BASIC TECHNICAL RULES

THE NUBIAN VAULT (NV) TECHNICAL CONCEPT

THE NUBIAN VAULT ASSOCIATION (AVN)

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CONTENTS

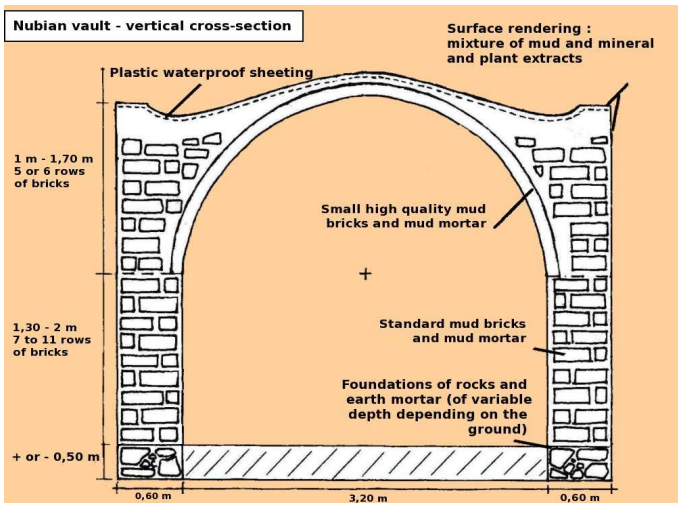
1. AN ANCIENT TECHNIQUE, SIMPLIFIED, STANDARDISED & ADAPTED

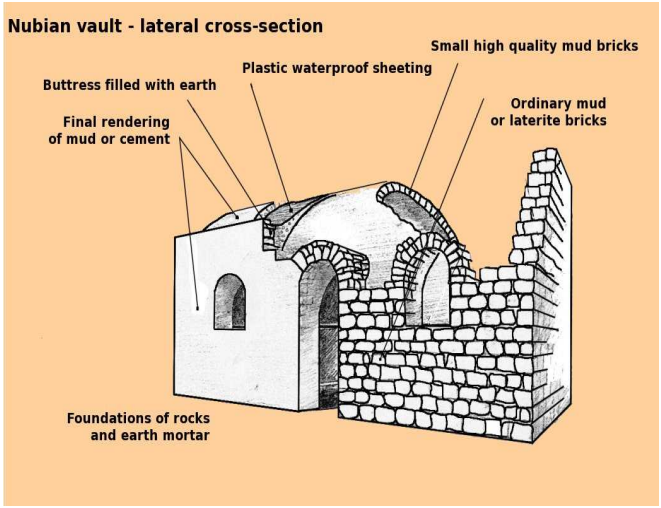
The **Nubian Vault** technique originated in Upper Egypt. It consists of the construction of comfortable and affordable buildings with mud brick vaulted roofs, using only local materials (rocks, earth, water), basic tools, and skills that can be mastered relatively easily. .

Vaults at the Ramesseum, Luxor, Egypt, built ~ 3,500 years ago

This technique was recognised by the NGO *Development Workshop* during the 1980's as providing a potential answer to the major housing problems faced by the populations of the Sahel regions of sub-Saharan Africa.

From 19989 onwards AVN re-examined the original technique, and simplified and standardised it to facilitate its adoption on a large scale. AVN has also adapted the technique to resist the heavy seasonal rainfall of the Sahel.





AVN's standardised version of the Nubian Vault

2. MAIN FEATURES OF THE NV TECHNIQUE

- The buildings are almost exclusively made of earth, an abundant locally available raw material, mixed with water and moulded into adobe bricks dried in the sun, and used as mortar. Stone - in the form of rocks - is only used for foundations.
- The roofs are exclusively vaults (no domes) and can be buttressed to form flat roof terraces.
- Construction of the vaults is achieved without the use of shuttering or any other supports.
- The buildings have a maximum internal width of 3m30: the walls are made of standard sized mud bricks, the vaulted roof and window / door arches with smaller, lighter, ones.
- A guide cable is used to define the arc of the vault and to guide the mason in his work.
- The walls, depending on their different functions, are of a standard width; the dimensions of openings, doorways, windows, alcoves etc are also standardised.
- As protection from seasonal rainfall, plastic sheeting is incorporated in the roof mortar. It is also possible to make mud bricks for the walls with pebbles / stones incorporated into their external surface which, when dry, form a suitable base for a waterproof cement render.
- It is possible to add an upper floor to make a two-storey building, provided this is foreseen at the time of the preparation of the foundations.
- Labour represents by far the major cost element of the NV Technical Concept. If appropriate / necessary, a large part of the labour element can be covered outside the cash economy (self-build, barter, skill exchange...). And when cash does change hands, it stays in the local economic circuits.

> The raw material (earth, rocks) necessary for NV construction are nearly always available close to the construction site. However, access to sufficient quantities of water may be problematic, depending on the site and the season, and care must be taken to make the necessary supplies when planning a project.

> In rural areas, cash payments need only be made to the qualified NV masons who have mastered the NV technique; unskilled labour and raw materials are generally provided by the client.

3. THE MAIN STAGES OF NV CONSTRUCTION

NB: *This brief presentation of the different stages of NV construction provides essential advice for clients, masons, and partners who wish to undertake a NV project. In no case can it be used as training material in the technique, and should not be considered as a substitute for on-the-job apprenticeship training on a real NV construction site.*

3.1. EXTRACTION, FABRICATION & TRANSPORT OF MATERIAL

Careful advance planning of the production and delivery of construction materials (earth, bricks, rocks, water...) to the site is essential. Poor management of these logistics can lead to major cost over-runs and problems and disputes between mason and client.

Mud brick fabrication

Delivery of earth

Transport of bricks

3.2. CHOOSING THE SITE

The site for a new NV building must be chosen with care - follow these two rules:

Result of floods in Burkina Faso

1) Avoid low-lying or damp ground subject to rain water run-off, as NV buildings must not have 'wet feet'. Bear in mind that some sites which during the dry season are far away from visible sources of water might get flooded during the rainy season.

Warning: M*ake sure that the site is definitely out of range of any possible flooding, or else....*

2) When laying out a NV on a limited site (for example, a specific, measured, plot of land), take care to allow for possible future extensions. The modular nature of the NV concept allows for the addition of later vaults alongside, in front, behind, or above the original one(s). This possibility should be allowed for in laying out the site at the start.

< *Laying out the site*

3.3. MAIN STRUCTURAL WORKS

3.3.1. Foundations

Foundations are essential for the integrity and longevity of all buildings. Everyone involved (artisans, masons, clients...) must pay particular attention to this important stage of construction.

Warning: *the foundations must never be under-sized or neglected.*

Foundation trenches for a NV will be more or less deep (30 cm - 90 cm) depending on hardness of the ground and the position of the vault - the objective being to sit the building on a sufficiently solid base.

The width of the foundations is constant, depending on the wall being supported:
- 70 cm for load-bearing walls supporting the vault
- 50 cm for the gable walls, which 'close' the vault
- 30 cm for internal partition walls.

<< *Building foundations with rocks + earth mortar*

The foundation trenches are filled with large to medium size rocks bound with earth mortar.

Warning: *in zones where there is a risk of heavy flows of surface water (or on enclosed plots, especially in towns), it is strongly recommended to raise and widen the foundations some 10 cm - 30 cm above ground level, to create erosion-resistant footings. The exterior of these footings should be made with something more solid than mud bricks: for example, laterite bricks, or concrete blocks filled with cement.*

If a first floor vault is planned from the start, or envisaged as a possibility at a later date, the depth of the foundations must be increased by around 25%.

NB AVN is currently testing the use of rammed earth for foundations, for zones where rocks are scarce.

3.3.2. Load-bearing walls

The load-bearing walls which support the vault are built of successive courses of large bricks and have a **minimum thickness of 60 cm.**

The courses are made up, in their width, of bricks laid alternatively lengthwise and width-wise, bound with earth mortar.

Joints between bricks must alternate from one course to the next to avoid any possibility of joints lying one above the other.

<< *Load-bearing wall showing alternating courses of bricks*

3.3.3. Arches in load-bearing walls

Various openings are made in load-bearing walls for doors and windows, and also for alcoves and cupboards to give extra storage space and to reduce the quantity of bricks and mortar needed.

Arches with planned alcove and window space

These openings are completed with **lintels in the form of arches**, formed over a barrel or an assembly of loose bricks. The arches are made with small mud bricks and closed (in the case of alcoves or cupboards) by a 20 cm thick partition. The arches must be built before the start of the vault construction, and must follow the predicted slope of the vault.

Note:

> The openings created are flexible, and their use can change during any future modifications of the building, especially in the case of extensions being added (for example, the 20cm partition wall of an alcove can be removed to make a doorway into a new vault alongside).

> The openings in the load-bearing walls must never be greater than 90 cm wide, and there must be a full thickness wall of the same width either side of any doorway, window, or alcove. For example: minimum 90 cm wide full thickness wall to the left / a 90 cm wide opening / minimum 90 cm wide full thickness wall to the right.

3.3.4. Gable walls

The gable walls are built with large bricks (**35 - 40 cm long**) which define the thickness of the wall. They must be built with a very slight inwards incline (of about 1 cm per metre of height).

<< A gable wall under construction

Note: *Gable type walls can also be built inside as partition walls. In this case, there is no slope to the wall - it should be vertical.*

3.3.5. The guide cable

A cable, composed of 6 steel wires twisted together, is stretched from the centre of one gable wall to the opposite one at the height of the start of the vault, and in its axis. It is firmly fixed on the outside of each gable wall, and defines the axis and the curvature of the vault throughout the length of the building.

<< The guide cable and cords

Cords defining the radius of the vault are attached to rings which can slide along the guide cable. A nail is attached to the end of each cord, to be used by the masons to accurately position the bricks of the vault.

Note: *The guide cable and the attached cords defining the radius of the vault are indispensable tools for the NV masons and their apprentices to enable them to construct the vault properly and quickly. The popularisation of the NV technical concept owes much to this simple and inexpensive tool, because, in addition to the aid it provides to masons on the construction sites, it helps accelerate the transfer of skill from the experienced NV artisan to his apprentices.*

3.3.6. Construction of the vault

The vaults are constructed **without formwork or shuttering**! They are built up with small (24cm x 12cm x 4cm) mud bricks made from good quality earth, such as that used for granaries. These bricks are placed course after course against the gable walls to form a vault which is basically semi-circular, except for the final segment at the stop of the vault, which is slightly ogival, forming a strong catenary shape.

The mason places each brick by hand, using an earth mortar very similar to that from which the bricks are made. The first few courses are laid at a slight incline against the gable wall. The mason alternates his work between the the top of the vault, to give time for the mortar to set, and the base of the vault where the courses are easier to lay.

<< Construction of the vault

3.3.7. Loading the vault; the plastic sheet; the parapets

Once the vault is completed, the masons build 'buttresses' by raising the load-bearing walls by 8 - 10 courses of large bricks, and filling the void created on the flanks of the vault with earth mortar and broken bricks. This 'loading' of the vault must be executed with care, especially if a flat roof terrace or another storey is to be added on top.

The height of the 'buttresses' can vary according to the client's wishes, but must reach at least 2/3 of the height of the vault. The best solution is to raise them to the height of the vault, thus forming a more or less flat roof terrace, because the more the loading on the vault, the stronger it is, and the flatter the roof, the lesser will be the effects of erosion during the annual rains.

<< 'Buttresses' under construction

To protect the vault against rain and erosion, a tough plastic tarpaulin is laid over the roof, after it has been smoothed down and given a slight slope for draining any rain towards the gutters. The plastic tarpaulin is then itself protected with an earth mortar render of at least 5 cm thickness, using a mortar that has been enriched with waterproofing adjuvants (shea butter, other traditional 'recipes', used engine oil etc) .

<< *Installation of plastic tarpaulin*

Note: *The tarpaulin is not a substitute for the regular and essential re-rendering of the roof, but it provides extra security to guard against any negligence by the proprietor or client in undertaking regular maintenance tasks. Protected from UV radiation by the protective earth coating, it will last a long time. It also provides an early warning signal: if parts of the plastic tarpaulin become visible, then it is clearly time for the proprietor to undertake the necessary and urgent maintenance and re-rendering tasks.*

Parapets (and balustrades in the case of a flat roof terrace) should be built during the same construction phase, using mortared courses of bricks coated with the same render as the roof and walls.

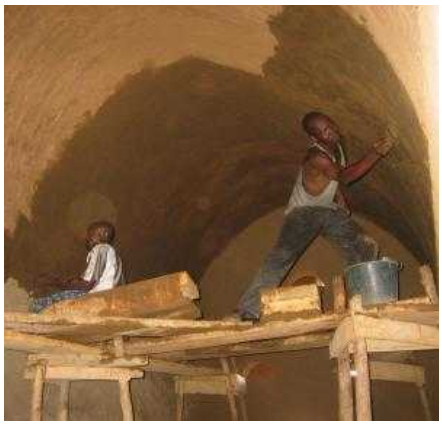
Note: *Parapets and balustrades are particularly exposed and vulnerable to bad weather. To make them more long-lasting, it is possible to reinforce them with laterite or concrete blocks, or even with reinforced concrete.*

<< *A mud brick balustrade*

3.4. INTERNAL FINISHES

3.4.1. Basic traditional interior finishes

The basic traditional finishes are generally made with a render of fine earth mortar, sometimes covered with a painted limewash coating.



Note: *Traditional coatings are well adapted to earth architecture, and have been used for centuries. The quality of the materials used and the skill in applying them means that they are long-lasting, even though regular maintenance is necessary.*

<< Application of a fine earth coating to a vault ceiling

3.4.2. Alternative interior finishes

Cement coatings can be applied to the interior walls (but **not to the vault**) to provide protection against damage, or against damp in bathrooms and kitchens.

Cement or concrete screeds can also be applied to the floor, which can then be either tiled or left as is.

A painted cement render on the walls and concrete floor screed

Note: the application of cement coating / render must be carried out according to strict technical guidelines to guarantee its permanence: the surface must be moistened, and a roughcast preparatory layer applied before the final finishing coat.

A damp-proof barrier of tar or plastic sheet should be laid over the top of the foundations and floor before construction of the walls or a concrete floor screed, to avoid moisture rising from the ground: a cement render over mud brick walls or over an earth floor will stop the walls from 'breathing', and make them damp.

3.5. EXTERNAL FINISHES

3.5.1. Basic (traditional) external finishes

These consist essentially of external earth-based coatings with various adjuvants.

Note: t*raditional renders are well adapted to earth architecture and have been in use for gnerations. The quailty of the raw materials used combined with the traditional skills in their application mean that lasting results can be obtained, on condition that regular maintenance (from 1 to 4 years for exposed surfaces) is carried out.*

<< Earth-based render on external walls

3.5.2. Alternative external finishes

'Alternative' finishes reduce the frequency of maintenance work:

1) Cement renders can be applied to the wall (never to the roof) in two ways:

- By using bricks which have been made with pebbles encrusted on their external surface, allowing the cement coating to adhere (cement won't stick to ordinary mud bricks).
- By fixing a wire mesh to the wall before applying the cement render.

Note: *the application of cement coating / render must be carried out according to strict technical guidelines to guarantee its permanence: the surface must be moistened, and a roughcast preparatory layer applied before the final finishing coat; the rendering should take into account the orientation of the walls and the season (avoid periods of rain or high temperatures).*

A damp-proof barrier of tar or plastic sheet should be laid over the top of the foundations before construction of the walls, to avoid moisture rising from the ground, as a cement render over mud brick walls will stop the walls from 'breathing.

2) Tar-based renders can be applied to both walls and roofs. Care should be taken to follow the necessary guidelines.

Tar-based render being applied to a roof

3) Hard bricks can be used for the external course of a wall if the necessary materials (cut stone, fired bricks, compressed stabilised eatth blocks) are available and affordable.

3.6. SECONDARY WORKS

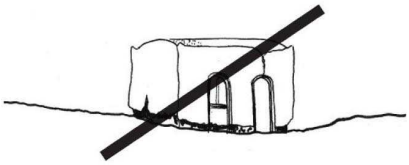
These include **interior and exterior carpentry, electrical wiring and fittings, plumbing, tiling, paintwork, and other wall and floor finishes**.

Note: *the execution of secondary works in a NV building is much the same as for other types of construction. It is, of course, essential to employ qualified artisans with the necessary skills, and to make sure that their various interventions on-site are properly scheduled.*

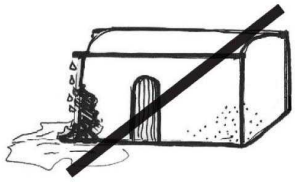
A NV interior with tiling, plumbing, electrical fittings, doors, windows, paintwork etc

4. BASIC RULES TO BE OBSERVED

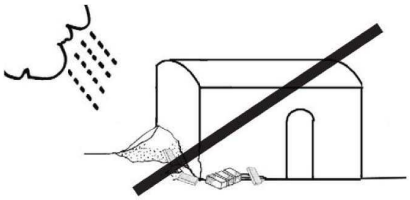
Do not build the house in a dry river bed or on damp ground



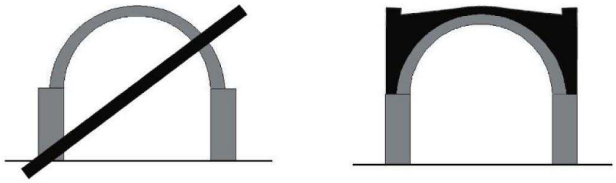
Make sure that the gutter spouts are long enough and are on the correct side



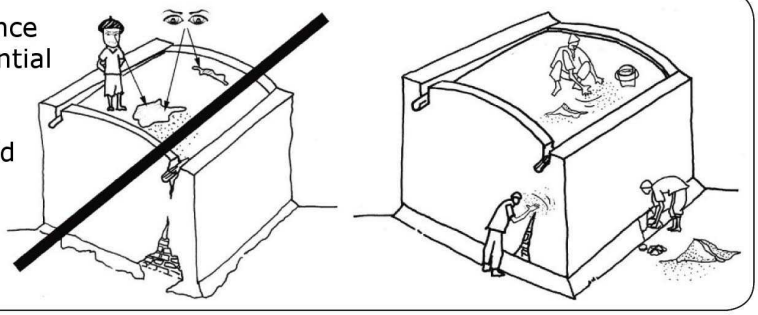
Ensure that the surrounding ground is clear so that rain does not damage the wall base



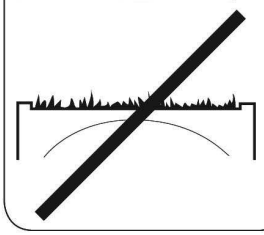
It is essential to infill and buttress the vault to ensure its stability



Regular maintenance of the roof is essential The plastic sheet must always be covered and should never become visible



No grass on the roof!



5. IN CASE OF ANY PROBLEMS...

If there is water penetration into the building, or stagnant water on the roof, or if abnormal cracks appear in the walls or roof:

YOU MUST CONTACT THE NV MASON WHO CONSTRUCTED THE BUILDING IMMEDIATELY

OR, IF NOT POSSIBLE, CONTACT THE NEAREST REGIONAL OR NATIONAL AVN TEAM!