Corbelled Stone Structures: Form

El Bombo, La Mancha, Spain

The elements of composition of an object are structure, frame and filler. Filler is the material filling the space between the structure and the frame. El Bombo is a stone shelter around Tomelloso in La Mancha province, Spain. Its composition has the construction and the frame separated by quite a few meters. In conclusion, we can say that something incredible happened there: the filler, mostly used as cheap stuffing material without any value, here makes the form.
I had thought that I was old enough to have already seen many things and never thought that I would discover so many new things in Spain. While flying over the Mediterranean on my return from Valencia, where I was invited by the Universidad Politecnica, I could hardly gather my thoughts about what I had seen. They had taken us to a landscape of gypsum, which is used there as a construction material. Not because they have too much of it, but because wood is sparse and they cannot build furnaces for burning lime, which demand higher temperatures. Back to gypsum: my colleague from Limoges, a geologist, showed us gypsum crystals, which resemble natural glass. Maybe I had seen some while in school, but my knowledge was rather deficient in this department. A surprise followed. In a typical multi-floor building we calmly reclined on the outer walls to take photographs of the interior. I was doing this until told by a colleague that the outer walls were only seven to ten centimetres thick. And they were made of gypsum! During construction their scaffolding was dragged upwards every half hour, since gypsum crystallises very fast and the wall can be finished in several hours. Afterwards I was careful enough not to lean on the walls, but still bravely walked on the floors. In the church (which has a blacksmith’s shop in the basement, the village granary above it, then a horse stable and the church effectively on the fourth floor) I noticed a hole in the ground carefully covered with planks. Of course I uncovered the hole and looked six meters downwards to the stable. Then I noticed the construction itself: between the very slender girders there was a gypsum (plaster) membrane with taut, curving, almost pre-stressed scaffolding. The upper surface could be walked upon. In the middle its thickness was some four centimetres. I took a photo, covered the hole, tiptoed out and never went back to the church. There was a sign saying „no pasar“, i.e. no trespassing, now I know why. All my colleagues – from Egypt to Belgium and Moscow to Portugal – agreed that they’d never believe the story if told before. Plaster is a construction material. Also. Now I know.

I would however like to talk about corbelling, construction in the dry wall technique, without binders. Not far from Madrid, in the La Mancha province, to which I travelled in sweltering heat, I found something even more amazing. Looking out through the clouds of dust rushing in through all the openings, I discovered stone shelters, called los bombos, whose form comes from sand, gravel and fillers. I wouldn’t have believed, but here’s the story:

HYPOTHESIS

El Bombo is an object of extremely simple structure. Protecing it from ruin today without using binders is not possible. Corbelling is undoubtedly one of the oldest construction principles for bridging space. It is more than six thousand years old as can be proved by the example from the subterranean sanctuary Hal Saflieni in Malta.¹ Such principle of overlapping above all demands a layout that is as round as possible, all the way from the ground, up to the keystone, while in the section an equilateral triangle can always be drawn. The latter ensures the construction height, which always equals half the square root of three.

By definition architectural form results from material, structure and circumstances in which elements were used. Stone shelters remerge in the medieval times, the oldest mentioned were by Degano from 1559, Horvatic from 1577 and Lassure from 1620,² but they are still being built today. At this point a statement and question emerge. Corbelling is a structure, the frame determines the form; the filler occupies the space between them. Question: can it be done otherwise? Theo-

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1 Juvanec, 2001: 1: 1-13
retically the answer is: no. In practice exceptions are possible. However, exceptions confirm the rule. One of these exceptions is El Bombo: an unpublicised but extremely interesting architecture, whose form is provided by the filler: sand and gravel. How is this possible?

**Structure, Frame and Filler**

In the composition of a building, the structure is the part that bears the load. The envelope, coat or membrane, mainly clothe the structure; sometimes it helps in load bearing. The filler is somewhere in between: sometimes it only fills the voids because its material is cheaper than the structure’s, more often it protects — usually before heat or cold. It is therefore a stuffing used as an insulator, sometimes it helps the structure to bear the designated load (with its weight).

**Filler**

The filler is the material that occupies the void between the structure and frame. It is functional for other purposes as well: binding, insulating or maintaining constant temperature. It also provides form. In Slovenia the most widespread — but also most commonly used filler was — hay, between the source of heat and the user. In granaries there is no filler — nothing, not conveying either heat or cold.

**Several Examples**

The filler is a material ranging from „nothing“ to stone (in modern architecture physical „nothing“ equals vacuum, while in vernacular architecture it implies the absence of physical material, the closest equivalent being of course: air), even bound into artificial stone, concrete. The space between hosts numerous materials, used by simple builders with such ingenuity that contemporary solutions, seen as wonders upon „discovery“, are today nothing more than common, ordinary and understandable.

Slovenian vernacular architecture possesses an excellent building for storing food, known as granary (orig. slov. kašča). It can be built, but with thick walls, thus preventing heat from entering too soon. Wooden granaries are less demanding, construction is easier, as is maintenance. The timber however also has to be rather thick, to insulate the interior. Our forefathers used a simple approach to prevent contact between the sun (heat) and sausage (sometimes also wheat, wine or other harvested goods). Between them, encased in a double wall, there was simply nothing. Direct contact between the source of heat harmful for the object and the object itself was thus prevented.

Historically speaking, the physical structures of buildings are very clear: at first large quantities of material hiding the structure were used (the Romanesque for example: thick walls, small openings and small spans with small useable spaces).

In Gothic architecture only load-bearing elements formed the structure: nets, which practically carry the structure were reduced to a minimum; they are almost clear theoretical static drawings.

Filling used in walls can be almost nothing, when we have a uniform structure, single wall. When my colleague B. Horvatič told me about a single wall on Krk (an island) whose height is 1.6 meters and composed of a single layer of stone, I had my doubts. He proved to me that it can actually be walked upon and to hold without collapsing. It can even withstand the wind or rather let it through intentionally left openings...

Unjulica is a magnificent structure.
In the Nuraghi village Su Nuraxi in Sardinia they have a wall that is composed of two layers of stone: the outer ones are chiselled, while the inner retain their natural, conical form. If two layers are built consequently an extremely strong structure emerges. In between there is hardly any space for fillers: sand only strengthens bonds between the stones, without using other binders.

Too much stone is when fertile soil is caught among rocks; to cultivate a field, vineyard or orchard we have to remove them. A field’s fertility doesn’t benefit from the presence of stone, therefore there is too much of it. A pile of stones, which is gathered, eventually disappears – back to the soil. The problem of „too much stone” is repeated.

A stone wall without mortar, is the simplest structure. It is a system with certain rules, such as: overlapping, directing elements, exchange. A „dry wall” is generally a two-dimensional structure that mainly defines open space and often appears in combination with other de-limitation elements. Stone structures in vernacular architecture are the simplest ones. Besides stone only hands and simple tools were put to use, but above all common sense. The „dry wall” system utilises the principle of overlapping, whereby every consecutive layer covers vertical openings in the former. Rather simple, only corners are more demanding. Complications begin when we try to bridge a void.

Corbelling: If we place a stone on another and push it slightly forward, it won’t move. If we push the next one in the third layer even further – but not across the common centre of gravity – we get the rudiments of corbelling. Its essence is dual: the ground plan has to be as round as possible, while the section angle has to near sixty degrees.

Sixty degrees is the angle seen in the equilateral triangle. The simple builder probably didn’t know that the height of such a triangle was half the square root of three, although shepherds played a simple game called „three sticks”. These were of equal length and could construct only one closed figure: the triangle.

Angles:
The equilateral triangle has three dimensions, three sides of equal length and three equal angles: \(180 : 3 = 60\).

The basic angle of an equilateral triangle is sixty degrees.

Height (h):
If the basis of an equilateral triangle is 1, its height \(h\) is equal to the opposite (vertical) cathetus of the equilateral triangle’s half, whose hypotenuse equaling 1 and by-lying cathetus equaling \(\frac{1}{2}\), form an angle of 60°:

\[
h^2 + \left(\frac{1}{2}\right)^2 = 1^2 \rightarrow h = \sqrt{1 - \left(\frac{1}{2}\right)^2} = \sqrt{\frac{3}{4}} = \frac{\sqrt{3}}{2}
\]

The height of an equilateral triangle is equal to the basis multiplied by half the square root of three.

If we built a structure whose angle would be less than sixty degrees, loads would work better in the frame, but the efficiency of drainage would be lesser, especially when the eave of the upper element reclines on the drainage surface of the lower. With a lesser angle, beginning from the ground, the utility of the internal space would be diminished, if at all possible.

Stone structural elements should be of exceptional quality (no veins or cracks) and have exceptional dimensions. Such stone practically cannot be found, but an angle of

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3 Zaragoza, 2000: 7
4 Juvanec, 2004: 7
5 Benvenuto, 1990: 105
6 Juvanec, 2004: 27
sixty degrees can be built even from undistin-
guished stones not larger than 20 centi-
metres (example: Pont on Menorca, Kažun in
Istria, Hiška in Karst).

Buildings with sixty-degree angles and,
above all, circular ground plans have re-
mained and we can learn from them. As a rule,
in corbelling circular ground plans are used:
the circle is the perfect figure and there are
no problems with corners. The circle closes en-
ergy flows and ensures safety throughout the
building phase.

Square and rectangular ground plans can
also be found: generally they form higher
spaces. Such spaces are usually divided into
two floors. The important fact is that the con-
struction with equilateral triangles and thus
at an angle of sixty degrees begins on the up-
per floor (Trullo in Puglia, Cabane in France).

A point of interest is that references ignore
corbelling: why, would demand a lengthy dis-
course. In the book Forms and Functions, which is undoubtedly one of the better re-
views of structural principles, corbelling is
only mentioned. Twice in fact, first as a cantil-
lever in construction and then as a disbur-
denring triangle in Greek architecture.

The arch: Egyptians used upside-down grad-
ing and the ratio 3:4, Greeks only used the
beam, while the Romans adopted the arch
from Etruscans. This is a planar construction
that uses conically cut stone, which rise ac-
cross from Etruscans. This is a planar construc-
tion with equilateral triangles and thus
– the Etruscans ac-
2

The dome: Contrary to the earlier mentioned
structures this one is spatial. It uses the prin-
ciple of the arch, which is spun around both
horizontal axes. Even here the ground plan is
circular, just as in corbelling. The difference is
that in corbelling all the layers are horizontal,
while in a dome all elements are spatial, each
with its own axis running towards the cen-
tre. After the beam, corbelling and arch, this

was the first spatial architecture that allowed
larger spans and defined larger spaces. De-
velopment of the dome reached its peak in
the middle of the second millennium with Mi-
chelangelo and Brunelleschi, but the Pan-
theon built two thousand years ago was the
first modern architecture.

In the structural sense the Pantheon in Rome
is a perfect sphere, with a bottom cylindrical
useable part and roof executed as a hemi-

circle; kažun varies, from round to square,
with emphasised to soft, almost mushroom
shape; pagliaddiu in Corsica externally
almost resembles a “proper” house, but in-
side there is a transverse corbelling with
sharp angles; trullo in Puglia, as we know it,
with its typical round ground plan (roof), and
pinacollo on the ridge, is only one type of the
building, but there are a whole range of com-
pletely different variations.

BUILDINGS WITH CORBELLED STRUCTURES

GRAĐEVINE KAO KONSTRUKCIJE S
POSTUPNIM KONZOLINIM NAČINOM
GRADNJE

We can stone to construct planar (walls) and
spatial elements (buildings). For the first we
have to respect overlapping of composite
parts, for development of spatial composi-
tions of the latter without binders, only one
solution is possible – corbelling.

It represents logical development from the
structure of the beam to the space: corbelling
is the connecting link between large and
small bridging elements, pieces of material
that can be assembled. Corbelling is a sig-
nificant step forward and combines: the pla-
nar principle of construction and spatial com-
oposition. This sequence holds even in time:
the first proof of corbelling reaches to the fifth
millennium BC, while the first dome was
seen at the break of the millennia.

The common feature of stone shelters is use
of corbelling in their internal structures. Their
exteriors vary: crot uses chiselled stone to
withstand snow and freezing in the Swiss
Alps; kažun varies, from round to square,
with emphasised to soft, almost mushroom
shaped roof; pagliaddiu in Corsica externally
almost resembles a „proper” house, but in-
side there is a transverse corbelling with
sharp angles; trullo in Puglia, as we know it,
with its typical round ground plan (roof), and
pinacollo on the ridge, is only one type of the
building, but there are a whole range of com-
pletely different variations.

7 Hamlin, 1952
8 Hamlin, 1952: 296
9 Hamlin, 1952: 329
10 Juvane, 2002: 1-14
11 Tiret, 2000: 46-48
12 Fabrega, 2003: 13
13 Juvane, 2001a: 11
14 Juvane, 2001b: 18-13
15 Juvane 2001a.
Form can follow structure, but it can also be completely different. We know of semicircular forms, stepped structures, even spiral ones, forms of geometrical figures and completely amorphous, formless ones. The latter are defined by their filler, the material, which, if simply put is closest to sand or gravel.

Girna in Malta and all other shelters utilise corbelling in their structure, while their exterior walls can run completely vertically. Thus a space is created between them, filled in with non-structural material – the filler. In places with no rain (Malta, Palestine, places in southern Italy) the filler is also the roofing material.

The construction and frame can be connected elements (load-bearing capacity and load), they can be unconnected and the space between filled in. El Bombo in Spain is the only shelter where the construction and frame are wide apart; the filler takes on the task of providing form.

El Bombo – Stone Shelter from La Mancha

El Bombo is the shelter for men and their livestock around the town of Tomelloso in La Mancha, Spain. The composition presents a structure completely separated from the frame, all of which is covered with stone. A pile of stone.

El Bombo is a one-, two-, three- or four-celled building. The living space is intended for man and has an open fireplace with a chimney (which generally doesn’t exceed the height of the pile, and thus can hardly be seen) and niches to the left and right (in Slovenia we call them levo). The cell for livestock has a man-ger, built along the whole length of the back wall. The floor is compacted clay; the walls are painted with quick lime in the living space and brown clay in the space for livestock, up to the height its user can reach, between 2.20 and 2.40 m. The entrance is usually on the southern side and there are no windows.

16 Pсадин, 1992; Juwan, 2001: 45
17 Rohlfis, 1965, 131: 1
18 Juwan, 2004: 4
19 Pedrero, 1999
20 Juwan, 2002: 4
21 Juwan, 2002: 37-46
A Pile of Stones can be a House or the Most Ecological Form of Human Dwelling

I understand ecological architecture as such, which works (both its organisation and structure), uses natural materials, that are not manipulated and therefore changed, which doesn’t harm nature (neither technically and technologically nor aesthetically), and which after decomposition doesn’t burden nature — stone used in corbelling constructions can be built into any contemporary architecture.

The ground plan of El Bombo can be small or luxurious, visible also from outside. The structural part is corbelling, with ties between its cells and openings for passages (even between the living space and stable). The entrance part is the first cell and is used by both users.

Corbelling or rather, all the cells, are meticulously and carefully built, around the usable part the builder builds a fence. Between them he shovelled gravel that strengthened the inner structure.

The ecological cycle of the relation between the vine and the environment, in which it grows, is defined by the vine that grows well in fertile soil mixed with stone. Such stone is often overabundant, thus the environment itself allows only growth of vines (in flat land also olives), and hinders the growth of other field produce. Gravel as a piece of broken stone is therefore available in the place itself, while larger stones have to be brought from nearby quarries. Gravel is strewn up to the ridge and higher. Sometimes the internal structure’s ridges are also shown externally as vertically planted stones.

The fence or frame of the structure is built from larger stones that also have a more constant form (they are flatter, at least on the outer side), thus the colour impression of these walls is much lighter than the filler’s. At least the entrance parts of the buildings still in use today are painted with quick lime; more affluent owners sometimes paint the entire wall, so that it is white, but the structure of the wall remains clearly visible. The most ardent owners even paint the gravel, although I’m not quite sure how they do it.

CONCLUSION

Los Bombos stand in vineyards, on a plane, in a circle of some five kilometres from the town, in all directions. This means that the people of the town of Tomelloso occasionally came to work in the vineyards and rode their donkeys. This doesn’t mean that they stayed there overnight: because of the continental climate work was done only in the mornings and sometimes in the late afternoon. The rest of the day they spent resting in the shade of Los Bombos, while their animals waited there for the passage home.

When I was writing an article for the magazine L’Architecture vernaculaire in Paris, I made two photographs depicting piles of gravel in Tomellos. Next to the first one I wrote: „A pile of stones, which isn’t a pile but El Bombo and...
under the second, which depicts an apparently equal pile of gravel „A pile of stones, which isn’t El Bombo, but a pile of stones”.

The form is utterly natural: a pile cannot be controlled. It depends on the size and form of stones in the gravel and dictated by the angle of strewing. The form, size and structure above the ground plan, chimney and fireplace or entrance are elements, which follow each other as is best suited. The form of the pile is constant and equal to all, but the combination of spaces below and differing height of fences (the frame is determined only at the entrance, elsewhere it is almost inexistent) softly taper from the ridges, across the saddles to the edge.

Man cannot dictate such form nor control it: if too much gravel is shovelled onto a place, in time it will slide downwards and create a logical external form aligned to the internal one. The theoretical elements of such form are therefore: 1) material and its angle of strewing, 2) internal form with necessary organisation of spaces, 3) both points (1 and 2) give the final and typical form, El Bombo.

In architecture we say that the outer form reflects the interior. However both the investor and architect much too often tend to destroy such relations by violent designing. El Bombo takes no such liberties.

Should one ask oneself: is nature the better architect than man?

El Bombo is the only architecture I know of, that is self-regulatory in its form.

The conclusion is a surprising fact: an amorphous material, used as filler, gives a natural form to the whole composition. Good form, aligned to content, structure and the environment.

Not even man can spoil it.

(Translated by IVAN STANIĆ, Ljubljana)
Konzolni način gradnje nesumnjivo je jedan od najstarijih načina zatvaranja prostora. Koristi se još prije više od sest tisuću godina, što potvrđuje prijer u Hypogeum Hal Saflieni na Malta. Takav princip gradnje zahtijeva troctor koji bi trebao biti što je više moguće okruglo po cijelom visini, dok mu je presjek jednakokrاني troctor koji osigura visinu konstrukcije koju je uvijek jednako polovici drugog kragu koriste.


Postavlja se tvrdnja i pitanje. Konzolni načini gradnje: B. Horvatiæ, ali ona se grade srednjem vijeku. Najstarije navode Degano (1559.), Horvatic (1577.) i Lassure (1620.), ali ona se grade i danas.

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Kamene konstrukcije s postupnim konzolnim načinom gradnje: OBLIK

El Bombo, La Mancha, Španjolska

Znanstveni prilozi

Sažetak

El Bombo

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