CENTRE FOR SCIENCE AND ENVIRONMENT

BUILDING SENSE: BEYOND THE GREEN FAÇADE OF SUSTAINABLE HABITAT

India Habitat Centre - New Delhi - 22-23/09/2014

Do Chala

Bangla Ghar and Vernacular Architecture

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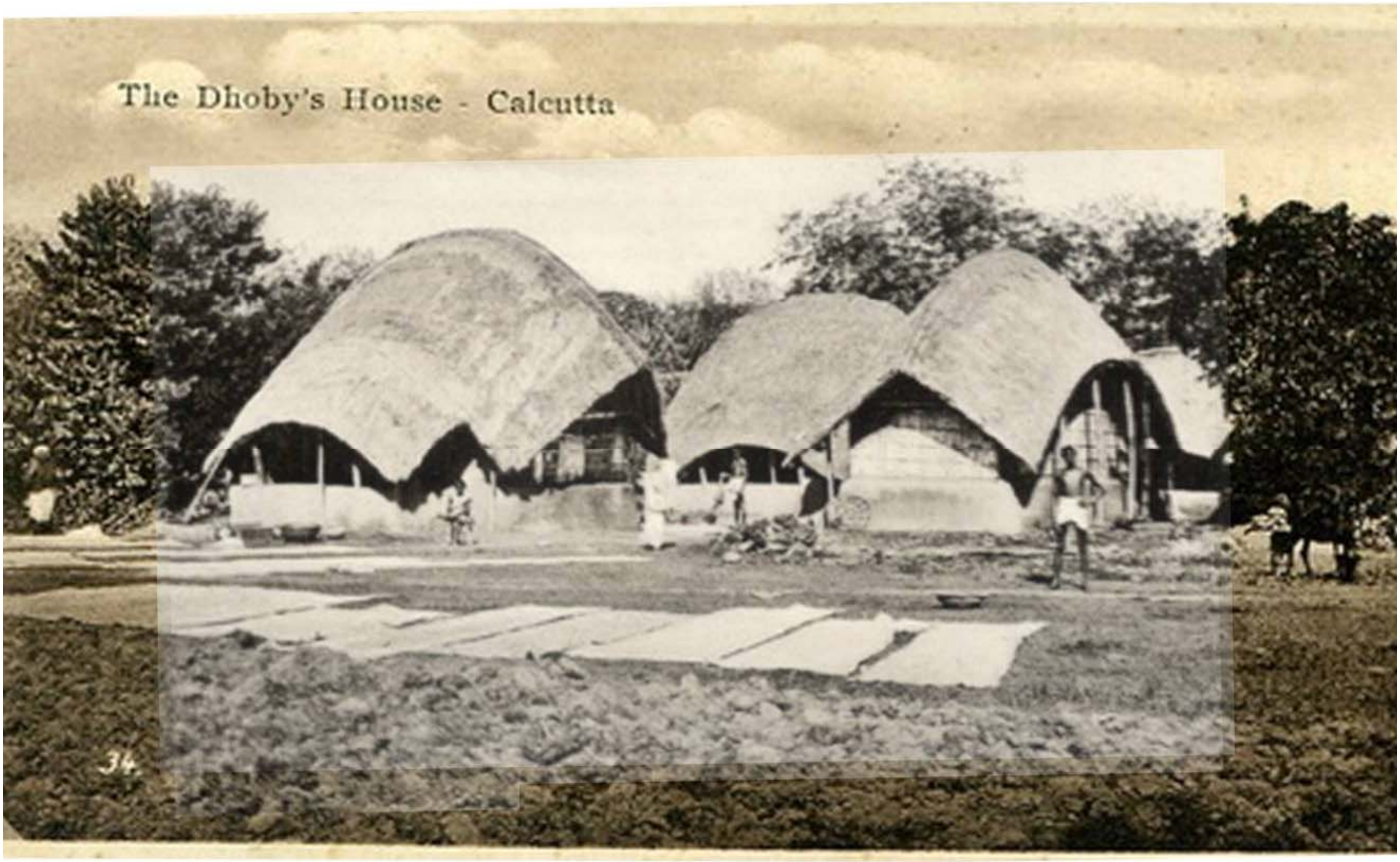
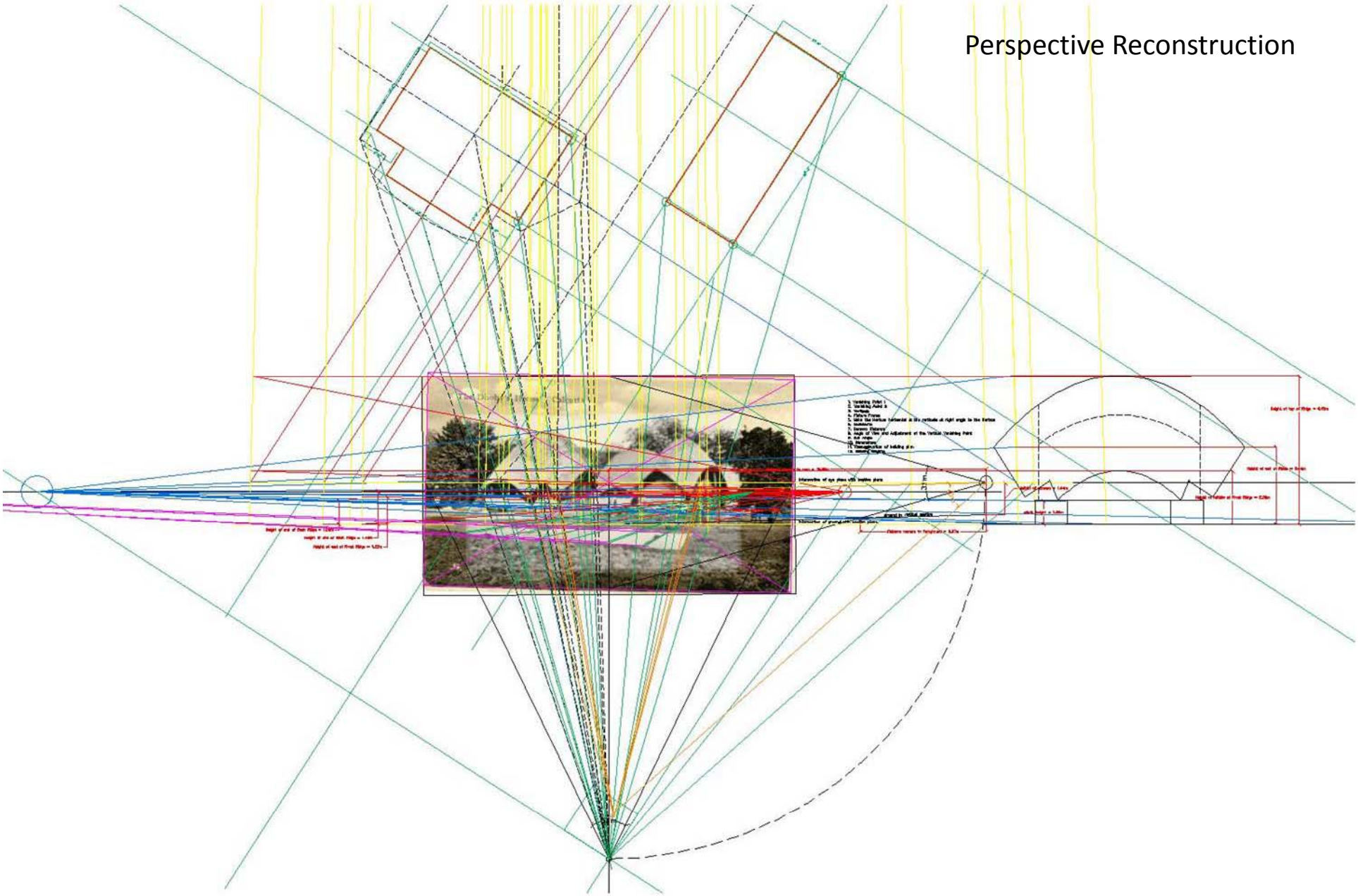
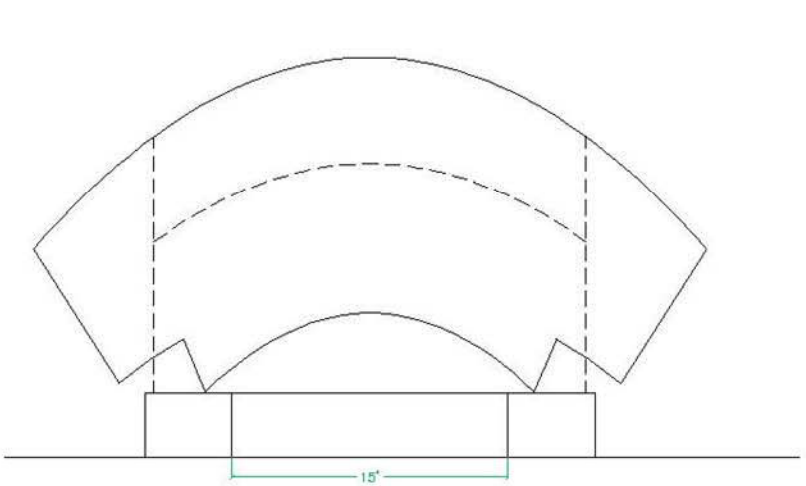
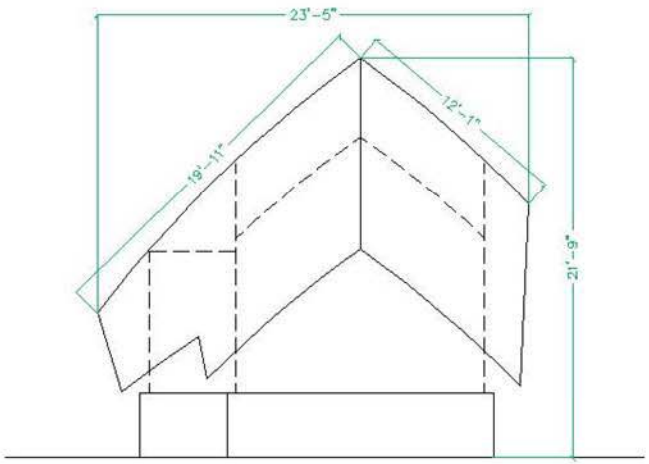


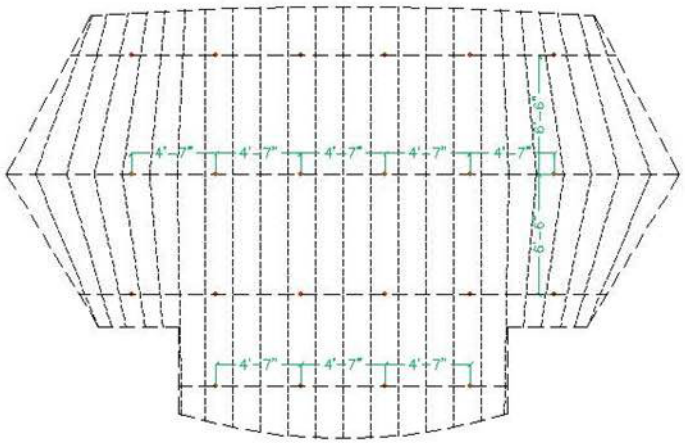
Photograph taken by Samuel Bourne around 1861 near Kolkata

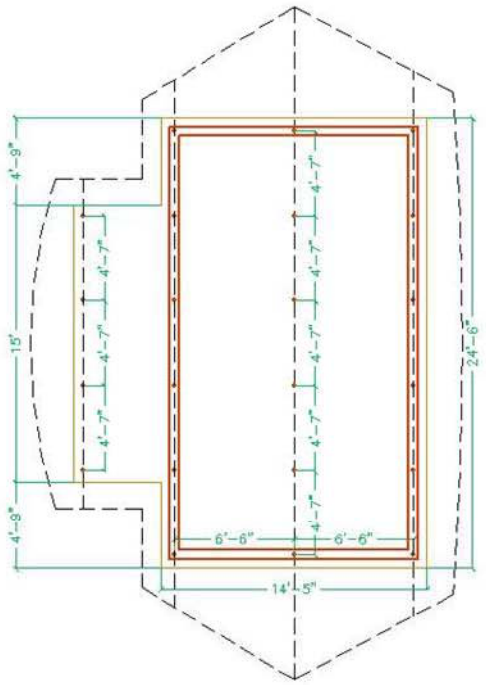
Perspective Reconstruction

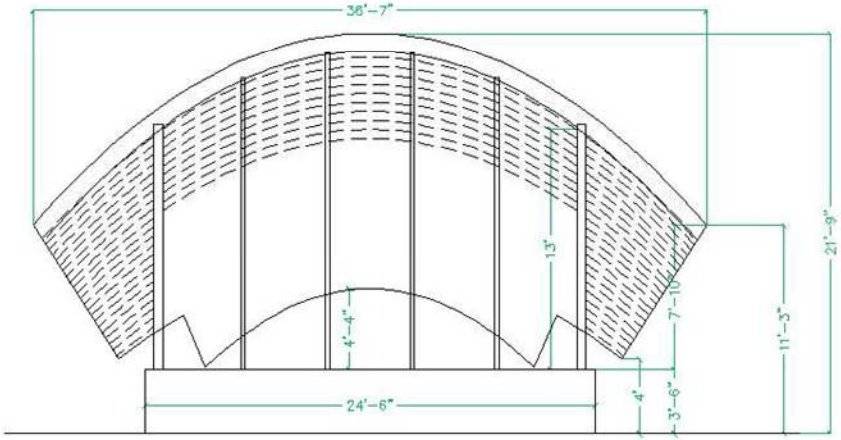








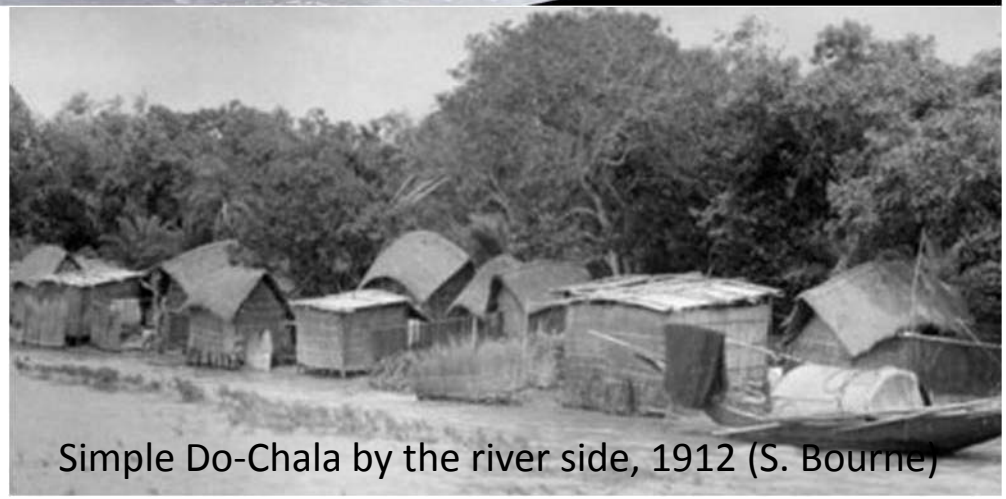




Dimensions obtained from the perspective reconstruction. With its strong double curvature, and almost touching the plinth, the Do-Chala is a dome but is made of mostly straight, slightly curved only, bamboo poles.

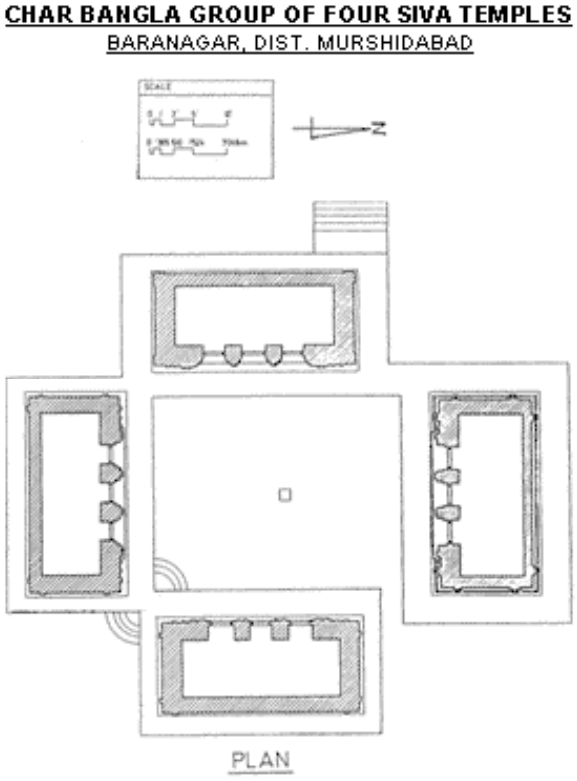
Sarada Devi's
New House,
in Joyrambati,
Hugli, West Bengal.

The roof is Char-Chala, not Do-Chala, but the round shape is preserved.



Simple Do-Chala by the river side, 1912 (S. Bourne)

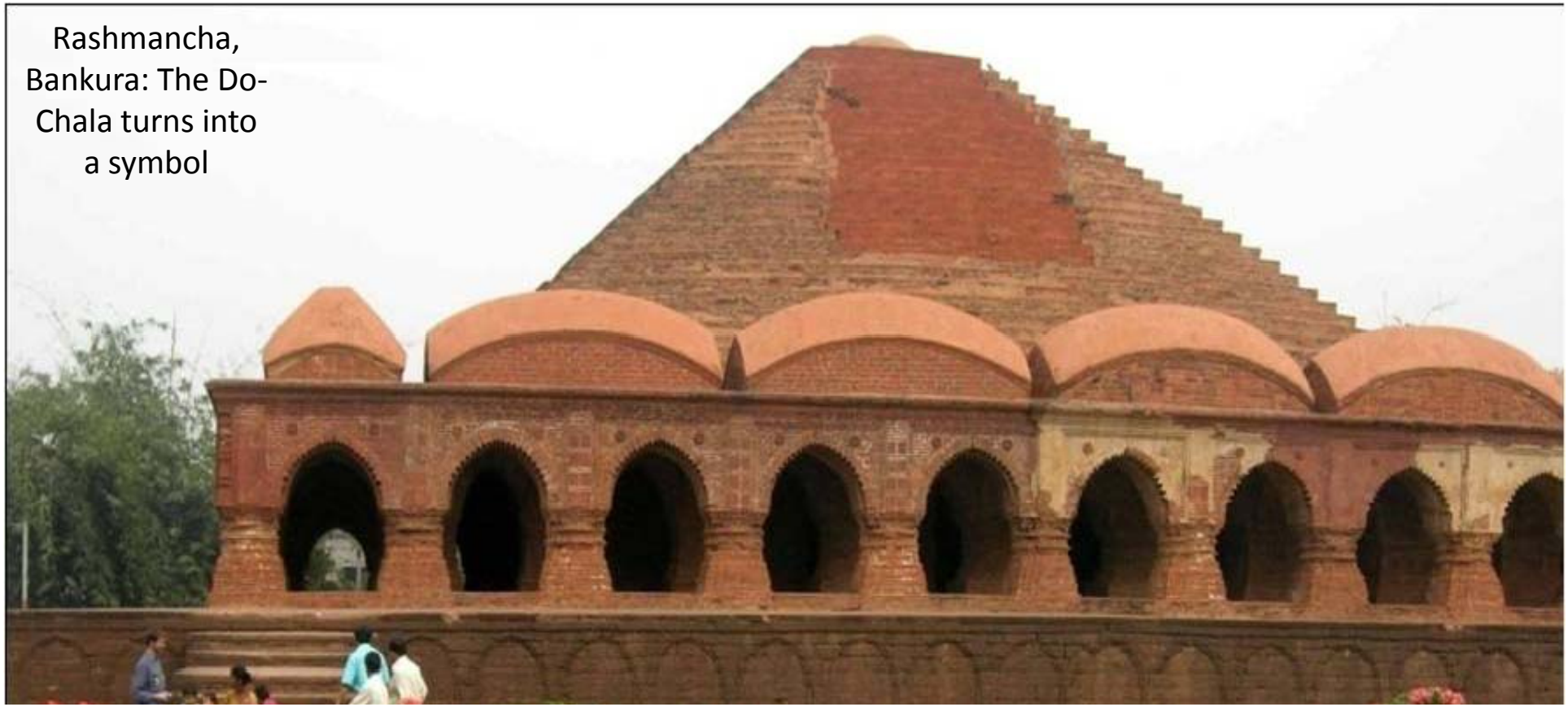
Char Bangla, Azimganj, Murshidabad, W. Bengal



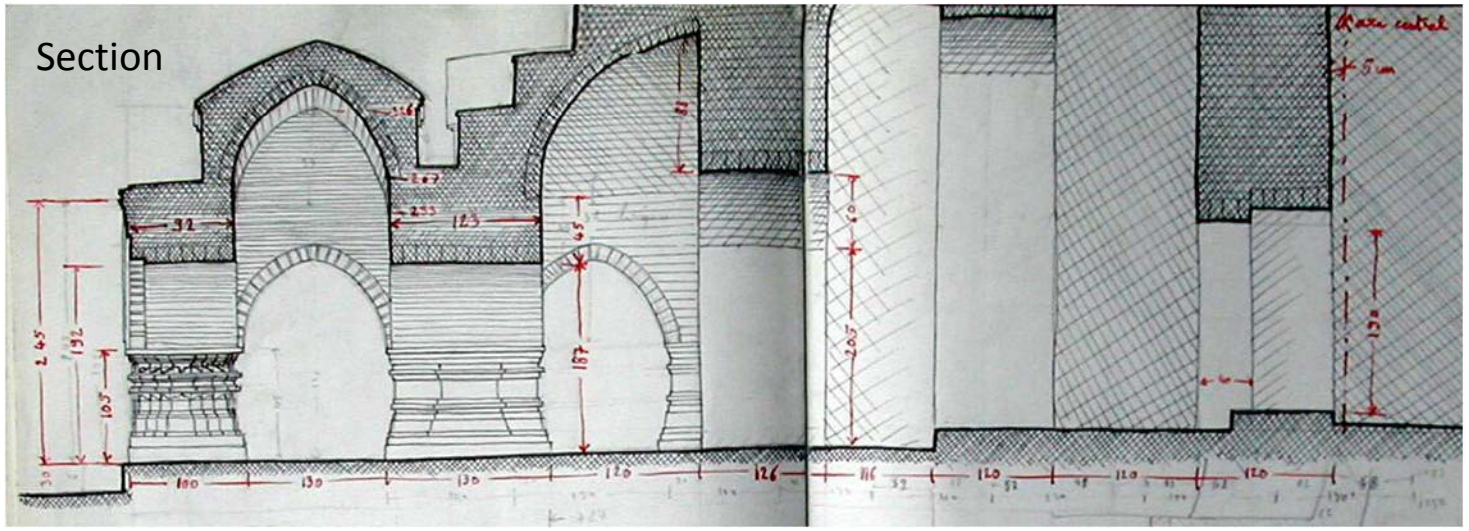
Fateh Khan's Mausoleum, Gaur

Ruin of a Do Chala Temple in Bankura, preserved by ASI. As is visible at the spring of the dome, it was built with terracotta tiles laid in lime mortar, at an angle compatible with construction without shuttering.

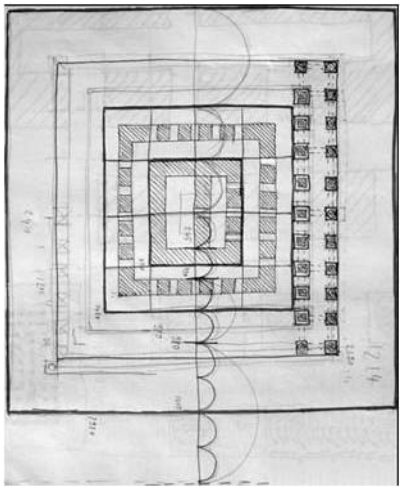
Rashmancha, Bankura: The Do-Chala turns into a symbol



Section



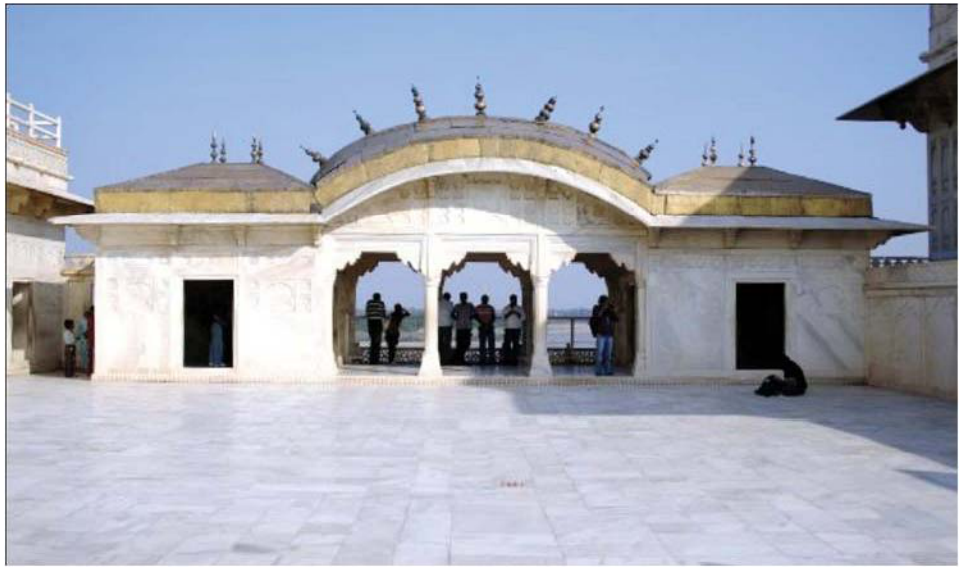
Plan



Bani Begum Bagh, Khuldabad, Aurangabad

Do-Chala with delicate, overhanging white marble slabs…

…souvenir from Bengal?



Agra Fort…

Lahore Fort…

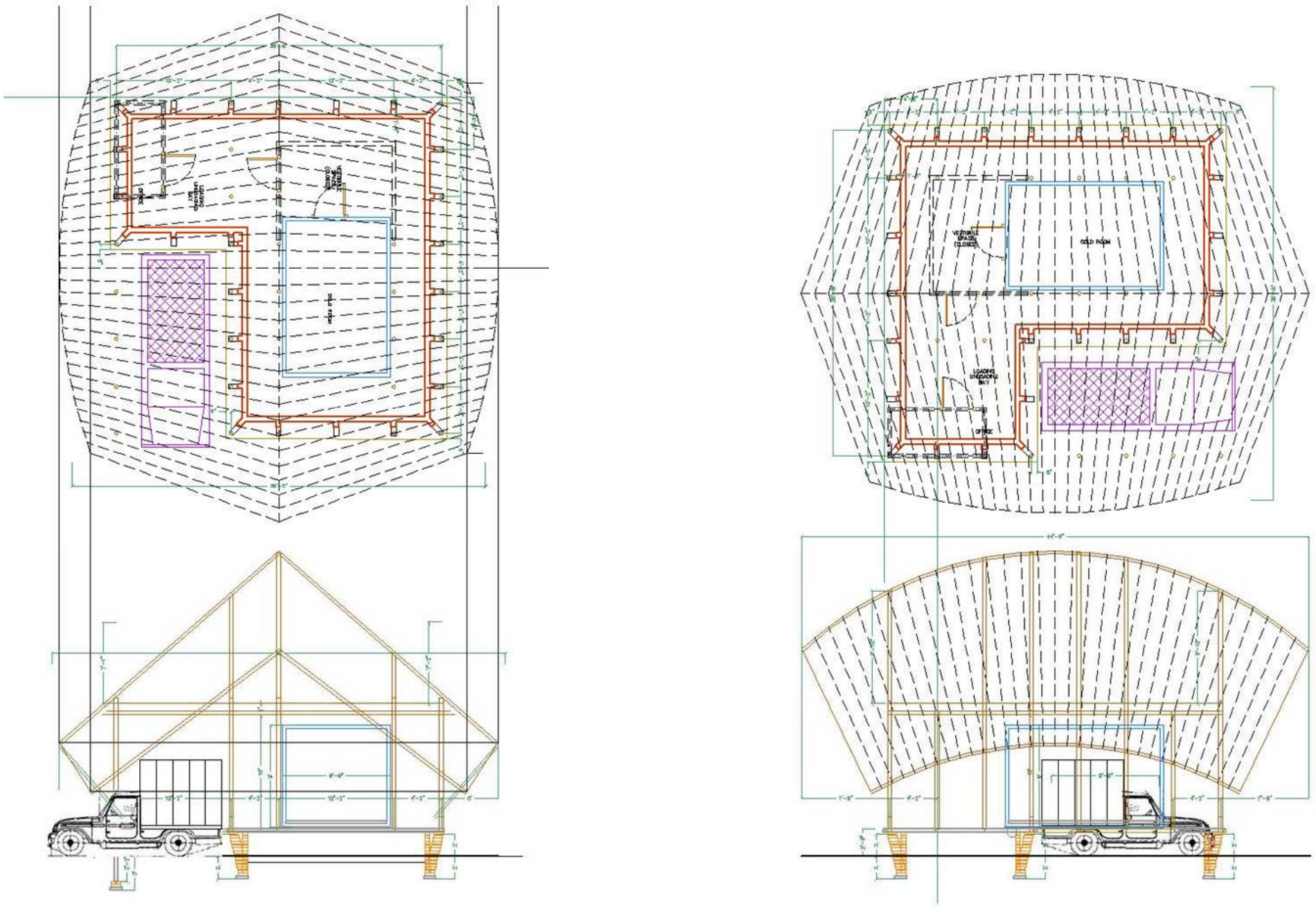
During construction in 1897

At the steel factory in Vyksa (Nizhny Novgorod, Russia) in 1897, Eng. Vladimir Shukov covered a hall of 73m x 38.4m without any support in-between, with a series of domes made of slightly curved steel sections arranged in a diagonal grid.

The hall was in use until 1980.

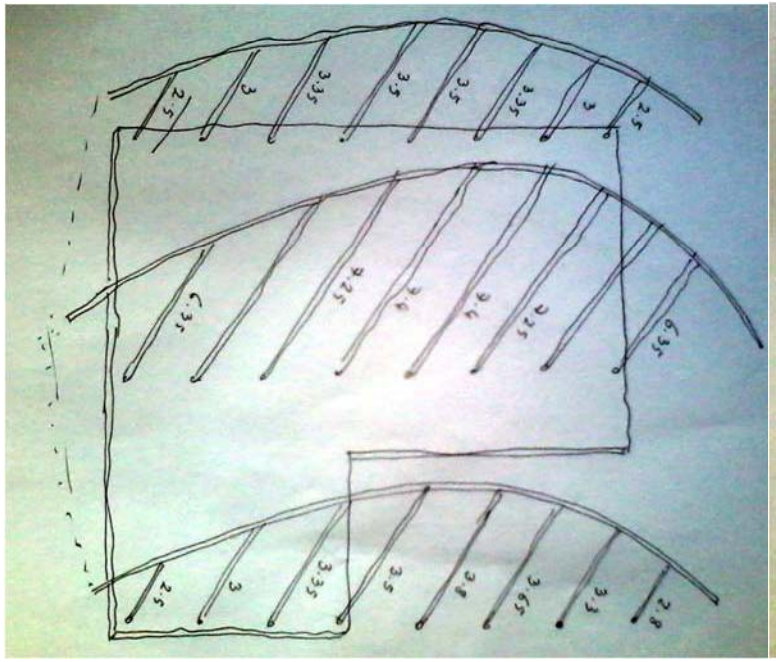
In order to achieve the high rigidity of a double curvature using mostly straight members, Shukov re-invented, exactly for the same practical reason, the Bengali Do-Chala dome, but this time in steel.

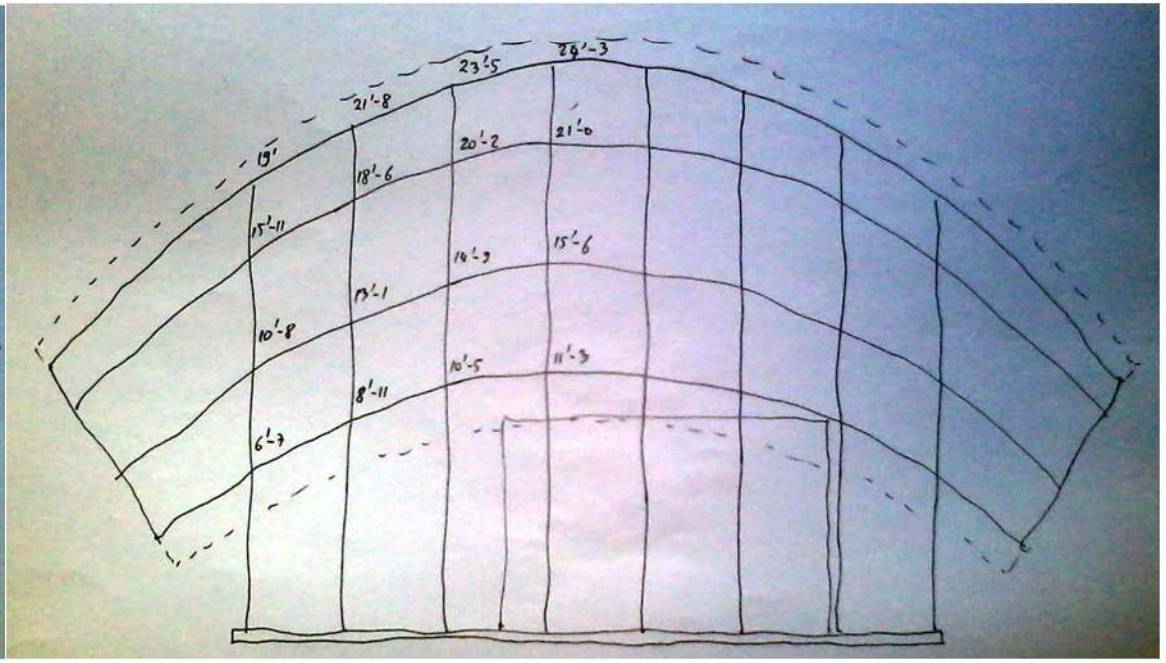
In ruin today

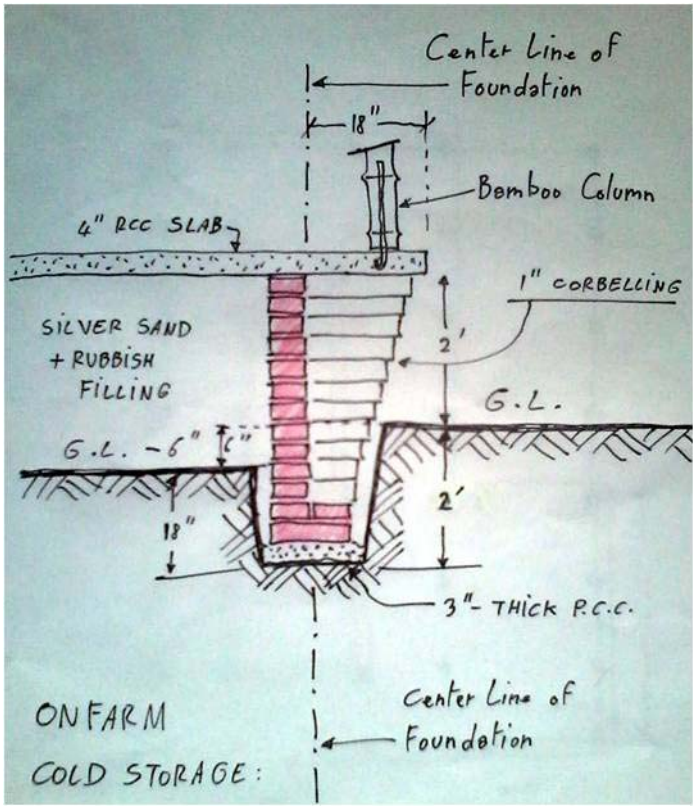


Cold Storage for a farmer’s co-operative in Nadia district

Erecting and Assembling the Structure by lashing; Trying to use the bamboos poles along their entire length, to make the most of the tensile strength and compensate for the relative weakness of individual joints... like a “pandal”!





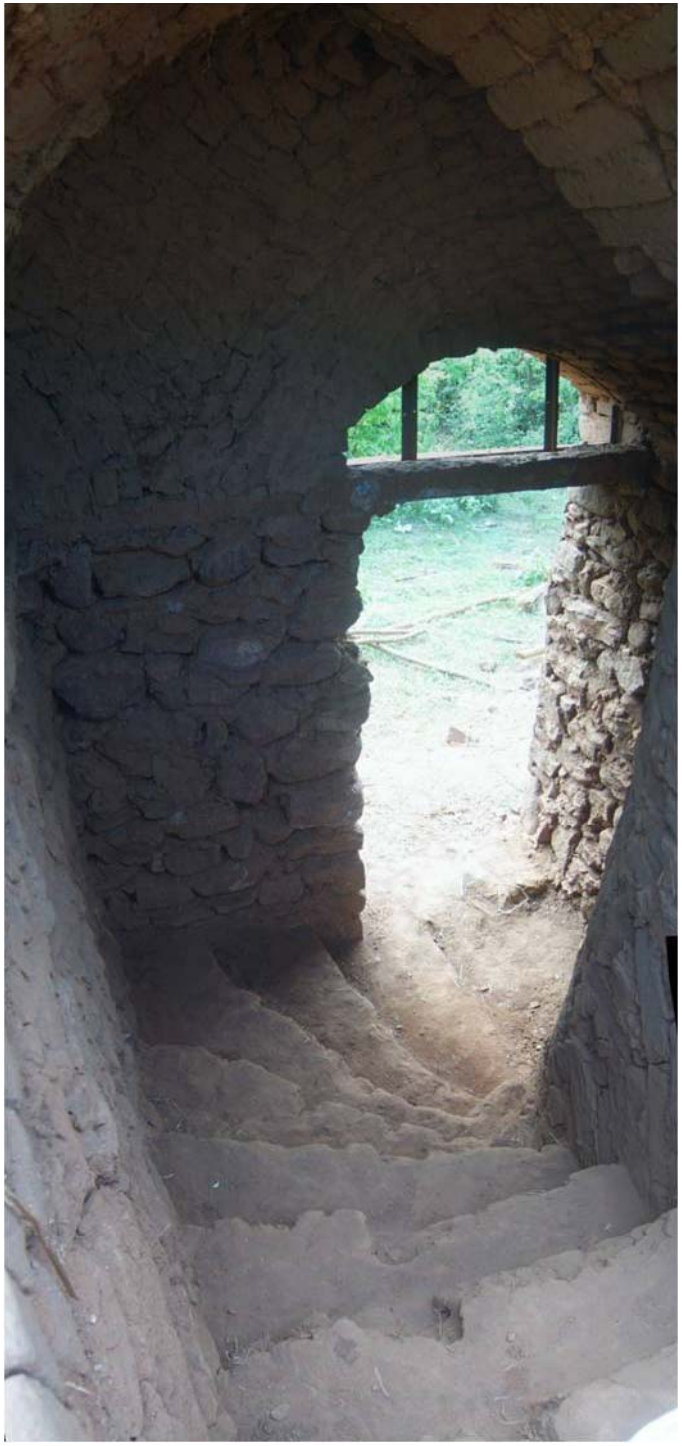


Grouting 12mm dia rods in the columns and grouting the rods-column assembly in the RCC slab

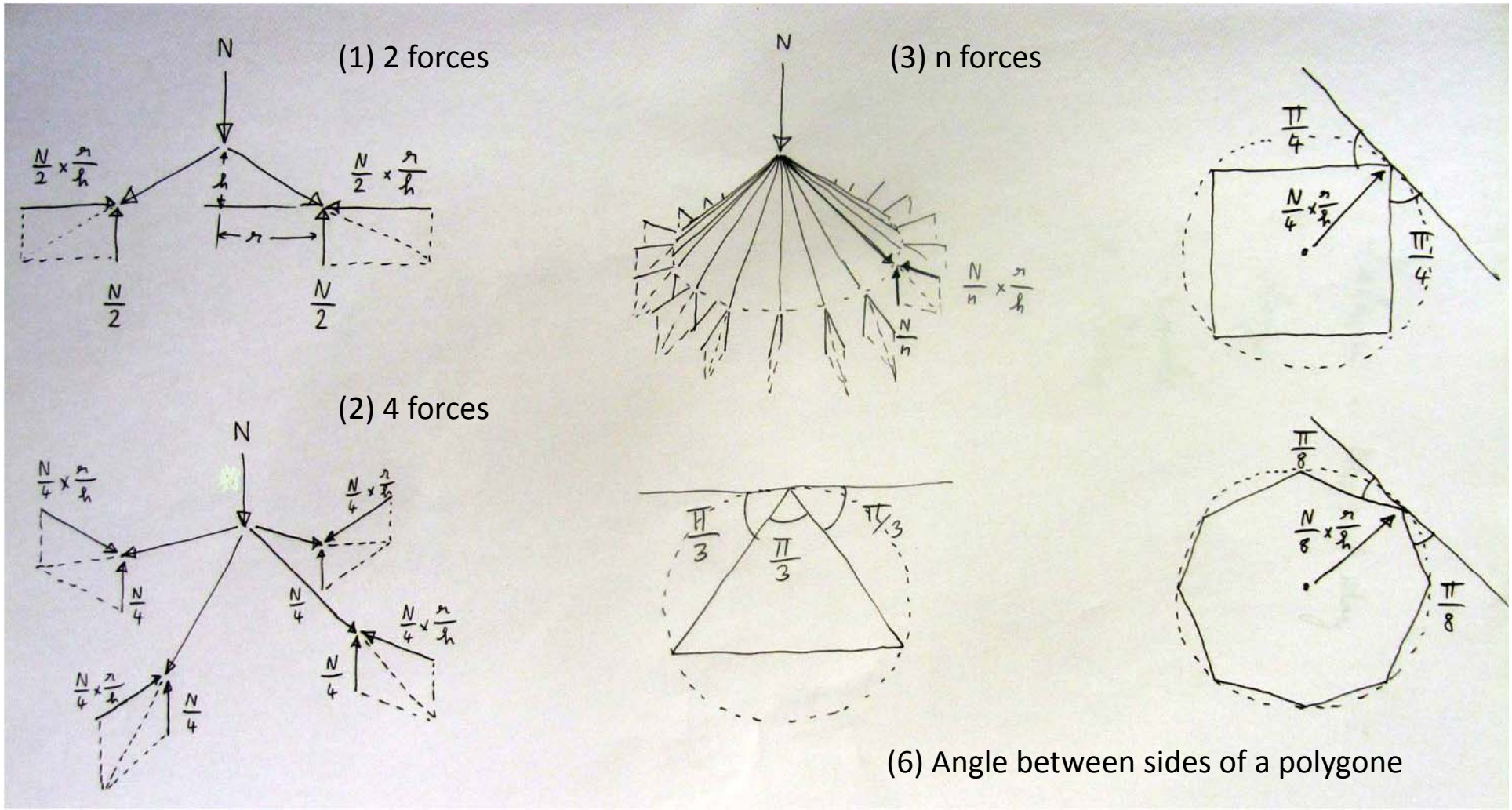
Vrihi Seed Bank in Odisha.

No wood available, no bamboo available:
The walls are made of stone masonry in mud mortar and the domes are made of adobe masonry.

A thin concrete tie runs throughout the building.



EQUILIBRIUM OF A CONICAL DOME (Using Galileo's vector sum and simple maths)



(4) Scalar sum of forces (summed for the full circle):

Horizontal: $\sum(N/n \cdot r/h) = N/n \cdot r/h \cdot n = N \cdot r/h$

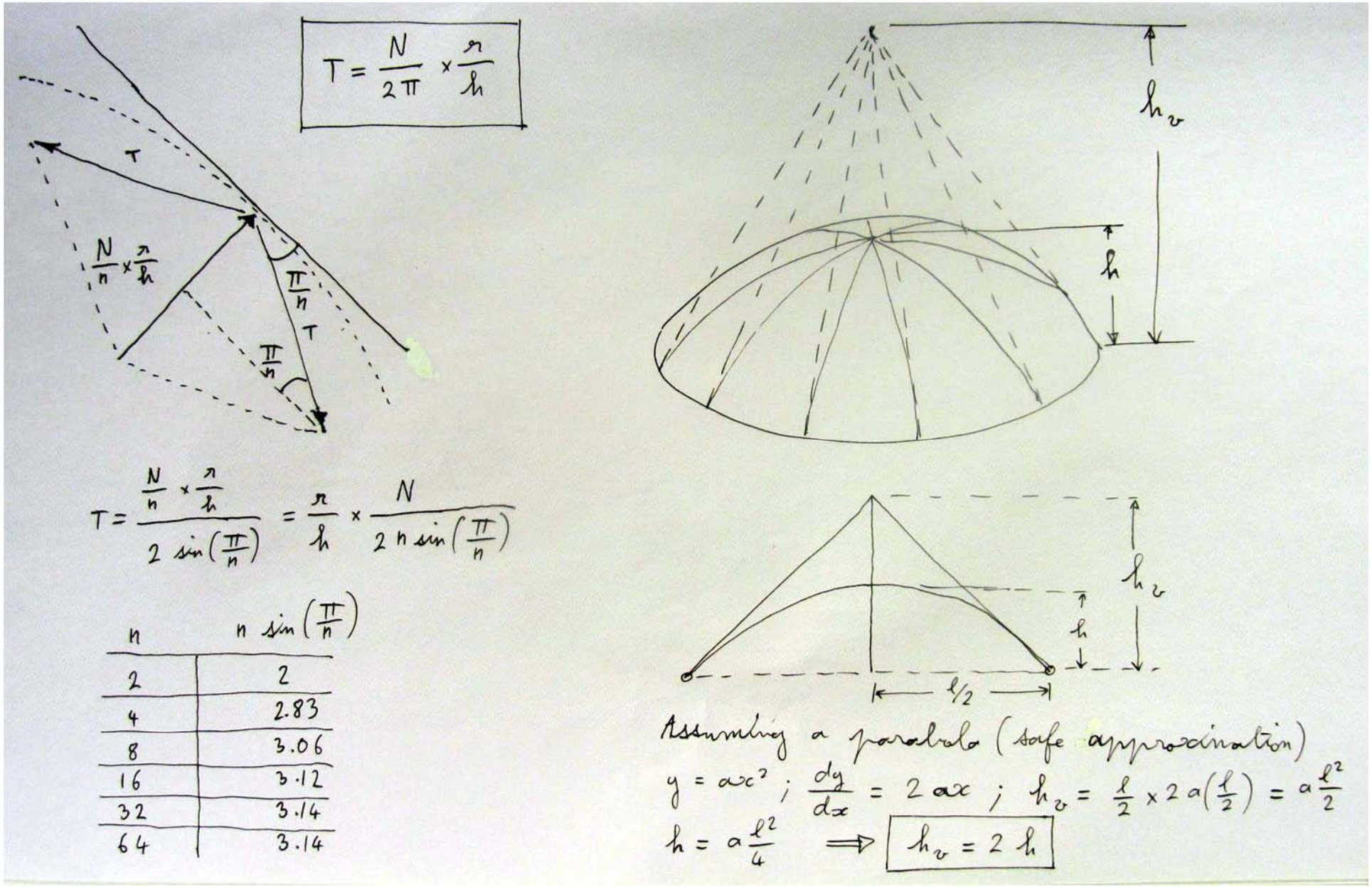
Vertical: $N/(2 \cdot \pi \cdot r)$

(5) Stress at the base of the cone with thickness=t :

Horiz. Stress = $N / (2 \cdot \pi \cdot t \cdot h)$

Vert. Stress = $N / (2 \cdot \pi \cdot t \cdot r)$

Vector sum: $s = N / (2 \cdot \pi \cdot t) \cdot \sqrt{(1/h^2 + 1/r^2)}$

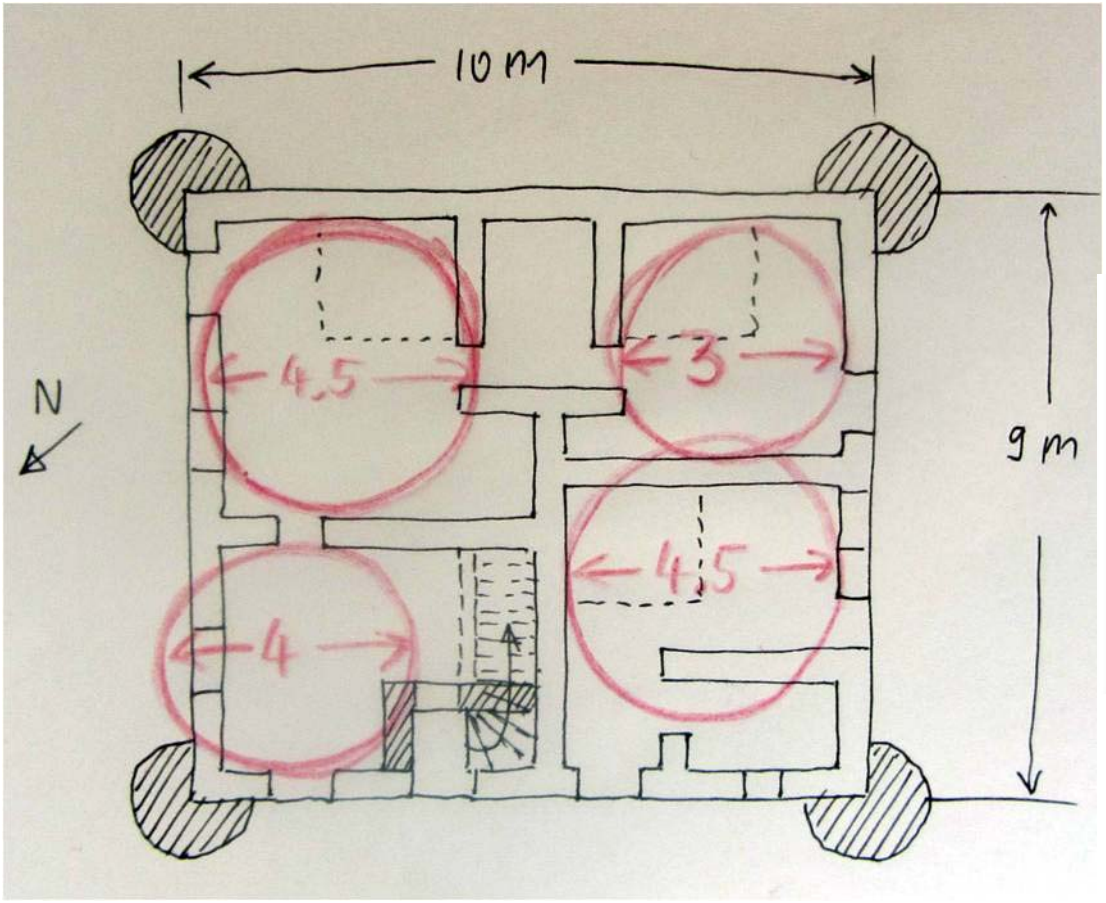


n	$n \sin\left(\frac{\pi}{n}\right)$
2	2
4	2.83
8	3.06
16	3.12
32	3.14
64	3.14

(7) Tension in the ring tie as n grows

(8) Estimating the "virtual" conical height from the actual, curved height

(9) Tension in the Ring Tie: **T = r/h x N/4 π**



With the preceding formulae, calculating tension in ring ties and stress at base for domes resting on irregular supports comes down to simply measuring the diameter of an imaginary circular dome spanning the largest dimension of the same bay (as above in metre.)

This is a safe approximation for rectangles.

…which is a task similar to drawing quadrilaterals for calculating a RCC slab on irregular supports by Yield Line Design:

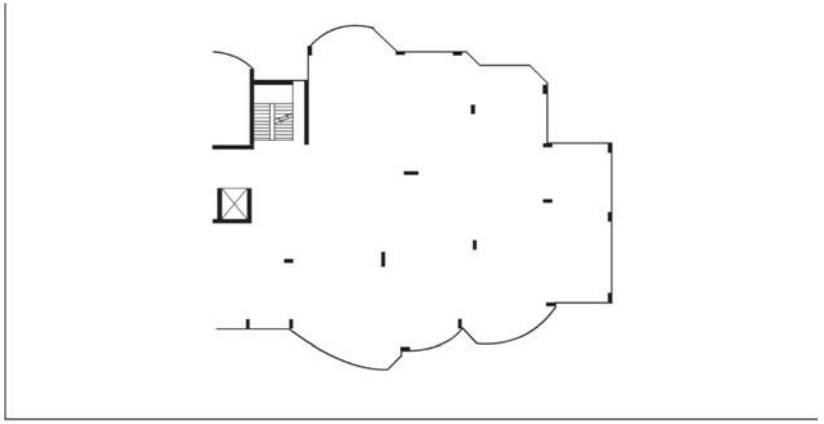


Figure 1.2 An irregular flat slab....

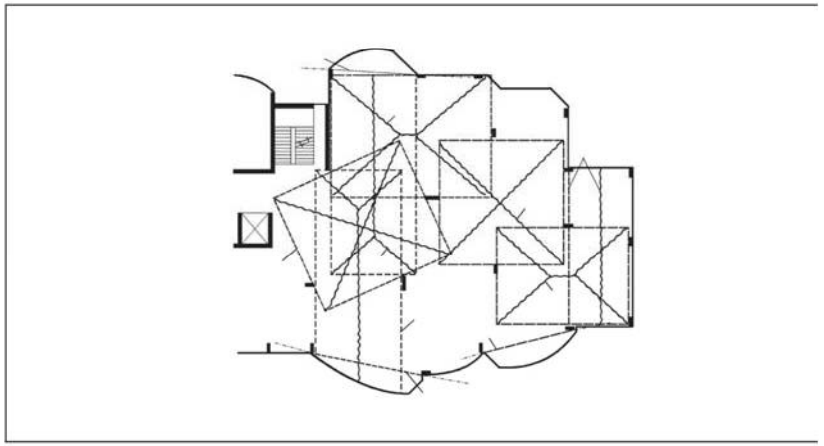


Figure 1.3 .....may be analysed using Yield Line Design – by considering quadrilaterals

Figures : Practical Yield Line Design, Gerard Kennedy 2006

However, calculation is sometimes more in the eyes and hands of the intelligent worker than on paper!

The construction of these domes is through visual estimation.
High up in the dome, the 'squares' meet to become a circle.

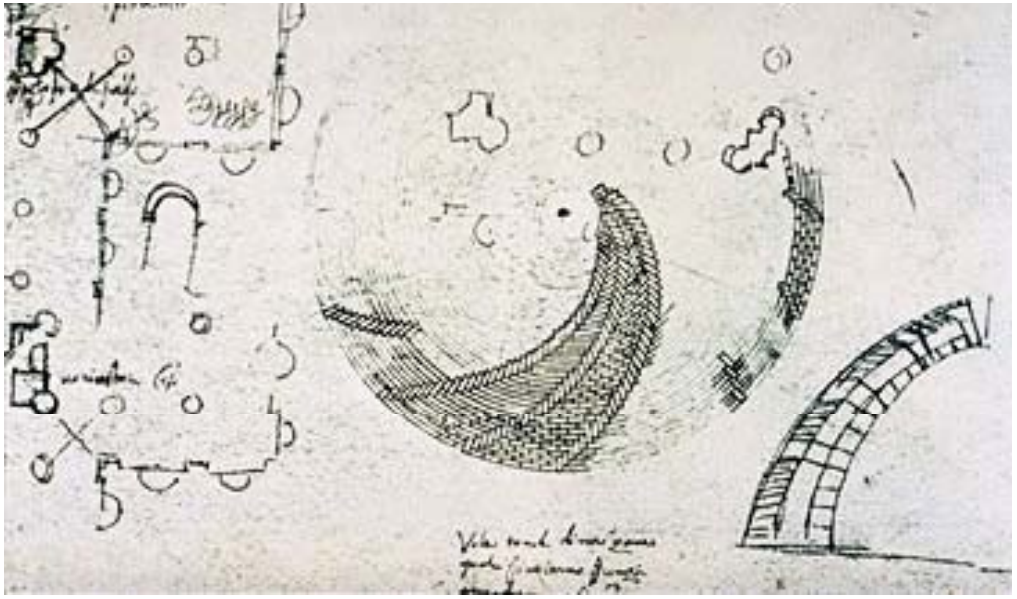
A contemporary warehouse covered by 25 domes in Iran.
Visibly, the expertise of the craftsmen is so high that they not only don’t need shuttering, even the 4 threads tied to the central stick that we used as a visual guide in Orissa, are not required.

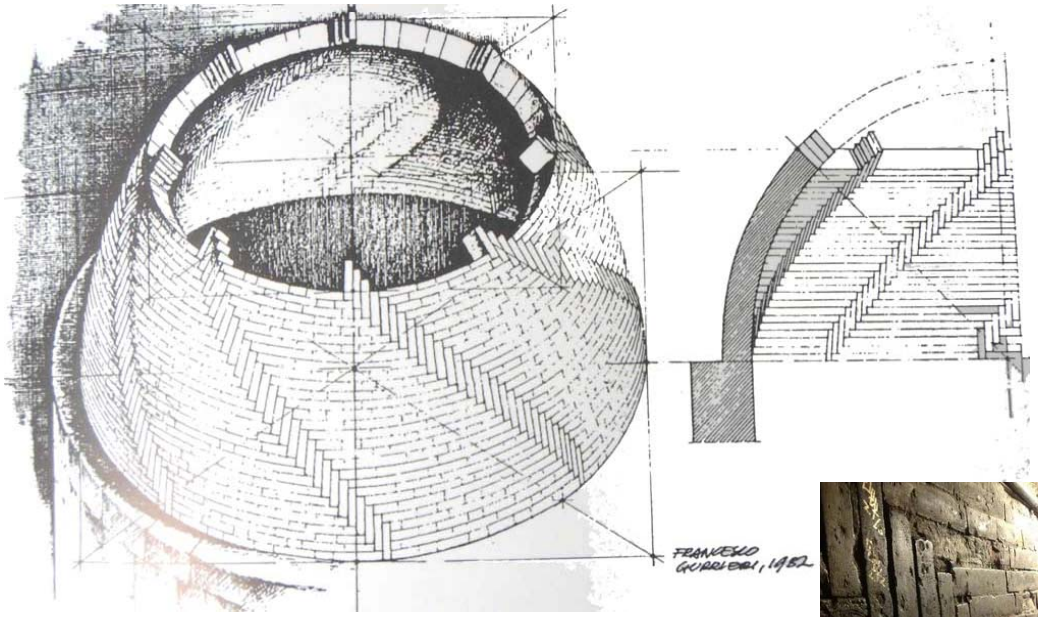
Snapshots from Badeh Salah (Lover's Wind) by Albert Lamorisse (1978): Domes without centerings

17. Masons insert dry packing in the interstices

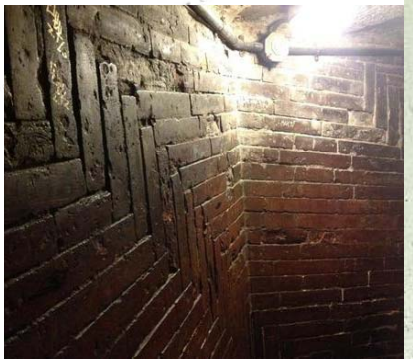
18. The inclined face of the rings gives support to succeeding courses

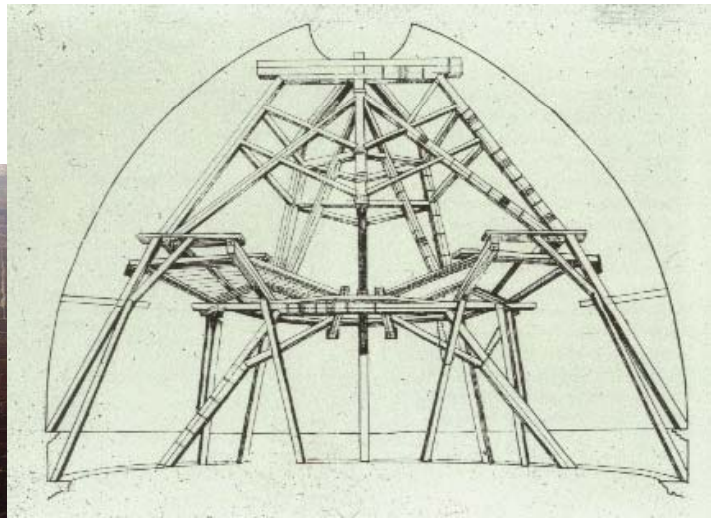
Photographs from Gourna, a tale of two villages , by Hassan Fathy (1969): Vaults without centerings





Dome of the cathedral of Florence (1418-1461) by Brunelleschi. The largest in the world at that time, no forest in the region had enough trees for making centerings capable of supporting it.





Therefore and for the first time in Europe, Brunelleschi designed a self-supported masonry dome, allowing the use of very minimal centerings.

I. — Voutes sur armatures a joints convergents.

Les armatures à joints convergents se composent ordinairement de deux sortes de briques, de briques carrées de 2 pieds antiques de côté (un peu moins de 0m,60) et de briques rectangulaires de 2 pieds sur un demi-pied environ (0m,15).

Avec les briques rectangulaires, on construisait des arcs, des anneaux espacés de 2 pieds d'axe en axe, et, au moyen de grandes briques carrées de 2 pieds de côté, on reliait ces anneaux deux à deux, ainsi que l'indique la figure suivante :

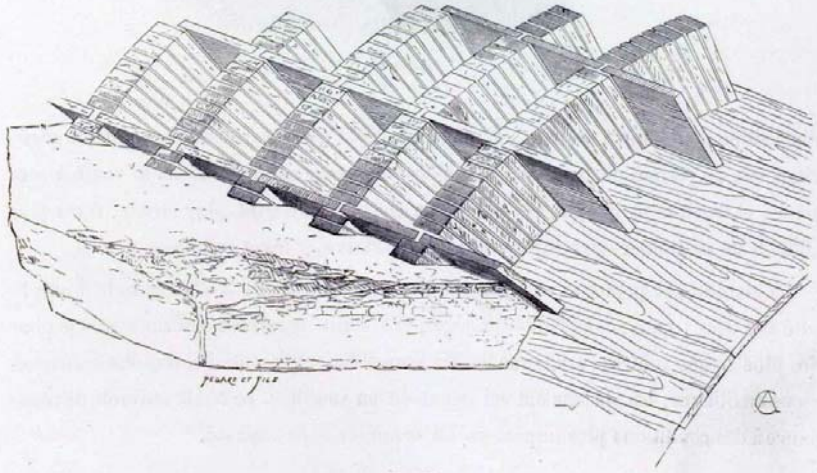


Fig. 18.

On obtenait ainsi, autour des cintres provisoires, une sorte de cage à claire-voie, qui peut être considérée comme le type le plus complet d'armature à joints convergents chez les Romains.

Les chaînes en briques noyées dans les voûtes romaines furent établies les premières, et les maçonneries brutes furent faites ensuite, ainsi que l'indique la discordance des lits de remplissage et des lits de l'ossature (fig. 8).

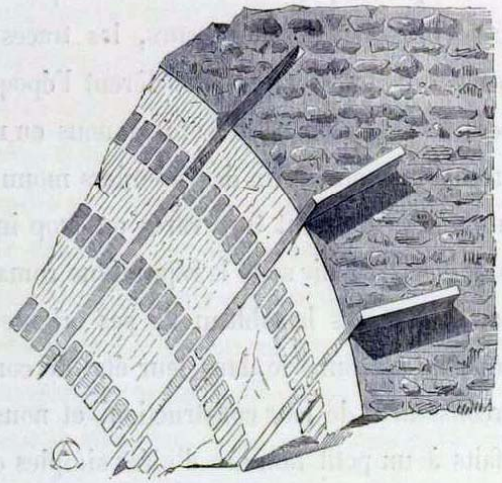


Fig. 8.

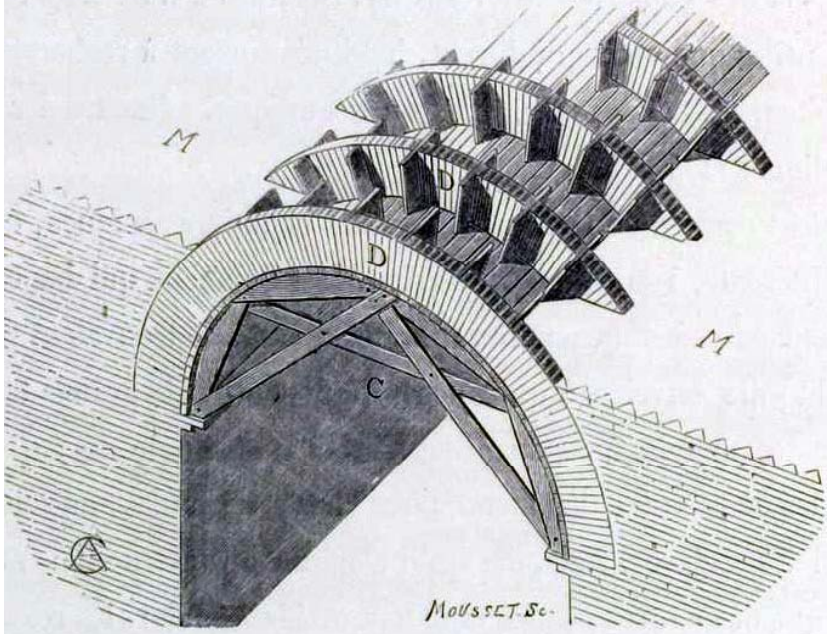


Fig. 13.

Romans always used centerings for their vaults and domes. The drawings by Auguste Choisy show how a light brick masonry frame, built by skilled craftsmen on a light shuttering, created enough support for pouring, layer by layer, a mixture of rough stones and concrete, massive but simple task, that can safely be done by unskilled labourers.

Auguste Choisy: L'art de Batir chez les Romains (1873)

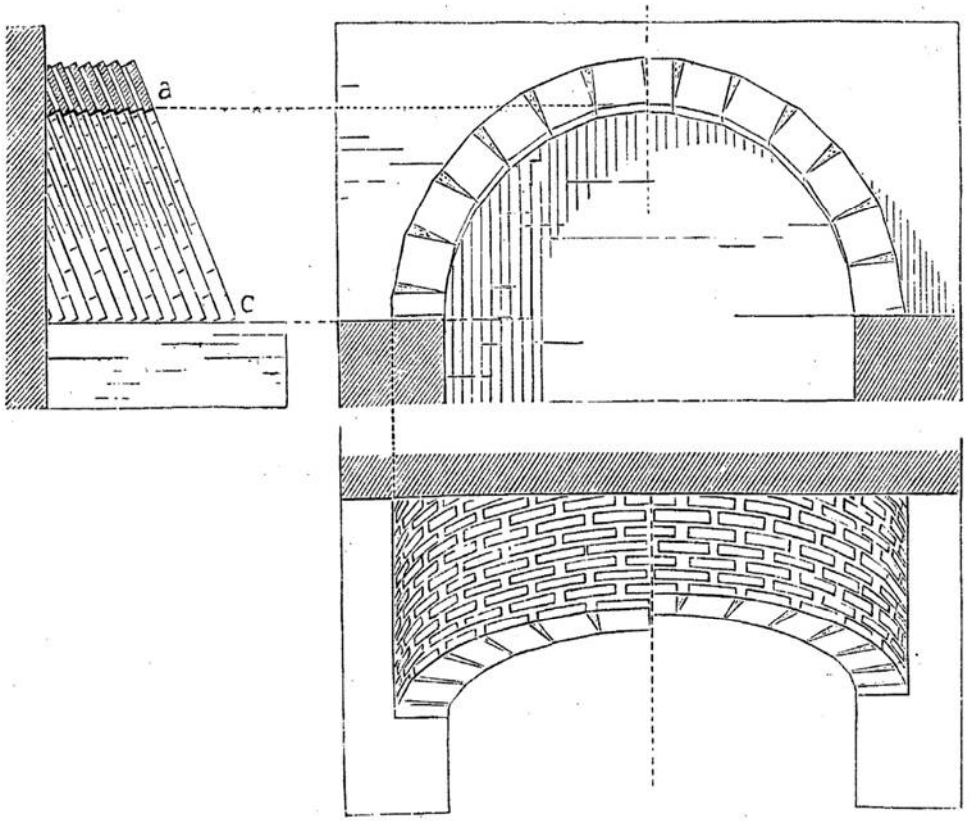
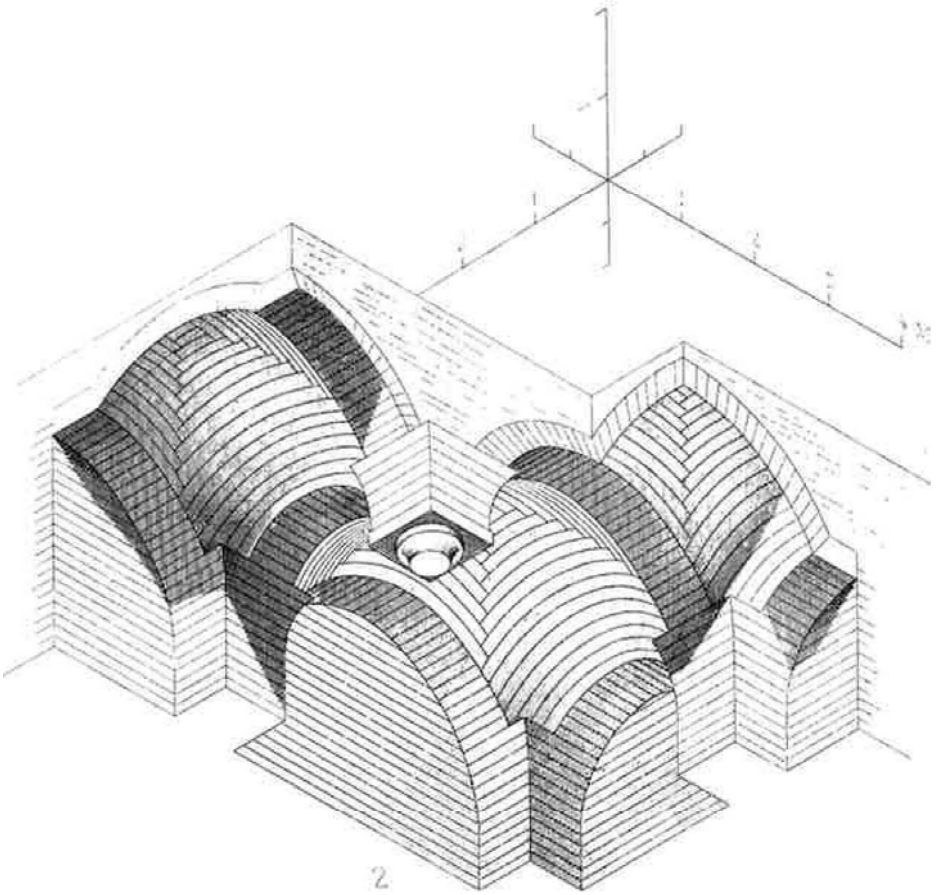
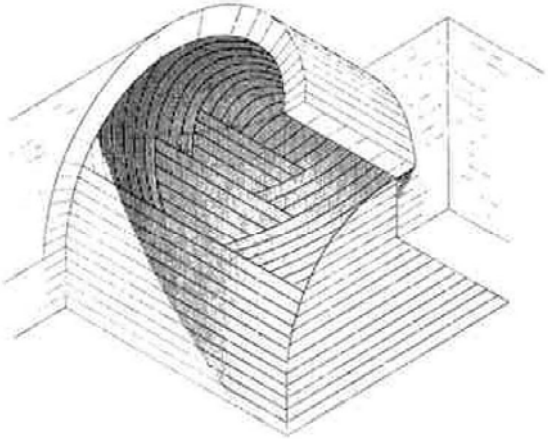


Fig. 31.



On the contrary, Choisy observed that vaults and domes in the Eastern Roman Empire were generally built without any centering, and therefore required very skilled craftsmen and expert supervision.



Auguste Choisy:
L'art de Batir chez les Byzantins (1883)

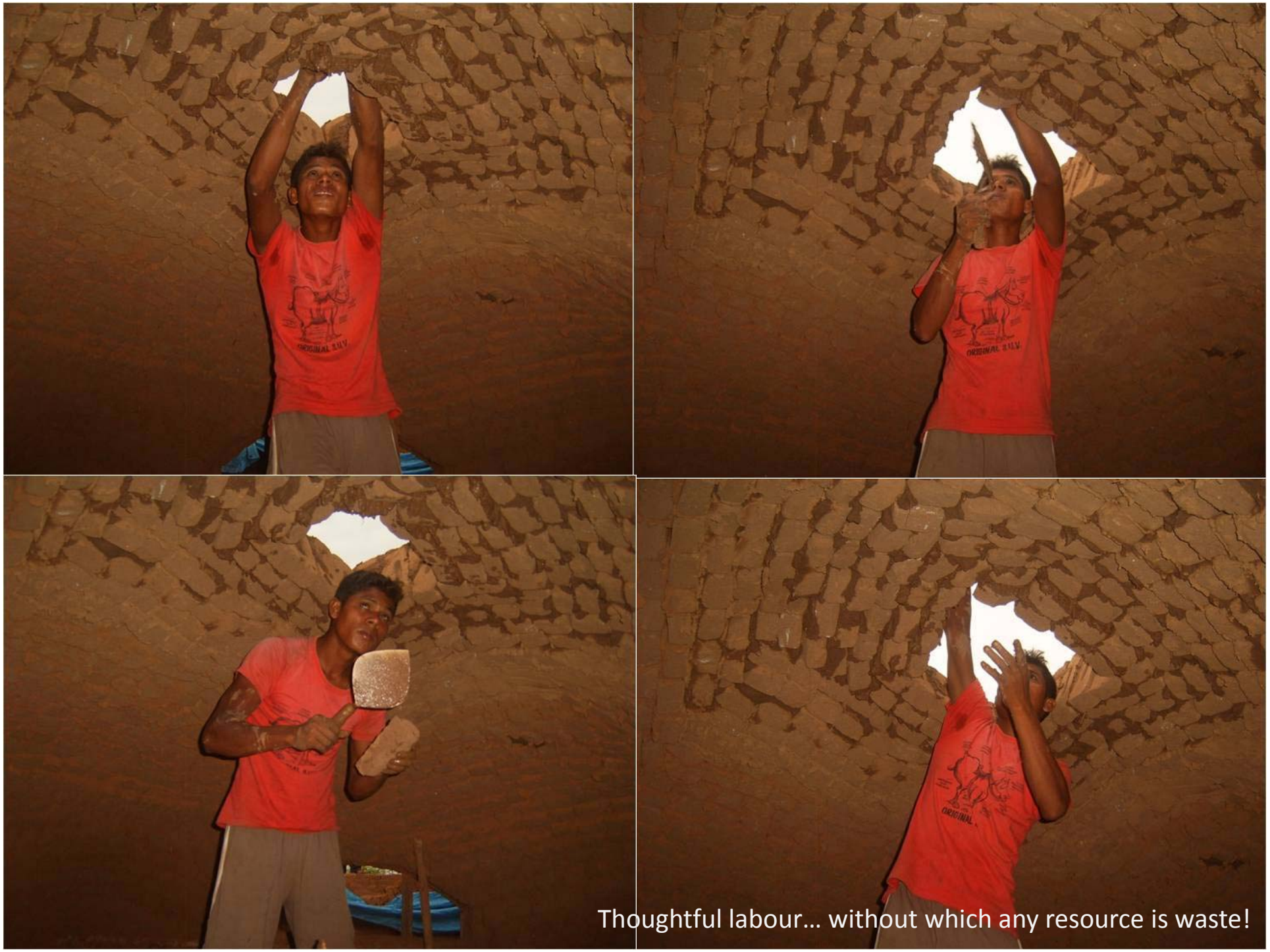
"The other principle, maybe more specific to the Roman organization, was to reduce, if not the overall quantity of labour, at least the intelligent labour, to as little as practically possible. In other words, to adopt, as much as the local resources allowed, a system of construction which allowed the employment, instead of craftsmen, of inexperienced casual workers, of war prisoners when available, of slaves, or, maybe even more often, to have the work executed by force by the populations of the territories which were to benefit from these works."
Auguste Choisy, Voûtes Romaines, 1867

"Analysing a Western Roman vault, you will hardly find into it a few brick links, forming its frame, its skeleton; the rest is but a formless mass, a filling of broken stones and mortar, a pure and simple accretion: ***One of these cleverly primitive achievements, from where intelligent labour is deliberately excluded and which testifies of a huge material force, passive instrument of a powerful will****. –In the Orient, on the opposite, in the Greek countries, everything is combination, everything is calculation; every fragment has, in the vault in which it belongs, its own place and purpose; E****verywhere is visible, side-by side with the overall concept, the thoughtful force which executes****: One feels carried away into a totally different world; and the monuments of these two schools thus reveal, right into their minutest details, the difference between the hands from which they have come."*
"In Rome, where the vault is a monolith made of a plastic material, its mass requires a mold; and the Roman architect gives a centering to each vault. But this centering, he refuses to build it simply for being discarded immediately after use: and in this thought he applies a mixed method of construction, half-framework and half-brick. Once the vault completed, only the framework disappears; The brick part remains embedded in the mass and contributes to its strength: To incorporate in the vault most of the centering which supported it, this is the essence of the western system. – With the Orientals, the idea of economy takes a more absolute form: For them the issue is not to reduce the cost of auxiliary constructions, the point is to eliminate them. The question of vaulting without centering, Greek architects address it squarely, and, thanks to astute arrangements of materials, achieve its resolution: Most of their vaults, they built directly into space, without support, without props of any kind. Their method is not a variation of the Western method, it is a very distinct one, and which does not even derive from a Roman source. This system is Asiatic."
Auguste Choisy, L'Art de Bâtir chez les Byzantins, 1883

With the emergence of modern capitalism in the 19th century we have internalised the slavery of the Roman Empire (Max Stirner: *"On the frontage of our time is not written anymore "know yourself!" but "exploit yourself"*), and instead of shaping its techniques, everywhere society allows itself to be shaped by technology, and the question which is staring at us is:

Why are machines producing essentially waste?

(C.K. Raju: The Eleven Pictures of Time; Nicolas Georgescu-Roengen)


Thoughtful labour… without which any resource is waste!