not to rely on energy to cool or light the classrooms.

Dynamic thermal analysis was undertaken using Oasys Beans software to analyse the variation in internal temperatures. Radiance software was used to analyse daylight levels and verify that the performance criteria were achievable without resorting to active systems (Figure 5). The classrooms were designed to have an illuminance of 300–3000 lx, which gives enough daylight in the space to perform educational tasks and not too much to cause glary conditions. This was possible as a result of an innovative facade made...
up of pivoting bamboo shutters allowing an optimum amount of natural light and ventilation at different times of day (Figure 6).

The classrooms are orientated so that the shuttered openings are located on the north and south elevations to allow for the maximum amount of airflow and daylight. The internal walls and ceiling are painted white so as to create a light internal space and closing the shutters prevents glare. The east and west facades are solid and shaded to protect the classroom from the strong low-lying early morning and late afternoon sun. These walls also provide ample space for pinning up teaching materials.

The off-centre pitch roof on each classroom is designed to generate a large area for rainwater collection used for drinking, hand-washing and cooking. The roof overhangs reduce glare internally and provide sheltered walkways externally.

The roofing is corrugated metal sheets, which are the preferred option locally and have advantages when collecting rain water as the hot metal prevents bacteria growing. The disadvantage is that the roof gets very hot and radiates heat into the space below and, when it rains, the noise can be disruptive to the class. This has been resolved by using fibre from coconut husks as insulation, which is sandwiched between the metal sheets and a split-bamboo ceiling (Figure 7).

5.3 Safety
Conveying the danger of earthquakes to buildings and their users is a challenge in Ghana – a major earthquake has not occurred in over 70 years. Nevertheless much of the country is subject to significant seismic hazard.

A Ghanaian code exists that includes seismic provisions (BRRI, 1990) and is based on a superseded version of the Uniform Building Code 90 (ICBO, 1990). However most educational buildings are not designed to withstand earthquakes, placing children at risk. If designed appropriately school buildings can play an important role in the aftermath of an earthquake by acting as refuge centres.

Dwabor is in an area of relatively high seismicity so the structure has been designed to meet the ‘life-safety’ requirements of Eurocode 8 (BSI, 2006), which provides a conservative solution in other areas of the country where the seismic hazard is lower.

5.4 Sustainability
The combination of a facade with a high proportion of openings and the need to resist seismic forces in the event of an earthquake resulted in a concrete moment frame rather than shear walls as the preferred structural solution. This creates more options for the infill walls where extensive use has been made of renewable and locally sourced materials. It also makes it possible for the community to carry out regular maintenance and repairs themselves.

The concrete frame was designed using locally sourced pozzolana made from clay and palm kernels as a 30% substitute for Portland cement. Mud bricks have been used for the base of the walls and fast-growing bamboo, which is widely available, was used to clad the walls and ceilings and provide a lightweight structure in the external shaded areas (Figure 8). These finishes can be adapted to suit various climates, cultures and availability of materials, increasing the possibility of replicating the prototype nationally and elsewhere in Africa.
In rural Ghana mud bricks and bamboo were considered as ‘poor man’s materials’. However the team was able to demonstrate that it was possible to make soil blocks using relatively low quantities of cement that were both strong and durable. Indeed, compressive strength tests confirmed them to be twice as strong as locally procured concrete blocks (Figure 9). Their proven strength, good durability and rich appearance means that as a result of this project they have gained a good reputation in the region and are now being used more extensively elsewhere.

6. Construction

A core intention of the project was for the construction process to offer hands-on training that would develop the skills of individuals for the benefit of the project and create future employment opportunities. As the workforce was recruited locally, including many people from Dwabor itself, the intention was that this would enhance the socio-economic fabric of the community as knowledge is transferred. At the opening ceremony certificates were provided to those who had worked on the project to verify their involvement and the training they had received (Figure 10).

In addition to the paid workforce the community provided voluntary labour. Initially there was strong enthusiasm that the Dwabor community would provide voluntary labour as a contribution towards the project. This enthusiasm proved difficult to sustain, particularly as the initial ground clearance, site levelling and digging drainage channels were labour-intensive but yielded little in terms of visible results. The teams were incentivised with free meals and also financial bonuses for being the best-performing work gang, but it became apparent that the voluntary labour scheme was in conflict with their other income-generating commitments such as farming, market selling and taxi driving.

The attendance of the community labour gangs dwindled despite efforts from both the local project management team and the community elders to keep them engaged. A good compromise was to have a full-time team of paid skilled and unskilled labourers but then organise mass community participation days that were less frequent when activities required large numbers of unskilled workers. For example, the village football teams competed with one another to strip fibre from the coconut husks for insulation.

Arup seconded a structural engineer to Sabre throughout the construction period, who lived in Dwabor with the community. As site engineer he provided support to the charity’s Ghanaian site manager who was responsible for supervising the works and ensuring progress. The secondee’s role included the introduction of a quality-control strategy on site, regular reporting, liaison as necessary with the design team and training a young Ghanaian engineer to take on the role of site engineer on future projects.

Typically there is little concern for health and safety on construction projects in developing countries and the site engineer’s responsibilities included raising awareness of health and safety risks and education on site safety. Signage was used to communicate the health and safety issues to the wider community alongside display boards explaining the design and its progress.

When the second kindergarten complex was constructed a year later at Ayensudo, a core workforce was selected from the Dwabor team to lead specific activities. This improved the quality of workmanship and reduced the construction period. For example, the timber roof trusses for the second school at Ayensudo were fabricated in a quarter of the time that it took in Dwabor.

7. Evaluation

Once the Dwabor kindergarten was complete (Figure 11), the design team carried out a review to evaluate the project in terms of both its buildability and functionality. This involved participatory workshops with the community; focus groups with teachers,
children, and labourers; and key informant interviews with the education service.

Many of the labourers were illiterate so they placed yellow (easy to build) and red (hard to build) stickers on the detail drawings and photographs taken during construction. Those with red stickers were discussed and the construction details were then adapted with their help to make it easier to build.

The workshops identified areas of the design that could be optimised before the next project and how the construction information could be revised to make it more user-friendly for the semi-literate workforce to interpret. The value-engineering exercise identified cost savings of 5%.

The construction information was repackaged into an A3 construction manual that, when used on the second kindergarten complex at Ayensudo, reduced the construction programme by 15%. The manual consists of different chapters providing user-friendly rules and guidance covering every aspect of the project, including when and how to carry out community consultations, criteria for site selection and guidance on site-specific drainage design.

The original two-dimensional construction drawings have been simplified so as to make the building process as understandable and accessible as possible. They are supplemented by three-dimensional images with easy-to-follow construction sequence cartoons and annotated material schedules (Figure 12).

8. Impact

When the Dwabor prototype school opened in February 2010 there was an immediate increase in attendance of 45% (Figure 13). A year later attendance had increased to 190%, with children coming from neighbouring villages.

For the last 2 years Sabre has measured the success of its classroom interventions through termly pupil assessments which measure the children’s educational attainment in terms of literacy and numeracy. The results show that the pupils in the schools where the charity has supported teachers and/or provided learning resources and infrastructure have outperformed their peers in non-supported schools by 60%.

Users report that classrooms are significantly lighter, cooler and quieter when it rains than traditional government-built structures, and the school out-performs government models in terms of space and cost per child. The school is 10% cheaper to build than a standard government school based on a cost per square metre.

The school design has been cited as providing some of the best kindergarten classrooms in the country by both the GES and Unicef; it has also been featured as an exemplar school in a review commissioned by the Department for International Development (GES, 2012). Rachel Hinton, human development adviser at Department for International Development Ghana said, ‘We have to say that this is one of the outstanding models that shows how education can be delivered in partnership between the local community, the school, the parent–teacher association and the government representatives, to provide a truly inspirational learning environment’.

9. Scaling up

A staged approach is being taken to scaling up the project: pilot, optimise, replicate, scale. Sabre is currently focusing its efforts within the Komenda–Edina–Eguafo–Abrem municipality of the central region. To date four kindergarten complexes have been completed and a further eight are planned in the municipality and neighbouring western region.

The sustainable kindergarten complex has been developed in response to a shortage of suitable kindergarten facilities nationwide. The design team has identified a series of studies to enable the prototype design to be adapted in different regions of Ghana where other building materials may be available or more culturally appropriate.

The existing construction manual will be expanded to include drawings and details of the extended ‘kit of parts’ and a visual matrix will demonstrate the range of material choices, truss options and infill wall sections appropriate to the different geographic zones and rural/urban contexts.

The studies will also look at specific requirements in urban areas and the pros and cons of different procurement routes, ranging from complete community-build to outsourced contractor-build.

10. Conclusion

This small project demonstrates how civil engineers, by ‘thinking locally’ and being open-minded and inclusive, have the ability to provide innovative and appropriate solutions that help to address the chronic shortfall in both the quality and quantity of educational infrastructure in sub-Saharan Africa. This way of designing is relevant globally, not just in developing economies. It has the potential to transform the role of civil engineers and the impact of the infrastructure for which they are responsible.

It is not about imposing external views of what it is assumed people want and need, it is about hearing what their needs are and responding with innovative solutions that meet those needs. Civil engineers who are sensitive to the needs of local culture and environment, as well as budgetary constraints, have a greater likelihood of designing buildings that provide long-term value because they are economically, environmentally and socially sustainable.

‘Thinking locally’ will help civil engineers solve the issues that face society more effectively. This requires fostering working relationships that transcend cultural and educational boundaries.
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References


Figure 13. Users report that the new classrooms at Dwabor are significantly lighter, cooler and quieter when it rains than traditional government-built structures, and the school out-performs government models in terms of space and cost per child.