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Fig. 1 Houses and their analyses – eight examples
Sl. 1. Analize kuća – osam primjera

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# Proportion Systems in Examples of Traditional Architecture in Wood and Stone in Croatia

## Sustavi proporcija na primjerima drvene i kamene tradicijske arhitekture u Hrvatskoj

HERITAGE
ORDER
THEORY OF PROPORTION SYSTEMS
VERNACULAR ARCHITECTURE

NASLIJEĐE
RED
TEORIJA SUSTAVA PROPORCIJA
TRADICIJSKA ARHITEKTURA

The article analyses the practice of proportion systems in vernacular architecture in Croatia. It focuses on vernacular architecture of two areas in Croatia. The first is traditional wooden architecture of the Northern part of Croatia where the composition is based on squares and their diagonals – growth based on the square root of two. The second is stone architecture along the Croatian coast, from Istria to Konavle, whose proportion is based on the square root of three divided by two.

U članku se analizira praktični aspekt sustava proporcija u tradicijskoj hrvatskoj arhitekturi. U središtu je istraživanja arhitektura koja se javlja na dva područja u Hrvatskoj. Prva je tradicionalna drvena arhitektura sjevernoga dijela Hrvatske, koja je komponirana na temelju kvadrata i njihovih dijagonala – porast koji slijedi kvadratni korijen iz dva. Druga je kamena arhitektura duž hrvatske obale, od Istre do Konavala, koje se proporcije temelje na kvadratnom korijenu iz tri dijeljeno s dva.

## THEORY IN PRACTICE

### TEORIJA U PRAKSI

Some thousand years ago, high theory was practically implemented in all forms of classical architecture. Those buildings are the result of the greatest thinkers of the world. Vernacular architecture, on the other hand, is a result of unlearned men who composed with skill, needs, possibilities and heritage. Heritage means culture and culture can not be a matter of surviving. Culture comes when all needs, all circumstances of survival, are fulfilled.

A typical example for this is decoration. In vernacular architecture there is no decoration, but the very architecture is definitely decorative. Can this statement be a mistake? No, since all the details in vernacular architecture work well together and their shapes result from its construction and its function.

The same is with proportions. While learned men know and use them, unlearned craftsmen use them sometimes in unusual ways, having no prior education on proportions. Some elements of theory are explored in this article, with practical implication in vernacular architecture.

### SQUARE ROOT OF TWO IN PRACTICE

#### KVADRATNI KORIJEN IZ DVA U PRAKSI

We know that the square root of two appears as a diagonal in a square. The square is a composition of two triangles with right angles and two sides with same lengths. We are familiar with examples in vernacular architecture that have exact ground plans, composed of squares. In a place near Nikomedeia (Macedonia, Greece) houses dating from 6220 BC are shaped in a $7.5 \times 7.5$ m grid. It is a square grid and the houses were built as squares.[1] Azmak and Karanovo (Bulgaria) houses from 5600 – 3800 BC also have a grid system measuring $8 \times 4$ meters.[2] This is not a square, but a rectangle, composed of two squares. The length of a diagonal in two squares is equal to the square root of five, but there are two diagonals of the squares, making together the right angle.

Square with its diagonal can be used for a number of things, such as drawing (a picture) or constructing (carpentry in a house). It is exact, but contains visual harmony that is transcendent, and not only in men's compositions – that is, in architecture – but in nature as well. Today we know mathematical expressions, but carpenters used to know proportions very exactly without the abstract mathematical representation.

It is not incidental that one finds a lot of compositions made out of the square root of two.

A wide use of square and its diagonal can be found in Slovene *kozolec* (hayrack), where the sustainable composition of this important vernacular architecture represents the essential part of its visual culture.

The square root of two and the square root of three divided by two are an essential part of vernacular architecture. Traditional builders did not know them and were not able to construct them, but they simplified them with straightforward tools. They used circle, square and triangle, and constructed them with the help of a circular trunk, square cross section of a beam, and three sticks. Three sticks were not only the tool, but a shepherds game too.

The main idea comes from carpenter's work: a beam, trimmed from a log, is square, and the log is circle. The carpenter did not know theory, but practice.[3] And this practice has been built in a number of examples of vernacular architecture. Slovene *kozolec* (hayrack) is composed from square and the square root of two both in detail and in entirety. Squares are used in the same manner for composing wooden architecture in the northern part of Croatia. Slovene *kozolec* has its height equal to the square root of three, but composed of one plus square root of two. It is the matter of simplicity in carpenter's work. This is the proof of simplicity of work and of complexity of thinking.[4]

1 FLETCHER, 1996: 214
2 FLETCHER, 1996: 215
3 JUVANEC, 2004: 19

## Square root of three in practice

### Kvadratni korijen iz tri u praksi

The square root of three is derived from a rectangle (one to the square root of two), where it plays the role of its diagonal. The square root of three is also the height of a hexagon.

## Triangle in construction

### Trokut u konstrukciji

One triangle, equilateral, is an essential point of ancient construction, known from at least 4500 years BC. It can be seen in engraved underground temple Hal Saflieni in Malta.[5] It shows construction of corbelling, where the cross section shows stratified layers of stone are placed one above another. The ground plan is mostly circular or in a shape close to circle. The vertical cross section shows a composition made on the basis of equilateral triangle, where the baseline is equal to one and the height is equal to the square root of three.

Today we know stone shelters, brilliant vernacular architecture, made by modest shepherds. Shelters are in use even today for sheltering against weather, located far from the homestead. In Europe we know shelters in Spain as *el bombo* (La Mancha), *barraca* (Catalonia) and *pont de bestiar* (the Balearics); in France they are mostly called *cabane,* but hundreds local names are in use, in Corsica there is *pagliaddiu* (North) and *barracun* (South); Switzerland has *crot/scele* (Poschiavo Valley); in Germany there are *weinbergshaeuschen* (near Worms); Ireland has *clochane* (Dingle peninsula), and *sweathouse, ashhouse*; Wales *pigsty*; in Italy there are *trullo* (Puglia), *caprile* (island of Elba), and *pineta* (Sardegna); Slovenia has *hiska* (Kras); Croatia *Kažun* (Istrian peninsula), *komarda* (Krk island), *bunja* Dalmatia and islands, *trim* (Hvar island), *vrtujak and toreta (Korčula island)*; Greece *mitata* (Peloponnesian peninsula, Crete); Malta *girna;* Morocco *tazota or nwalla*; Palestine *mantarah*; Egypt *nawamis* (Sinai).

Triangle can be seen in constructions all over the world: from North America to Siberia. It is not important whether it is wooden or stone construction: *tipi* or *tipee* of Canadian Indians is a typical example.

## Triangle in composition

### Trokut u kompoziciji

Equilateral triangle has been used for other purposes too. In physics a sunbeam comes to the mirror at the same angle as it comes out: the angle of incidence and the angle of reflection are the same. Reflection is in use to make a miracle, where the Sun is coming from the earth and is not shining only on the sky. There is the question of how the builders from ancient times knew about the square root of three.

Temples were made by the wisest men of the time, but modest stone shelters were not. Where is the key? The answer is pretty simple – in one of shepherds' playing toys. Shepherds and their children had knifes and were surrounded with nature where they could find a lot of branches. The game 'three sticks' was very popular among them. With three sticks they could make only the geometrical form of an equilateral triangle.

Of course, sticks are not the only means of constructing the equilateral triangle. It can be done with a rope and two pins, like a theoretical model of the square and delineated arcs. The intersection defines the height of triangle where all three sides are the same.

We understand that human body is close in proportion to the golden section. But the square root of three is an essential length for the body.

This constructional principle is used in at least 95 percent of stone shelters, and it is typical for corbelling.

The square root of three is more important than we think.

Theoretically it is not so simply to express it, but in practice it is very popular. This is illustrated not only in constructions but in the human body as well.

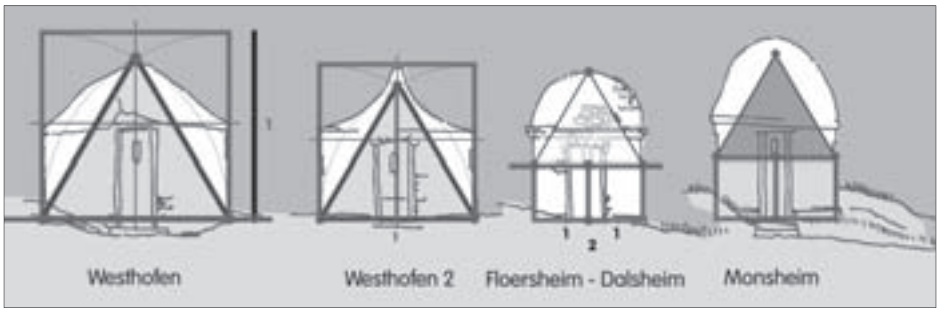



Fig. 2 Weinbergshaeuschen near Worms, west Germany. The building is defined as "watching tower", and it can not be wider than one and half meter since it is not meant for sleeping, but for watching. It is a high construction, but equilateral triangle is certainly used for construction.
Sl. 2. Weinbergshaeuschen kod Wormsa, zapadna Njemačka. Objekt je definiran kao osmatračnica i ne smije biti širi od jednog i pol metra jer nije predviđen za spavanje nego promatranje. To je visoka konstrukcija, no za nju je zasigurno korišten jednakostranični trokut.

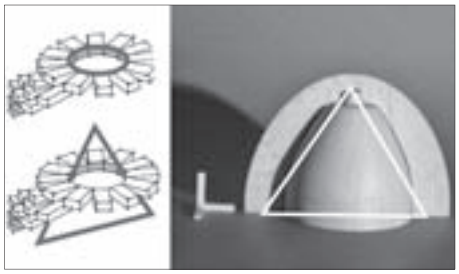


Fig. 3 Theory of corbelling in practice: ground plan, cross section and equilateral triangle, defining the middle of the wall and top stone
Sl. 3. Teorija postupnog konzolnog načina gradnje u praksi: tlocrt, presjek i jednakostranični trokut koji definira sredinu zida i kamen na vrhu

Fig. 4 Kozolec (hayrack) in Verd, near Bistra in Ljubljana marshes. The width and height are the same, measured from the base (named "baba" – old woman carried the construction) to the top. All the compositions use squares, squares in squares, with growth in proportion of 1 to $\sqrt{2}$.
Sl. 4. Kozolec (jasle za sijeno) u Verdu kod Bistre, Ljubljansko barje. Širina i visina su jednaki, mjereno od donjeg dijela (koji se naziva „baba" i nosi konstrukciju) do vrha. U svim konstrukcijama su prisutni kvadrati, kvadrati u kradratima s rastom proporcija u omjeru 1 prema $\sqrt{2}$.

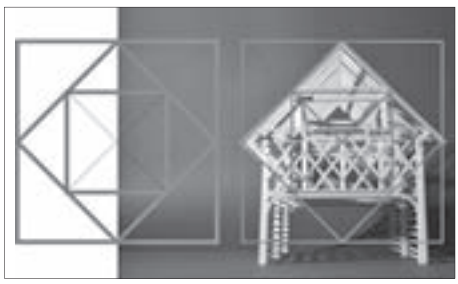
## Croatia in Practice: Wood and Stone

### Praksa u Hrvatskoj: drvo i kamen

## Wooden Architecture of Northern part of Croatia

### Drvena arhitektura sjeverne Hrvatske

The northern part of Croatia has really wonderful wooden architecture. It is full of car-



4 Juvanec, 2004: 20

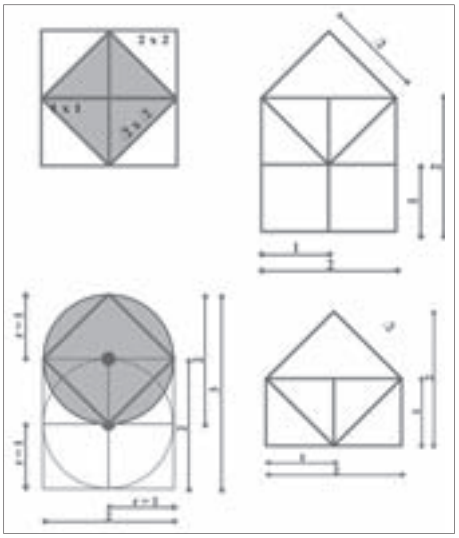
5 Juvanec, 2000: 115

FIG. 5 BREST PROKUPSKI. TWO SQUARES PLUS A SQUARE $\sqrt{2}/2$ BY $\sqrt{2}/2$
SL. 5. BREST POKUPSKI. DVA KVADRATA PLUS KVADRAT OMJERA $\sqrt{2}/2$ S $\sqrt{2}/2$

FIG. 6 GLINA. SQUARES IN SQUARE WITH BASELINES EQUAL TO 1/2, $\sqrt{2}/2$ AND 1
SL. 6. GLINA. KVADRATI U KVADRATU S OSNOVICAMA KOJE IZNOSE 1/2, $\sqrt{2}/2$ I 1

FIG. 7 PLESNO. SEVERAL SQUARES CONSTRUCTED WITH THE HELP OF THE SQUARE ROOT OF TWO OR DIAGONALS OF THE SQUARES
SL. 7. PLESNO. NEKOLIKO KVADRATA KONSTRUIRANO UZ POMOĆ KVADRATNOG KORIJENA IZ DVA ILI DIJAGONALA KVADRATA

FIG. 8 PRINCIPLE OF COMPOSITION WITH THE HELP OF THE SQUARE AND ITS DIAGONAL – SQUARE IN THE SQUARE, SQUARE ON THE SQUARE, CIRCLES IN THE SQUARES, SQUARE AND TWO SQUARES (RECTANGLES 2 : 1)
SL. 8. PRINCIPI KOMPOZICIJE S KVADRATOM I NJEGOVOM DIJAGONALOM – KVADRAT U KVADRATU, KVADRAT NA KVADRATU, KRUGOVI U KVADRATIMA, KVADRAT I DVA KVADRATA (PRAVOKUTNICI U OMJERU 2:1)



penter's details, constructions and flat decoration made from planks. At the first sight it can seem as architecture of decoration. However it is not because decoration itself is the result of construction. This architecture is real vernacular architecture since there are no two similar buildings, even though the basis is always the same. What is the catch?

According to the architects Davor Salopek and Zdravko Živković, this architecture consist of a basement on stones (clearly visible), two-floor body and a gable, with the inclined roof in the ration one to one, or 45 degrees.

The lower floor is smaller than the upper one for 30 to 90 centimeters of corbelled beams. An enlarged ground plan is not used for seating or for beds, like in Islamic architecture, since all surfaces on the upper level are essential bigger.

This corbel is constructed to make shadow, as well as to make the lower floor cooler (since it is used for animals and for storing crops in a sort of granary; therefore lower temperature is needed). Another possible reason is to protect from rodents since mice or rats can not climb the horizontal overhang. The front elevation is composed symmetrically – from the ridge of the roof to the composition of windows. The entrance and covered staircase are always on the longer side of the house. The most important and most interesting is a proportional analysis. Order itself is not used as force, but for simplification of construction as well as elevation (view).

I searched 8 examples, based on the drawings of Davor Salopek and Zdravko Živković, and the essential proportion system I found is square. Six of eight front elevations have two squares, and two of them have one and a half square on the very roof. The roof's inclination is definitely 45 degrees, and contains the right angle on the top. The lower part is square again, with the width equal to the height.

The composition of windows, normally two of them on each floor, is made with another square, with the baseline equal to one divided with the square root of two. So, there are only the lengths of 1/2, $\sqrt{2}/2$, 1, $\sqrt{2}$, 2, 2 and $2\sqrt{2}$.

Six of eight examples are composed of a whole square, and the last two, composed with the help of two squares in the body plus a complete square on the roof.

The practice of using the square root of two with the right angle, if the baseline is equal to one, is widespread, mostly in vernacular architecture. The diagonal as the square root of two and the baseline equal to one is the essential part of the composition of Slovene *kozolec* (hayrack) in both, the slim and stout version, found in north and in south of Slovenia, in details as well as in the whole.[6]

Dr Langenhein found this proportional system as 'Slavic quadrature' in many front elevations of houses and farm buildings of East Europe, from Slovakia to Croatia.[7]

More examples, more exactness and more work are needed for an exact scientific survey, but for the beginning I can say that the square with its diagonal is definitely the essential and important part of the composition in wooden architecture of North Croatia. This represents its typical characteristics and could be used in architecture today.

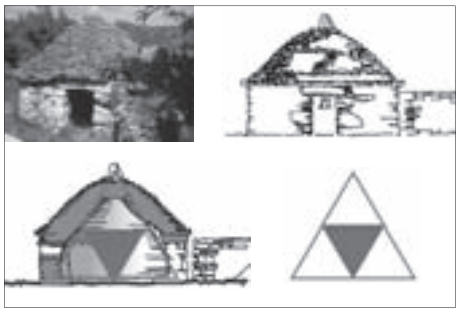
## STONE ARCHITECTURE: ISTRA TO KONAVLE

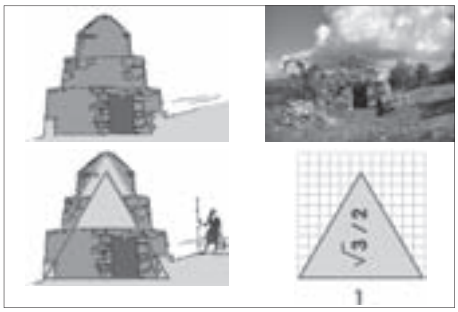
### KAMENA ARHITEKTURA: OD ISTRE DO KONAVALA

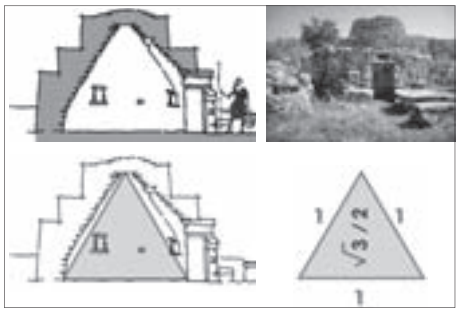
Stone shelters are the simplest buildings in stone, built in corbelled construction. The typical characteristics are the corbelled construction, with the use of stratified layers of horizontal stones, in unique construction and shape, and the frame which gives the outer view and the shape itself.

In Croatia, stone architecture has been researched in the frame of Bilateral Agreement Slovenia/Croatia in the programmes of the Ministry of Science No BI-HR /07-08-012 and

6 JUVANEC, 2007: 64-70
7 LANGHEIN, 2004






BI-HR /09-lo-022, and the project "The Stone of Mediterranean" took part under the high patronage of his Excellency Dr Mario Nobilo, ambassador to Croatia.

While in complicated shelters there are several different proportion systems, in simple ones, and most common in Mediterranean, the equilateral triangle is clearly visible.

Complex buildings can have a number of proportion systems – from the golden section (it serves for sheltering people) to the Egyptian triangle. Several systems in one building is a possible case, but typical there is only one, appearing in the whole composition as well as in details. This is in actuality the most important fact.

The typical proportion system found is the equilateral triangle. Theoretical, scientific work has been done on some hundred buildings[8] from Mediterranean, Austria, Switzerland, Germany, Ireland, Wales, England, Iceland, Greece, Morocco, Malta, Sinai and Yemen. In all of them the equilateral triangle can be found as the representative proportion system. It can be seen in cross section as well as in elevation and in details. Interesting is its implementation in construction itself.

The baseline contains an inner diameter plus two halves of wall thickness. The top of the triangle ends at the top stone or in the middle of it. It seems to be complicated, but it is not. Practice shows the baseline ('one' or '1' in triangle) as the length from the outer wall at the door to the bottom of the ground plan.

Theoretical height is equal to the square root of three divided by two. A height that is larger than the mentioned one represents more material and much more work without any practical result. A smaller height does not exist because those constructions collapsed over time. This system applies on most corbelled buildings and can be found on small as well on the biggest ones. My documentation can show 'pont de bestiar' on Menorca (the Balearics) with the diameter equal to ten meters and the heights of 8.5 metres. But there are higher points as well.

## Case study: stone shelters in Croatia

### Analiza primjera: kamena skloništa u Hrvatskoj

There are a lot of experts in the field of stone architecture, more or less in details. All the problematic areas are covered by Christian Lassure in "L'Architecture Vernaculaire" and on *Pierreseche.com*. Istrian *kažun* is revealed by Tihomira Tepinac Fabijanic in the book "Le Casite" published in 1994 ("Kažun" in Croatian, 1996). Important is the systematic research work of Dr Berislav Horvatic, and in practice there is the architect Branko Orbanic with a lot of accomplishments all over the Istrian peninsula.

**Kažun** is a typical corbelled buildings in Istria, with its circular, square and rectangular ground plan. The roofs are made with more or less visible, accented freeze and the top stone, that is, a pinnacle on the top. Kažuns are in use for sheltering people, not animals. Flocks of sheep are protected in more or less circular folds in stone close to the building.

**Trim** on the island of Hvar is wide in use in the vineyards (the plain behind Stari Grad named Ager), but can be seen on the hilly ridge of the island too. Most of trims have stepped roofs and they are about three to four metres high (to the top plate). Due to its big construction the stone is relatively small and the triangle is traced in free cross section.

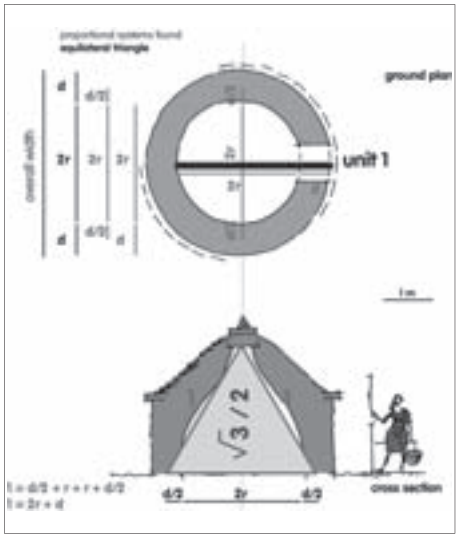
**Vrtujak** near Vela Luka on the island of Korčula represents important cultural heritage. Korčula used to be covered with vineyards, whereas today there are mostly trees. Some shelters are now hidden in the bush, even those with watch towers (with views to the sea or to other shelters). On a sloppy terrain *vrtujak* has normally rectangle ground plan and in some locations extremely thin walls. Very often there is practical 'equipment' for work in the vineyard: cisterns with 'catching platforms for collecting water as well as basins for blue copper with the name 'vitriolac' (the name comes from 'vitriol').

Fig. 9 *Kažun* near Kanfanar: triangle can be traced from points in the middle of the wall, at the height of the benches around, to the pinnacle's centre of gravity.
Sl. 9. Kažun kraj Kanfanara: trokut uočljiv ako se spoje točke na sredini zida, na visini klupa i u točki gravitacije stožastog kamena na vrhu kažuna.

Fig. 10 *Toreta* in Salapućeva njivica is a wonderful example of vernacular architecture. Now it is just partly ruined, only on the surface, while the inner, visible construction is perfect. Big wooden door and sheep folds tell us about its use some decades ago.
Sl. 10. Toreta u Salapućevoj njivici je izvanredan primjer tradicijske arhitekture. Danas je tek djelomično uništena na površini, dok je unutarnja, vidljiva struktura u savršenom stanju. Velika drvena vrata i torovi pokazuju kako je korištena prije nekoliko desetljeća.

Fig. 11 *Trim* in Jurkovica in Ager serves as a shelter in the vineyard which is in use even today. Around the buildings there are benches and a table, and open basin for water and vitriol or blue copper (locally called *vitriolac*).
Sl. 11. Trim u Jurkovici na Ageru služi kao sklonište u vinogradima koje je i danas u upotrebi. Oko građevine se nalaze klupe, stol te otvoreni bazen za vodu i vitriol ili galicu (lokalno ime vitriolac).

Fig. 12 Case study: proportion system in typical (average) *vrtujak* – the ground plan with a mathematical sum of the wall thickness plus the inner diameter. The cross section shows equilateral triangle with its height, equal to $\sqrt{3}/2$.
Sl. 12. Primjer analize: sustav proporcija u tipičnom (uobičajenom) vrtujku – tlocrt s matematičkim zbrojem debljine zida i unutarnjeg promjera. Presjekom prikazan jednakostranični trokut s visinom koja iznosi $\sqrt{3}/2$.




8 For Croatia see bibliography: Juvanec, documentation – Kažun, Komarda, Bunja, Trim, Vrtujak, Toreta

**Toreta** near the village of Smokvica is a big building with stepped roof and sheep fold around it. Toreta has a wooden door since it was only used for sheltering shepherds. Around or near toreta, sheep pen with sheep folds can be found, but with wooden construction of the roof. The walls can be very thin which required extreme craftsmen work. Corbelled construction is definitely perfect. Today the state of roofs, after decades of no maintenance, is relatively good. The buildings are almost intact.

The origin of toreta is uncertain. According to the legend that lives among old people in Smokvica, it came from Spain. This is one possibility. Another, quite possible origin is also from Spain, but from Menorca, where the village is called 'toreta', and where stone shelters are also known. Or another possibility that it came from Catalonia, from Torroella del Mongri, where similar buildings can be found. The legend tells about mariners, who travelled around the world and took the idea and the shape back to the island of Korčula. All this is possible, but the same buildings can be seen in Puglia, not far from Korčula, just across the Adriatic Sea.[9]

It is a pity that vernacular architecture in stone today represents only heritage and memory.

## CONCLUSION

### ZAKLJUČAK

The two groups of buildings, wooden architecture of the north and stone architecture of the Adriatic coast are not all that exist in Croatia. However, these examples are familiar to me, but representative enough to show the square and triangle in vernacular architecture in common use. Proportions, math and geometry are a matter of high theory. In vernacular architecture they are in use in another way, simplified and for simplification, with all the same successful results.

This research of vernacular architecture shows how important mathematics is, both in theory and practice. And, if little shepherds enjoyed in playing with three sticks, if this is theory in practice, if stone shelters are composed with the help of this work, mathematics comes naturally. My research proves that mathematics is an important part of architecture too.

[Lektura: ŽELJKA MIKLOŠEVIĆ, prof.]

9 JUVANEC, 2006

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## SOURCES

### IZVORI

#### INTERNET SOURCES

##### INTERNETSKI IZVORI

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#### ILLUSTRATION SOURCES

##### IZVORI ILUSTRACIJA

FIG. 1-4, 8-12 B. Juvanec
FIG. 5 B. Juvanec, based on: SALOPEK: 1991
FIG. 6, 7 B. Juvanec, based on: ŽIVKOVIĆ: 1993

## Sažetak

## Summary

# Sustavi proporcija na primjerima drvene i kamene tradicijske arhitekture u Hrvatskoj

Primitivni čovjek sam je stvorio prve mjere, i to prema svojem tijelu. Drugim riječima, to su bile antropomorfne mjere. Naravno, njegov je prvi „dom" bila rupa u zemlji, špilja, gdje je bio zaklonjen barem s četiri strane, dok je jednu stranu morao štititi sam. Postavlja se razborito pitanje: je li kamen, materijal koji je čovjek razumio i bio mu blizak, bio drugi korak u zaštiti? Ili je to, pak, bilo drvo, materijal lakši za obradu. No, i za drvo i za kamen potrebne su ruke i um, i za konstrukciju iz oba materijala koristio se modularni sustav.

Dok se u postupnom konzolnom građenju mogu koristiti potpornji u različitim oblicima, rezani kamen zahtijeva drukčiji sustav dimenzija, no u skladu s načinom gradnje. Horizontalne, kao i vertikalne cigle povezuju konstrukciju, posebno na rubovima. U tom se slučaju koristi jedna polovina te čak jedna četvrtina duljine. Jedna potpuna cigla sastoji se od četiri četvrtine ili dvije polovine. Matematički je to jednostavno izraziti kao 1/4 + 1/4 + 1/4 + 1/4 = 4/4 ili 1/1 ili 1. I dok u teoriji tvrdnje mogu biti točne ili netočne, u praksi konstrukcije ili stoje ili ne stoje. Sva stara arhitektura koja se danas može vidjeti jest dobra arhitektura jer su se loše konstrukcije urušile davno prije. To je praksa.

Divna drvena arhitektura sjeverne Hrvatske tipičan je primjer reda u drvenoj tradicijskoj arhitekturi. Puna je dekoracije (koja je prema Vitruviju samo dio kompozicije), i to uglavnom u zabatnom i prednjem fasadnom dijelu kuće. Kompozicije se doimaju iznimno mirne, u stanovitom redu i održive. Proporcijski im se sustav temelji na kvadratu i kvadratima unutar njega, konstruiranim s dijagonalom. Teoretski, to je proporcijski rast na temelju kvadratnoga korijena iz dva. To je sustav kvadrata u kvadratu, ili kompozicija od dva ili tri kvadrata. Dijagonale, koje se uglavnom koriste za komponiranje zabata, tako su kvadratni korijen iz dva, kvadratni korijen iz pet (u slučaju dva kvadrata) i kvadratni korijen iz deset (u slučaju tri kvadrata s uobičajenom dužinom 3 = $\sqrt{9}$ i dijagonalom koja je $\sqrt{10}$).

Moje su analize primijenjene samo na nekoliko građevina u sjevernoj Hrvatskoj, a to nije dovoljno za pravi znanstveni rad, no gotovo 80 posto njih sagrađeno je po sustavu kvadrata ili više kvadrata, što je vrlo važna činjenica. Za dokazivanje teze, međutim, potrebno je više građevina, više mjerenja i analiza. Teorija ponekad može biti neugodna, ali njeno potvrđivanje u praksi, gdje se mogu pojasniti načini funkcioniranja, izuzetan je dio posla.

Najvažniji primjer slovenske tradicijske arhitekture, *kozolec* (jasle za sijeno) konstruiran je na temelju kvadratnoga korijena iz dva. U praksi se to može svesti na krug i u njemu upisan kvadrat kojem je baza jednaka jedan, a promjer kruga kvadratni korijen iz dva. Postoje dva tipa kozolca (uglavnom u mjestima sjeverno i južno od rijeka Ljubljanice i Save), i to kvadrat u kvadratu i kvadrat na kvadratu. Oblici su različiti. Prvi je širok, dok je drugi uži i manji. Naravno, to nije stvar teorije, već prakse, s obzirom na to da se širi *kozolci* nalaze južno od Ljubljane na većim poljima i većim potrebama za sijenom, a uži *kozolci* na planinskim dijelovima s manje prostora i manje sijena.

Postupna konzolna gradnja jednostavna je metoda kojom se horizontalni slojevi kamena stepenasto slažu jedan na drugi. Cijela se kompozicija temelji na kvadratnom korijenu iz tri podijeljeno s dva. Jednostavno rečeno, to su jednakostranični trokuti kojih je visina jednaka kvadratnom korijenu iz tri podijeljeno s dva, ako je baza jedan. Sva skloništa izrađena u kamenu (suhozidna gradnja) izgrađena su na taj način, buduci da visina viša od kvadratnoga korijena iz tri kroz dva nije funkcionalna (višak materijala, rada i prostora), dok manja visina nije dovoljna da bi se sklonište uopće sagradilo. Jednakostranični trokut može se pronaći u kamenim skloništima na prostoru od sjeverne do južne Hrvatske: *kažun* u Istri, *komarda* na otoku Krku, *bunja* u cijeloj Dalmaciji, *trim* na otoku Hvaru, *vrtujak* i *toreta* na Korčuli, *kućarica* u Konavlima pokraj Dubrovnika.

Bez obzira na kružni ili kvadratni, ili pak pravokutni tlocrt, presjek je jednak kvadratnom korijenu iz tri podijeljeno s dva. To znanje nije zaboravljeno. Najrecentnija građevina na kojoj se koristio postupan konzolni način gradnje izgrađena je 2008. godine na otoku Korčuli pomoću mojih analiza i dokumentacije. Unutarnja joj je visina 3,05 m, što potvrđuje moju teoriju.

Teorija i praksa puno su povezanije nego što mislimo. Mi danas poznajemo teoriju kao matematiku i geometriju, no nekada se ona razumijevala kroz praksu s jednostavnim alatima i puno razmišljanja. To je posebno vidljivo u hrvatskoj arhitekturi, bilo drvenoj ili kamenoj.

**Borut Juvanec**

## Biography

## Biografija

**Borut Juvanec**, Dipl.Eng.Arch., Ph.D. is a professor at the Faculty of Architecture, University of Ljubljana, Slovenia. He is an expert in the theory of architecture, its origins, principles od proportion and vernacular architecture. He occasionaly gives lectures at many European universities. He is the author of several monographies, articles in monographies, journals and electronic media. His scientific and research work has been exhibited in several European cities. He is an active member of ICOMOS Paris/Ljubljana, CEEPUS programme Vienna, ISPROM Sassari, SPS Le Val, ISG Graz, CERAV Paris, ARTE Caceres, Patronat de Sant Galderic, Barcelona.

Dr.sc. **Borut Juvanec**, dipl. ing. arh., profesor je na Arhitektonskom fakultetu Sveučilišta u Ljubljani. Bavi se teorijom arhitekture, njezinim početcima, principima proporcije i vernakularnom arhitekturom. Povremeno gostuje kao profesor na mnogim europskim sveučilištima. Autor je niza monografija, članaka u monografijama i časopisima te u elektronskim medijima. Njegov znanstveni i istraživački rad bio je prikazan u nekoliko europskih gradova. Aktivni je član ICOMOS-a Pariz/Ljubljana, CEEPUS programa Wien, ISPROM Sassari, SPS Le Val, ISG Graz, CERAV Pariz, ARTE Caceres, Patronat de Sant Galderic, Barcelona.