**ANALYSIS OF BAMBOO SCAFFOLDS IN THE CITY OF MUMBAI, INDIA**

Bamboo is an ideal material for scaffolds tanks to its high resistance and its lightness. The joints are done so that a vertical force acts directly on the tied node. In the case of high diameter canes, the friction can be increased by making the rope pass between the two canes. The ropes used are soft, so that it’s possible to modify their tension.

The scaffolds method doesn’t need any hole that could create week points or need any dowels.

The lashed joints are the most effective, cheap, historical and frequent method to join bamboo canes. The organic ropes (mostly bamboo and rattan, but coconut, rafia and sago too) are preferable to other solutions (nylon, plastic, iron) because of their total compatibility with bamboo and aesthetic reasons.

Their resistances are very high: a natural fibres rope with the diameter of the dimensions of a man’s arm can reach 130 tons.

Usually these natural materials are softened in water and only after tied they get dry and create a very strong joint (it is necessary to hold up the structure until their complete drying).

Many times with the lashed joints there are dowels that pierce the final part of the cane (the one which is next to the other cane). But it’s better not to create week points and, if necessary, it’s preferable to use natural fibres ropes than wood dowels, because wood has got a different kind of dilatation from bamboo, so there can be problems in joints and in all the structure if there is no sufficient space for dilatation between wood element and bamboo culm.1

Probably the first bamboo scaffold was built about 5,000 years ago in China, even if its technologies and systems have been establish about 2,000 years ago. They are procedures and solutions taught and handed down in time from generation to generation and that today we try to interpret and encode under laws and norms that follow tradition, not always with success, with safety coefficients, specific terms and laws.

The next analysis is based on the observation of scaffolds in the city of Mumbai. It is a personal photographic documentation made with the base of knowledge from various specific studies on scaffolds, in particular by INBAR (International Network for Bamboo and Rattan) and by Hong Kong Polytechnic University.2

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1 Most of the information are taken from “Il 31 bamboo-bambus”

2 Most of the information are taken from:


1. ELEMENTS OF A SCAFFOLD

As “post” we mean the main vertical elements, that send the forces directly to the ground; they are put on a distance of about 1.8 – 3 metres. Between them we put the “standards”, the secondary vertical elements. The connections between these beams are horizontal elements named “ledgers”, put with a distance of about 60 – 75 centimetres. The “transoms” are the bars perpendicular to the building that let put on them the footbridges for worker’s transit. The diagonal members are put where necessary in the three space directions, so both to stabilize the plane “post – ledger” and “ledger – transom” (Fig. 1, Fig. 2).

Fig. 1: Main elements in a bamboo scaffold
Fig. 2: Distances between elements
2. **LASHED JOINTS WITH COCONUT FIBRES ROPE**

Usually the joint between structural elements in iron, concrete and wood structures are the most delicate point of the structure and they need to be calculated and dimensioned very carefully (even for economical reasons). But in this case, the joints are made by workers (many times kids) that simply learn the technique and repeat it in similar ways for different cases (different number of beams to tie, different angles). They are made by hand joints with no previous calculation nor tests in their life time. The calculation is substituted by the experience, and the tests with the observation while time passing.

These joints are the elements in which it’s mostly evident the effort of the modern science to follow the thousand-year knowledge, to establish numerical laws where logic observation, ability and practical sense rule. Every case is different because it’s different the shape and the height of the building, but also the weather and the mechanical properties of bamboo, the eventual necessity of joining bamboo with iron scaffolds and so many other elements which are impossible to catalogue in general norms (Fig. 3, Fig. 4, Fig. 5, Fig. 6).

The first images (Fig. 3) are frames from a video of workers that tie bamboo: the technique is elementary, with no mathematical or physical logic more complex than friction between beams and coconut fibres ropes and the resistance of the ropes. These rules could be studied in laboratory but they are made more complicated by the specific contest, so that the analysis of one specific joint is nonsense because the number of rounds of the rope is not predetermined (and probably if it was it wouldn’t be done by the worker), the humidity (impossible to say precisely because of the different climatic zones and period of the year), the conservation of the scaffold and any other relevant characteristic of the specific place.

Very often the norms that we can find for making bamboo scaffolds or for the correct conservation of the beams collide with the reality, with the techniques of experience, with the specific and unpredictable contest and with the monsoon.
Bamboo scaffolds in India
These are frames from a video of an Indian worker fixing together two bamboo culms with a coconut fibres rope (the most used in India). The sequence clearly shows the easy and fast operations (the entire video is less than one minute). The last image is the same joint made by me as demonstration of the simplicity of the making.

First we fix the rope around the vertical culm making a loop. Then we start to pass the rope diagonally between the two beams some times in one sense and then some times in the other sense (the number depends on the specific case). Finally we tie the rope with a simple knot.
Bamboo scaffolds in India

Fig. 4: The four views of a joint between two beams

Fig. 5: Joint between three beams
Fig. 6: The variety of joints in a scaffold
3. SYSTEMS TO ANCHOR THE SCAFFOLD TO THE BUILDING AND TO THE GROUND

To anchor of the scaffold to the building there are different methods, like ropes (the same used to tie the beams) fixed to some hooks put into the facade (Fig. 7) or to the gutter pipes or to any other element (Fig. 8, Fig. 9), and bamboo beams that pierce windows or walls (Fig. 10, Fig. 11).

Sometimes we can find other beams contrasting the detachment of the scaffold from the building.

For the ground joint, the beams are simply lean and aren’t fixed in any way (Fig. 9). They are many times cut at the end so that the surface in contact with the ground is less, probably that is to limit the problems with water infiltration.
**Bamboo scaffolds in India**

Fig. 9: Anchorage system to the facade and the ground detail

Fig. 10: Bamboo piercing the window and the other elements to support
Fig. 11: Bamboo piercing the wall
4. STORAGE OF THE ELEMENTS

In the city we can find many times piles of bamboo canes and coconut fibres ropes waiting to become a scaffold (Fig. 12, 13). This kind of storage doesn't care about meteoric conditions, but we must think that when the scaffold is up the monsoon rains are not a problem.

Fig. 12: Storage before assembling in Mumbai

Fig. 13: Storage of materials in Mumbai
5. VERSATILITY OF BAMBOO SCAFFOLDS

One of the characteristics of bamboo scaffolds is their versatility: bamboo easily adapts to any shape (Fig. 14) and it’s often used to complete the metal scaffolds (Fig. 15) thanks to this quality and its lightness.
6. MEN’S WORK

The following images (Fig. 16, Fig. 17) just give an idea of the Indian construction sites and the condition of men working on bamboo scaffolds.

Fig. 16: Men working

Fig. 17: Erection of the scaffold and maintenance of the façade
7. **OTHER DETAILS ON SCAFFOLDS**

The following images are necessary to complete the observations on bamboo scaffolds (Fig. 18, Fig. 19, Fig. 20, Fig. 21). The first one refers to beams used for increasing the resistance of the joint in case of high forces with a tourniquet (Fig. 18).

![Diagram of a tourniquet](image1.png)

**Fig. 18: Tourniquet**
Fig. 19: High distances between elements

Fig. 20: Integration with metal scaffold
Fig. 21: Different looks of bamboo scaffolds
8. OTHER TYPICAL USES OF BAMBOO INSIDE THE CITIES

The images that follow document the presence and use of bamboo in Mumbai city for the structure of various commercial and private stalls (Fig. 22, Fig. 23, Fig. 24, Fig. 25).

Fig. 22: Open air roofing
Bamboo scaffolds in India

Fig. 23: A bar on the beach

Fig. 24: Stalls in Colaba market
9. A PARTICULAR CONSTRUCTION SITE: THE GATEWAY OF INDIA

The Gateway of India is the monument symbol of the city of Mumbai. It is a triumphal arch that celebrates the colonial power. It was inaugurated in 1924 but it became a symbol 24 years later, when the last British regiment left the country passing under it. These are images of the construction site of its restoring, where we can notice bamboo as a completion of the upper part of the metal scaffold, as inner scaffold (Fig. 26), and in other practical uses (Fig. 27) inside the construction site (with the typical coconut fibres ropes and various recycled materials).
Fig. 26: Metal and bamboo scaffolds outside and inside the Gateway of India

Fig. 27: Other practical uses
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