An Agricultural Training Center: Case Study in Nianing, Senegal

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Introduction

To many developing countries and especially those in Africa, it has become increasingly evident that in spite of the tremendous efforts being made to provide education for their children, they have not been able to meet all of their educational requirements. Since the demand for education nevertheless continues to rise, these countries have had no choice but to try to obtain greater returns for their limited investments. Hence, a search for new approaches to the financing of educational buildings. Such facilities need to be created in Africa by Africans which will be less expensive than the conventional school building and more conducive to the attainment of national educational objectives. African society has a long and valuable tradition of communal actions to which fresh impetus is being given by the vigorous striving for self-reliance observable today throughout the continent.

Although self-reliance efforts in the construction of schools has become an accepted approach for providing educational space, nevertheless, it has not received the necessary technical support to ensure the required quality and imagination. Thus, the opening of new opportunities to African states to tap the non-monetary sectors as a key resource to achieving greater self-reliance in building schools has become the centre of attention.

Furthermore, when we speak here of educational spaces, we are speaking of them as an extension of the dwelling space. This means that materials and available techniques for building them can be similar, given the climatic conditions and norms for comfort pertaining in the same locale. In a wider sense, dwellings, markets, dispensaries, schools constitute educational spaces to the extent that they are places where knowledge is transmitted from person to person. Thus, an educational space corresponds to a liberated dwelling space for it is used by a wider group of individuals than only school-goers.

The issues which lie behind a school building such as the one in Nianing may be summarized as follows:

- reducing the ever increasing capital and recurrent costs of education and in particular the reduction of building and maintenance costs;
- doing away, as far as possible, with the over-reliance on imported building materials and techniques which require high level skills, thus alienating the masses from participating in the educational process and consequently widening the gap between the school and the community it serves;
- the provision of an educational facility that possesses the quality of built-in flexibility and which answers to the demands of curriculum reform and innovative teaching methods;
- the provision of an educational facility that reflects the cultural capacity of the community in utilizing the human and material resources locally available.

Certain basic criteria can be delineated if the goal of self-reliance is to be achieved.

Materials and building technology

1) The materials and techniques to be chosen should contribute towards providing buildings that possess the durability and performance of those ones conventionally built, using cement block walls and reinforced concrete or corrugated iron sheet roofs if they are to be acceptable to the communities.

2) Materials and techniques used in the construction should play the role whereby they contribute directly to socio-economic development. They should provide an alternative to imported materials and give preference to those fabricated from locally available materials in order to generate employment opportunities for local labour.

3) It would be better to avoid the use of materials that work in tension, such as timber and reinforcement steel which are costly and imported. The employment, therefore, of materials working in compression under determined geometrical forms and which permit the provision of spaces of reasonable proportions imply resorting to the possibility of using the arch, the vault and the dome.

Labour

Labour constitutes a basic resource for building which can be found anywhere. Furthermore, the skills of the labour force depend above all on the local architectural practices. Generally speaking, local labour in Senegal is not skilled in modern building techniques and the complicated logistic skills required for them. To make full use of the local human resources, the following conditions need to be fulfilled:

1) the scale of the project must correspond to the level of organization within the community;
2) the period during which the construction was to take place should coincide with that when no agricultural activities take place;
3) technical guidance and training-on-site should be provided since they are a crucial element in improving the capacities of the labour force.

Logistics

1) The complexity of supplying building materials to a site is proportional to the number of different types of construction materials utilized, and the efficiency of the transport infrastructure. Materials for conventional modern construction are often not found near the site, whereas those used in traditional vernacular architecture are available.

2) Furthermore, the use of both types of materials requires a two-tier supply structure which will include a central fund for procuring imported materials and a local fund for purchasing materials on site (Likewise, such use of two types of materials will create a need for two types of skills since a good skilled craftsman in the modern sector is not necessarily skilled in traditional building techniques.)
General Background and Ideology

The living conditions in the Sahelian environment have not contributed to promoting the construction of permanent dwellings. Nature imposed frequent population migrations, thereby encouraging temporary dwellings. Apart from a solid artisanal practice and an ancient influence from the East brought about by Islamic and Mediterranean monuments, elements of a traditional architecture were non-existent except in the valleys of the Nile and River Niger, and the areas surrounding them.

It is only in the last 50 to 100 years that such a precarious existence started to slowly give way to an aspiration for more stability around the emerging poles of development.

The modern house is a rectangular one. The walls are usually made of cement blocks with reinforced concrete tie beams at the top and bottom and columns. The roofing is of corrugated iron sheets. Such a house is ill adapted to the climate of the region. The enclosure of the house is in cement blocks.

The traditional hut, the case, is on its way to disappearing in spite of its thermal comfort and low cost. The modern house which requires less maintenance is considered a good investment. The lack of skill in modern construction results in a poor application of modern materials and techniques.

At the same time, with an ever increasing population and already limited resources, materials are becoming scarce, such as timber which is a material that encourages traditional architecture.

With such scarcity of local materials, the way remains open for invasion by corrugated iron sheets, reinforced concrete and hastily made cement blocks which now stand to be the costly symbols of emancipation and prosperity in spite of their poor quality and architectural insignificance.

Under these circumstances, the foundations of an adapted architecture need to be created for which only limited possibilities are available. One should therefore make maximum use of the traditional techniques and expression which need to be rediscovered. Between ill-adapted imported techniques and non-improved traditional techniques as the two extremes, there is a place for an adapted architecture which reintegrates the climatic data and expresses itself through exploiting the best qualities of available local materials and labour.

Human Resources: The Employment Problem

A study conducted in 1974 in the neighbourhoods of Rufisque (second largest town in Senegal) 25 kilometres from Dakar revealed the following:

- In four neighbourhoods surveyed out of a total population of 14,540 the population of working age amounted to 50 percent (i.e. 7270). The active population was found to be 1920, which gives a 30 percent employment rate. However, the official number of unemployed persons is given as 8 percent.

If we consider that to be unemployed officially a worker must have a salary and be registered in the Labour Office, we find that most of the people without employment have no fixed salaries;

- The qualified labour force (management executives, high level technicians, middle level technicians, skilled craftsmen, etc.) represents 35.3 percent of the working population. The semi-skilled represents therefore 64.7 percent.

Importance of Traditional Sector Activities

There exists in the urban and semi-urban areas two well defined economic sectors: the modern sector and the traditional one. This dual aspect plays an important role in the employment problem. The modern or formal sector is characterized by capital intensive techniques, high salaries and operations on a large scale.

The second sector which is traditional, informal and non-structured and composed of economic units has the opposite characteristics in having abundant labour (labour intensive), small scale operations, traditional working methods and modest earnings distributed amongst those working in it (production or service labour, individual carriers, street vendors, etc.).

In the context of Senegal, where visible unemployment poses an acute problem, the importance of the traditional sector cannot be overlooked for it contains a considerable labour force which has low productivity and underemployment. In most cases, this sector absorbs 40 percent of the working population (46 percent in Rufisque). One also observes that the job supply in the modern sector has reached its limit of supplying jobs. This can be attributed to the limiting factor of its need for qualified labour. Further, one can say that the traditional sector is often a temporary refuge for workers seeking a permanent salaried job. Its high capacity of absorption reduces the pressure on the urban labour market by ensuring returns (uncertain and modest) to an important part of the labour force.

Principles of Action

To improve employment opportunities in a country like Senegal, one can conclude that:

- the only sector able to meet efficiently and at short notice employment demands is the traditional sector;
- it is particularly desirable to have a large number of minimum investment projects where the labour costs for a product or operation exceed the capital investment for the constant element such as materials;
- employment in the traditional sector does not require a high level of skills;
- as far as the construction market is concerned, a high level of skill should not be required of the labour force and with some training and guidance can improve the quality of the output.

Thus, one of the concerns of the project was to use labour intensive techniques. In this regard attention was given to training manpower on the site by a skilled mason.

The team of architects from BREDA found and hired an experienced but unemployed master mason whom they trained in the...
building system by building a first prototype structure in Dakar itself in 1975. With the commissioning of the Agricultural Training Center, the mason agreed to move to Nianing, where he trained a number of local men in the necessary techniques and supervised the totality of the construction which lasted for twelve months. However it should be noted that the availability of the BREDA architects for controlling the quality of execution was a determining factor in the success of the operation. Their participation amounted in all to twenty months of work of an architect for the research, training program, drawing up of plans and supervision.

The Structural Concept of a Prototype

The system proposed and experimented upon by the team is characterized by its short span between parallel bearing walls. 1 The openings in the bearing walls are achieved by means of arches over a span which can extend to eight metres. The short span can be covered in a sense perpendicular to the walls either using traditional materials, a vault or a thin membrane of ferro-cement on condition that the stability of the bearing walls is assured at the central part of the arch. To counteract the horizontal forces on the peripheral walls, buttresses were employed.

Studies were made on the built-in flexibility of the proposed prototype. These were done in a comparative study made on the functional aspects of educational spaces constructed using modern construction techniques and the spaces the proposed structure will provide. It was found that with an arch spanning 6.40 meters and two bays covered with vaults having a span of 2.8 meters space could be provided for 40 pupils with spaces for individual work in the niches. Such spaces would likewise allow for innovative teaching/learning situations such as working in small groups, large groups and for other activities such as drawing, painting, modelling, etc. The space could also serve as a theatre during inclement weather. Further, the possibilities for grouping a number of buildings to form a complex was...
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Completed prototype unit in Dakar (1980).
Photo: B. Taylor.

Drawing of the structural system developed by BRED/ Dakar.
Source Environment Africain, Dakar.

studied and found to be adequate.

Construction of the prototypical structure with an area of 40 square meters took place on an experimental building lot in Dakar in 1975. Building costs totalled 5000 CFA francs per square meter of gross area, out of which 47 percent was for labour. The subsequent project in Nianing which began in 1976 proved to be the first opportunity to apply the system on a large scale.

Material Resources

The choice of materials or construction technique has both psychological and technical implications. In the first place, it expresses a way of life. In the case under consideration, such choice has to take account of the aspiration for having a durable building, which will enhance the value, and limited financial resources which could lead to an unwise use of the imported and so-called 'modern' materials.

It was therefore found that the use of local materials with simple techniques rather than industrialized ones seemed to present several advantages, of which the following are the most important:

- local materials have undeniable qualities which are sometimes superior to those of modern materials (i.e. thermal qualities which often cannot be matched — at least not for a reasonable cost);
- they are less costly and readily available in the immediate surroundings of the building site;
- their extraction, treatment and use can easily be carried out by a labour force which is abundant and with minimum skills;
- the control of its quality is easy and does not require foreign specialists. When its quality is low it can be considerably improved through simple research.

Construction Materials used in Nianing

Sand

The basic building material is earth, the only abundant material around Nianing. Sea sand (grain size 0.2 — 2 mm) and dune sand (grain size < 0.2 mm) are available in abundance.

The sea sand was extracted from the higher parts of the seashore which has been washed by rain and thus the salt content is minimal. The dune sand was extracted on the site after excavating the top layers of soil which contain excessive amounts of organic material.

Bricks

Sand has no cohesion. A binding material must be used to render the soil structure more coherent if it is to resist forces in compression. The granulometry of the sand used is a determining factor in the brick's resistance in compression and the required quantity of the binder. If the grain size is the same, the intergranular cavities will be maximized and larger quantities of the binding material will be required. Further, if the grain size is too large, a rapid erosion of the bricks is likely.

In order to determine the optimum granulometry, compression tests were carried out on 38 cubes having different mixes of sea sand, dune sand and cement. It was found that a mixture containing equal quantities of sea sand and dune sand and 125 kg/m³ of cement (9 percent by volume) had a resistance to compression of 17 kg/cm². The production of bricks for Nianing had to be carefully controlled to maintain good quality ones. In order to avoid quick drying which affects the chemical action in the cement, bricks were watered and stacked in the shade. Irregular watering was likewise avoided and bricks were watered during six days, twenty-four hours after coming out of the mould.

Mortar for the Roofing

The roof vault was made in three successive layers. The first, which represented a thin vault, was of mortar made of a mixture of sea sand and cement (250 kg/m³). The second layer, in order to offset the horizontal stresses in the vault and contribute to its thermic inertia, had a mix of equal quantities of sea sand and dune sand and cement (125 kg/m³). The third and last layer, which is to ensure that the vault is waterproof, is of a mix of equal quantities of sea and dune sand and 375 kg/m³ of cement. To ensure a good bond between the three layers, the vault had to be completed within a week. Fast drying was inhibited by protecting the surface using thin plastic sheets.
Mortar for the Joints

Mortar for the masonry was a mix of sea sand and 250 kg/m² of cement and this was found to be practical and adequate. To avoid quick drying of the mortar, bricks were soaked in water before they were laid. Masonry was watered once a day during one week. Joints were made with a 2 centimetres shrinkage which was filled with a mortar of a rich mix leaving a joint shrinkage of 3 millimetres. Joints were watered during several days.

Millet Stalks

The millet plant provides, besides the staple food, large quantities of ± 2.0 metres long stalks in the Nianing area. These stalks are used to fence dwelling plots as well as for the construction of huts. Nevertheless large quantities of stalks remain unused. Since they are not a durable material and decompose rapidly, they can be used temporarily and then be discarded. Aware that Senegal has to import all the timber it needs, millet mats were found to serve as shuttering in the construction of the vaults.

Wire Mesh

Although no reinforcement of the vault is required, wire mesh was used to reinforce the vault to ensure security during construction. The first layer of the vault, being a thin vault, such reinforcement was found to be necessary and was to cover a width of one metre centred at the apex. The wire mesh used had 4 centimetre stitches.

Having found that the price is three times that of galvanized wire from which it is made and which can be found in any village shop, the wire mesh was manufactured on site, thus providing an opportunity for employing local labour. Thus, compared to the first experimental prototype, the cost of reinforcement of the vault in Nianing is only 10 per cent of its total cost.

The Notion of Comfort

This aspect was studied from the point of view of the following factors:
- heat and sun radiation;
- humidity during certain periods of the year (rainy season);
- low temperatures during the months December and January;
- violent winds with lashing rain (July to September);
- sand laden winds.

The first three factors of these are closely linked with the notion of thermal comfort which in itself depends on four main environmental conditions which are:
- air temperature;
- humidity;
- air movement;
- radiation.

While air temperature and humidity are difficult to control without mechanical means, by controlling air movement and thermal radiation it is possible to considerably increase the feeling of comfort. This is achieved through the control of openings to attain optimal air movement and better orientation to avoid sun penetration, as well as thermal isolation.

In the case of Nianing, the vaults were studied with a view to increasing their capacity for storing heat during the day (insulation by accumulation) which is a crucial factor since during the bigger part of the day the buildings are occupied.

Climatic Factors

The Micro-Climate of Nianing

Micro-climate is that of the site and its immediate surroundings and as such various factors contribute to it. In the case of Nianing, the presence of the sea influences the climate. The case is especially so during the dry season where the micro-climate, compared to the dry continental climate of the region, is more humid with small diurnal temperature differences and lower maximum temperatures.

During the day, from 3:00 p.m. onwards, a cool wind blows from the sea. During the night a hot dusty wind blows from the land to the sea.

Architectural Programme of the School

The Nianing Agricultural Training Centre created by CARITAS-Senegal has a regional character since it receives trainees from all around the area. It was designed to receive 50 full-time trainees for a period of two years, who are sons of peasants in the area. It also receives trainees for short training courses of one month twice a year per group. The full-time courses are from October to May and short training courses take place during the
holidays June to mid-July. From mid-July to end-September the full-time trainees do practical training in the field of grain cultivation.

Based on a study of the training programme content and time allocation, the required spaces were established as follows:
1 classroom for 40 students
1 multipurpose hall
1 house for overseers
2 staff houses
10 dormitories of 4 beds each
3 dormitories for part-time trainees
1 kitchen with ancillary service area
1 library
Sanitary facilities for the administration, teachers and trainees. Evacuation is water borne using sceptic tank.

Technical Data

The Structural System Used

The system is characterized by short roof spans between bearing walls with arched opening having a span of 7.2 metres in a sense perpendicular to the vaults. The roof spans are of the order of 3.2 metres.

The geometrical forms of the foundations, the bearing walls reinforced by buttresses on the outside of the arches and the vaults have been chosen so that they all work in compression.

The Vault and the Short Span

By its geometric form, an ideal vault works in compression thus permitting the covering of space with materials working in compression and which are readily available (sand, stone, bricks, etc.) without having to resort to materials working in tension.

The ideal vault does not exist. It is often suggested that the form of a catenary in an inverted sense is ideal. True as this may be such a form offers the resistance to a uniformly distributed load without positive and negative moments, concentrated loads in the vault, wind loads and the fluctuation of the
Agricultural Training Centre, Nianing, under construction. Plywood centering being set in place, and millet stalks laid on top for formwork. Cement is then applied over the stalks.


Much higher than its dead load. However, most important about the test is that the stability of the bearing walls is a determinant factor of the stability of the entire structure. The deformation of the vault was less than 5 per cent of the total elastic deformation. The plastic deformation could be seen in well-defined cracks. During testing the vault supported a concentrated load of 400 kg/m² without the occurrence of any visible cracks and without a measurable sag at its apex.

The Arch — The Large Span

The geometric form of the arch permits the provision of a large span using materials working in compression. Such form is also determined by economic factors and construction techniques.

The arch with a plain centering permits having a building of minimum height compared to other types of arches and is therefore more economical. Its execution with a single centre of a circle is the least complicated. However, the stress of the horizontal forces on the foundations are higher than in the case of arches where the ratio between the height and span is higher.

The span of the arch depends on:
- the spaces required;
- the resistance in compression of the materials used in its construction;
the condition of the soil under the foundation.

A span of about 6.0 metres already allows the creation of spaces for various educational activities in a classroom. Up to about 7.5 metres span the stress in compression does not go beyond 10 kg/cm², which is the admissible stress for the materials used.

The bearing capacity of the soil determines the span of the arch. In Nianing, cracks appeared in the crown of large span arches. However, spans of up to about 6.0 metres were achieved where the foundation soil was composed of fine sand without the appearance of significant cracks at the crown.

There are several risks of instability of the arch:
- lateral buckling
- vertical buckling
- rotation or sliding of the foundations.

The solution chosen for the lateral buckling was to reinforce with 38.5 centimetres long bricks laid horizontally all along the length of the bearing wall which decreases springing with a factor of 2.6 on condition that the joints are well filled.

To solve the problem of vertical buckling, buttresses were provided on both sides which decrease the degree of springing by a factor 3.6 if the buttresses have the same thickness as the arch.

The eccentric loads transmitted to the soil by the foundation, as well as their horizontal component can provoke a displacement and a rotation of the foundation. It is necessary to study the admissibility of the arch span for each type of soil. Further, foundations should be conceived in a manner whereby eccentric forces on the foundation are avoided.
For a semi-circular arch, the keystone of the arch poses a special problem. Since the axis of symmetry goes through the keystone, the forces in the latter are horizontal and can only ensure coherence between the arch's elements. If the shuttering is removed during the construction phase and before posing the vault, the compression centre remains near the centre of gravity of the middle section of the arch and there are no traction forces in the arch. Whereas the compression stresses are highest in the upper extremity and lowest in the lower extremity.

Once the vault is posed on the arch, the vault contributes favourably to the bearing capacity of the arch, thanks to its own rigidity. The compression centre will now move to the centre of gravity of the section comprising both the vault and the arch. The risk here is that tensile stresses might be instigated in the lower part of the arch's section and cracks may appear.

This cracking can even be more serious if the shuttering is not removed before the vault is posed, since in this case no compression stress will be existing in the arch before such posing. Cracks which start at the bottom of the centre of the arch and move upwards do not entail the risk of affecting adversely either the bearing function of the arch or the stability of the construction. However, cracking can provoke the risk of bricks coming loose and falling on somebody.

**Solutions to Localized Instability**

A large keystone, the upper width of which is larger than the lower, makes it impossible for an element to fall down. The width of the keystone should be $\frac{1}{10} \times \text{the span}$.

Another solution is the incision of the vault to create an expansion joint above the centre of the arch in order to keep the centre of compression near the centre of gravity of the arch.

Roofing can also be done at two levels with a light roofing for the upper and a heavy one for the lower. In such a case, the loading transmitted to the foundation will be almost concentric and its rotation will be minimal. This will reduce the risk of cracking.

A way of ensuring security in case a crack occurs is by doweling with mortar of a rich mix. This will prevent, in the case of two parallel cracks, elements from sliding and falling. Further, to prevent elements from sliding, special bricks with keys can be employed in the construction of the arch.

**Bearing Walls and Buttressing**

The weight of the vault and that of the wall do not bring about a compression force at the base of the wall in excess of 1 kg/cm². Meanwhile, compression forces increase considerably because of the horizontal component at the point of support of the vault.

The walls supporting the roof are always built of solid bricks in order to ensure the homogeneity of the wall to create a counter force to
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View of vaulting at Nianing as seen from the roof
Photo: C. Little/Aga Khan Awards

the horizontal ones from the vault. Special attention should be given to the bonding to ensure this. Superposed joints cannot be tolerated in this case. Modular blocks were used which made this possible without having to resort to cutting bricks.

One can increase the stability of the bearing wall in two ways:
- by increasing the thickness of the wall;
- by reinforcing the wall with buttresses.

One notes that increasing the thickness of the wall is costly and has a marginal effect on increasing stability. Also, the bricklaying in a thick wall can prove to be more difficult for masons with limited skills. Therefore, the best way to improve stability is to use buttresses.

In order to obtain optimum stability by means of using buttresses, they must be monolithic with the bearing wall and placed at regular intervals. The upper limit of the distance between two buttresses should be six times the thickness of the wall. The distance between an end buttress to the end of the wall should not exceed two times the thickness of the wall.

These limits were established to answer to the constraints of flexure and shear stresses in the bearing wall.

Foundations

The foundations in Nianing have been designed to ensure a uniform loading on the soil. They are 60 centimetres deep. The first layer is stabilized and well rammed laterite with a minimum thickness of 20 centimetres. It is poured directly in the foundation pit without any blinding. Two courses of masonry are then placed on the top of it which form an integral part of the foundation. The loading of the soil in Nianing was limited to 1 kg/cm² and from the nature of the soil it was found that the angle of internal friction of the soil was 20°. The horizontal component of the support reaction could therefore not go beyond 1/3 of the vertical component.

To avoid settlement of the foundations, the laterite layer was placed directly on the surface of the excavated soil without any sand fill.

Also, every effort was made to ensure the uniform loading of the soil so that differential settlement does not occur.

Stability of the Structure during Construction

While the stability of the peripheral bearing walls is assured using buttresses, that of internal walls is ensured by the symmetry of the roofing vault since the horizontal components of the two adjacent vaults on the wall counteract each other. However, while this is the case on the completion of the building, it is not so during construction.

The possibility of propping the walls to absorb the horizontal forces on them was considered but abandoned since it can be a source of errors and needs close supervision. The procedure was therefore adopted of building vaults in sections.
Waterproofing and Rainstorm Drainage

The tightness of the roof was ensured by a layer of a rich mix of mortar (400 kg/m$^2$ cement).

However, thermal expansion during the day and contraction during the cool hours of the night caused hair cracks in the roof, as well as larger cracks at regular distances where the roof was long. The latter took place in the joint between parts of the vault. For this reason, wire mesh was used to reinforce these joints.

Thus to ensure that the roof was waterproof, the following actions were taken:

- the exposed surface of the vault is painted with lime each year. The lime fills the cracks and expands with humidity closing the cracks. Further, its white colour proved to be advantageous in reflecting the sun's rays and reducing insolation;
- expansion joints in the vaults were covered with bitumen felt;
- gargoyles were provided and the slopes leading water to them were increased to ensure a quick evacuation.

Projects after the Nianing Experience

After the experience of the experimental building of Nianing, other buildings were constructed using the short span concept.

Our preoccupation during the architectural conception of these buildings was the provision for stability during construction. During the execution, the supervision by the architects was much less frequent. A silo, a classroom in Nianing Village, a church, and many middle-level vocational training centres were built. However, due to special implications in design and construction, only the silo will be mentioned here.

The Silo — N'Diarao

For better stockpiling the following considerations were taken into account:

- the need to maintain a constant temperature;
- protection against insect penetration;
- the capacity was to be 200 metric tons;
- the need to use local materials;
- the need for more skilled masons.

Thus the silo of N'Diarao was considered an alternative for a modern silo. It was constructed using the short span concept and all the materials used were working in compression. Sand was extracted from near the site and the masons were from the village where the silo is located.

The silo was designed and constructed to provide the optimum conditions for grain storage which are:

- an average thickness of the roof of 45 centimetres, allowing for a maximum fluctuation of temperature of around 3°C day and night;
- the silo was hermetically closed in order to allow for the generation of methane gas which renders life impossible for rodents. As such the penetration by insects and rats is impossible during the period of storage;
- the silo was protected against humidity through the floor;
- the buttresses of the bearing walls were towards the interior of the silo to allow for a larger storage capacity.

In the construction of the silo, no reinforced concrete was used. This necessitated a design where the pressure on the walls was counterbalanced by the weight of the roof. The technical means employed were:

- the pressure of the grain on the external walls was limited by the adaptation of the height of the roof to the natural slope of the grain, as well as on the flooring sloping upwards towards the outside walls;
- each element of the silo is statically stable, which eliminated the problems of stability during construction;
- with these details and precautionary measures, the villagers were able to execute the project themselves under the supervision of a chief mason who had no previous expe-
The building costs were 12,000 CFA francs per stored ton. Considering that the value of a stored ton is 36,000 CFA francs and that loss in the traditional silo can amount to as much as 25%, the N'Diari silo can be amortized within one and a half to two years. Since about 50 per cent of the cost was reinvested as labour costs in the village, the cost of the silo could be considered as 6,000 CFA francs per stored ton.

This detailed presentation of the technology introduced onto the Senegalese building market was intended to reveal the construction techniques and the levels of expertise required for it to be operational. Had time permitted, other factors of equal importance would also have been discussed, such as the way in which architects, masons and trainees interacted and communicated as the building site progressed. The socio-cultural implications of the system and its diverse uses, also merit attention and have been discussed elsewhere.

Reference Notes

1 See initial study published by the UNESCO regional office for Education, P. Busatto (and others), Flexible Short Span Structure for Low Cost Educational Building (Beirut, 1973)

2 50 CFA francs equal 1 French franc

3 Snelder, R. Participation de la Population locale dans la construction du Daara de Malika, (typescript), 1981

This text follows the main lines of a joint essay, Vers une meilleure utilisation des ressources locales en construction, Centre de formation agricole à Nianing, (UNESCO, 1978) by Oswald Dellicour, Kamal El Jack, Chris Posma and Paul de Walick