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Izvorni znanstveni rad
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Starohrvatske crkvice šesterolisnog tipa na splitskom području – prirodno načelo ekonomičnosti ili štedljivosti*

Old Croatian churches of the six-leaf type in the Split area – a natural principle of economy or thrift*

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SAŽETAK

Promatrajući niz temeljnih poglavlja kojima se bavi znanstvena analiza teorije arhitekture i povijesti umjetnosti, moguće je uočiti nekoliko, iako različitih, međusobno čvrsto povezanih bitnih tema. Među njima se, kao vodeći, ističe problem graditeljskoga oblika koji se javlja kao posljedice utjecaja organizacije prostora, fizički definiranoga konstruktivnom strukturom djela, dok na likovno-estetskom planu nalazimo postojanje skale elemenata i načela sređivanja svake arhitektonsko-graditeljske kompozicije. Budući da su teme arhitektonskih oblika, to jest, definicija arhitektonskog korpusa, gotovo neiscrpne, s obzirom na ukupno široke mogućnosti prilaženja svakoj od njih,

SUMMARY

Observing a number of fundamental chapters dealing with the scientific analysis of architectural theory and art history, it is possible to note several, albeit different, closely related topics. Among them, the most prominent is the problem of the architectural form, which arises as a consequence of the influence of the organization of space, physically defined by the construction structure of the work, while on the visual and aesthetic plane, there is a scale of elements and principles of arranging each architectural construction and architectural composition. Since the themes of architectural forms, that is, the definition of the architectural corpus, are almost inexhaustible, given the broad possibilities of being attached to each of them, this paper presents a narrow analysis that looked at the influence of nat-

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u ovom se radu prišlo užoj analizi kojom je promatran utjecaj prirodnih zakonitosti na arhitektonsko djelo i to u segmentu načela ekonomičnosti ili tendencije ka štedljivosti u djelima starohrvatske arhitekture na splitskom području. Na temelju eksperimentalne geometrijsko-matematičke analize, koja je ovim radom po prvi put javno predstavljena u Hrvatskoj, nastojalo se što egzaktnije utvrditi pravu vrijednost ekonomičnog postupanja u definiranju dispozicije tlorisa crkvica centralnoga šesterolisnog tipa, promatrajući njegovu interpretaciju u likovnosti njihovih habitusa i kompaktnosti unutarnje strukturalne jezgre. Obradom odabranih primjera nastojalo se steći što pouzdaniju sliku o učinku i ulozi prirodnih zakonitosti u kreiranju tih autohtonih starohrvatskih „malih katedrala" na području Splita.

KLJUČNE RIJEČI

crkvice šesterolisnog tipa
– načelo ekonomičnosti ili štedljivosti
– splitsko područje
– starohrvatska sakralna arhitektura

Uvod

Osnovna poglavlja teorije arhitekture obuhvaćaju problem definicije prostora u arhitekturi, funkcije prostora, konstrukcije, koja kao materijalno-tehničko ostvarenje definira željeni arhitektonski prostor i njegov morfološki plan – oblik, uz kompozicijske zakonitosti, tj. usklađenje elemenata oblikovanja temeljem načela arhitektonske kompozicije – reda, ritma, simetrije, proporcije, euritmije i drugih kompozicijskih zakonitosti. (1)

U razvoju teorijske misli postoje raznoliki pristupi navedenim temama, raznoli-

ural laws on architecture work, in the segment of the principles of cost-effectiveness or tendency towards frugality in the works of early Croatian architecture in the Split area. On the basis of the experimental geometric-mathematical analysis, which was for the first time publicly presented in our country, we tried to determine, as precisely as possible, the true value of a cost-effective way of doing things in defining the layout of the planes of churches of the central hexagonal planar type, observing its interpretation in the likeness of their habitus and the compactness of the internal structural core. By working on selected examples, we tried to get as reliable a picture as possible of the effect and role of natural laws in the creation of these indigenous old Croatian „small cathedrals" in the Split area.

KEYWORDS

hexagonal-type churches
– old Croatian sacral architecture
– principle of cost-effectiveness or thrift
– Split area

Introduction

Basic chapters of the theory of architecture are concerned with the problem of defining space in architecture, the function of space and construction, which, as a material-technical realisation, defines the proposed architectural space and its morphological plan form, with compositional rules, i.e., harmonisation of the designing elements on the basis of the principle of architectural composition – order, rhythm, symmetry, proportion, eurythmy and other rules of composition. (1)

The development of theory involves various approaches to the above topics, various methods of solving them, as well as various conclusions, as a result of different conceptual, design, formal, rational, constructivistic or functionalistic approaches to the analysis. (2)

ke metode njihova rješavanja i raznoliki zaključci kao posljedica raznolikoga idejnog, oblikovnog, formalnog, racionalnog, konstruktivističkog ili funkcionalističkog pristupa analizi. (2)

Promatrajući široku materiju koju proučava teorija arhitekture, moguće je uočiti da je niz čimbenika koji sudjeluju u procesu nastanka pojedinog arhitektonskog djela, a osobito u definiciji njegova materijalnog tijela (korpusa), još uvijek u znatnom dijelu otvoreno za znanstvenu analizu.

Jedno od područja u kojemu nalazimo bogatstvo istraživačkoga materijala, osobito u pogledu morfološkoga plana, predstavlja područje prirode.

U prirodi, kojoj pripada i sam čovjek, nalazimo gotovo nesagledivo bogatstvo oblika koje u globalnoj podjeli možemo razvrstati u oblike anorganske (nežive) i organske (žive) prirode. Tu je još jedno isto tako nedovoljno istraženo polje oblika, koje pripada graditeljstvu živih bića niže organizacijske razine od čovjeka.

U svim tim prostornim definicijama postoje zakonitosti koje njihove sastavne elemente drže na okupu, stvarajući oblik koji vidimo u prostoru. Prema njihovu učinku ti oblici izgledaju upravo tako kako su predstavljeni u realnosti.

Oblici u prostoru i zakonitosti njihova definiranja

Kao što je već spomenuto, u našem prirodnom okolišu postoji velebni fond izvedenih oblika. U krugu analize oblika živoga svijeta, razlikuju se tri glavne grupe oblika – biljni svijet, životinje i čovjek. A u podgrupi oblika koji su „izgrađeni" nalazi-

Observing the broad area investigated by the theory of architecture, it can be seen that a number of factors involved in the process of creating a particular piece of architecture, especially regarding the definition of its material body (corpus), are still in a considerable manner open to scientific analysis.

One of the fields that offer an abundance of material for research, particularly regarding the morphological plan, is the area of nature. Nature, which includes man as well, contains an almost endless wealth of forms, which, in the global division, could be sorted into the forms of inorganic (inanimate) and organic (living) nature. There is also another under-researched field of forms, belonging to the building activities of a lower organisational level than human one.

All of these definitions of space include rules that keep their constituent elements together, creating a form we can see in space. According to their effects, these forms appear exactly as they are represented in reality.

Forms in space and the rules of their definition

As mentioned above, our natural environment offers a magnificent fundus of derived forms. Three main types of forms can be distinguished in the area of analysing the living world – plant worlds, animals and man. In the subgroup of the "constructed" forms, there are the objects of human building and architecture, together with, not often perceived but still fascinating, group of built objects apart from this world and the impact of man-building performed by nature itself. (3) Construction analysis of these forms reveals the regularity by which they are structured, and which can be interpreted mathematically as proof of their presence.

One of the acting rules of structuring spatial forms is cost-effectiveness or thrift, which is in an

mo djela ljudskoga graditeljstva i arhitekture i ne tako zapaženu, ali fascinantnu grupu uradaka graditeljâ koji stoje izvan toga svijeta i utjecaja čovjeka – graditeljstvo same prirode. (3) U analizi građe svih tih oblika uviđamo pravilnost po kojoj su oni strukturirani, a koje se mogu matematički interpretirati kao dokaz njihove prisutnosti.

Jedna od djelujućih zakonitosti strukturiranja prostornih oblika je ekonomičnost ili štedljivost, koju u neživom svijetu prouzročuje sama sila gravitacije povezujući tvari u kuglaste oblike (planeti, zvijezde, galaksije), a u živom svijetu štednja je u neposrednoj funkciji samoga održanja jedinke u prostoru (egzistencijalne potrebe).

Prema načelu štedljivoga postupanja stvoren je termin „lex parsimonia"; lex, legis, f. (*lat.* zakon) (4) i parsimonia -ae, f. (*lat.* štedljivost, štednja). (5) Tumačenje pojma ekonomičnosti nalazimo kao *„načelo postupanja u gospodarskoj aktivnosti koje teži ostvarenju što većeg učinka uz što manji utrošak neophodnih činilaca."* (6)

Kao vizualna posljedica primjene načela ekonomičnog postupanja ili tendencije prema štedljivosti, nalazimo kvalitetu jednostavnosti. Pojam jednostavnosti razumijeva odsutnost bilo kakvoga balastnog materijala i dodatne dekorativnosti. U likovnom izražavanju ostvarivanju kvalitete jednostavnosti izrazito pridonosi uporaba ritma, razmjera i osobito simetrije u strukturiranju mase određenog djela.

Opće je prihvaćeno tumačenje da se Priroda ispoljava u većini svojih aktivnosti i nastalih oblika upravo karakterom izrazite štedljivosti i jednostavnosti u svojim postupcima. (7) Također je nedvojbe-

inanimate world caused by gravity itself, joining matter in spherical forms (planets, stars, galaxies), while cost-effectiveness is in a living world in a direct function of individual survival in space (existential need).

The term „lex parsimonia"; lex, legis, f. (*lat.* law, rule) (4) and parsimonia -ae, f. (*lat.* cost-effectiveness, thrift) has been coined following the rule of cost-effective practice. (5) The term „cost-effectiveness" is described as *„the principle of acting in economic activities so as to aim at as high an effect as possible, with as low expenditure of necessary factors as possible."* (6)

The visual result of applying the principle of cost-effective practice or the tendency of thrift is the quality of simplicity. Simplicity includes the lack of any unnecessary material and additional decorativeness. In the field of artistic expression, the quality of simplicity is strongly promoted by the use of rhythm, proportion and, particularly, symmetry in structuring the mass of a particular object.

It has generally been acknowledged that Nature expresses itself in most of its activities and forms created exhibiting the character of extreme cost-effectiveness and simplicity in all of its actions. (7) It has also been proved without a doubt that cost-effectiveness and its values are directly linked to the act of creation in Nature. (8)

The cost-effectiveness component in Nature

In general, numerous phenomena and forms can be found in Nature that have been created by the most diverse activities and creation processes. If we, on one hand, disregard exclusive explanations on a completely predetermined process of formation for these phenomena and forms in Nature, (9) and on the other, the opposite explanations on a completely independent process of arbitrariness and coinci-

no dokazano kako su ekonomičnost i njene vrijednosti neposredno vezane uz sam stvaralački čin Prirode. (8)

Komponenta ekonomičnosti u Prirodi

Općenito uzevši, u Prirodi nailazimo na brojne fenomene i oblike koji su nastali iz najrazličitijih aktivnosti i procesa stvaranja. Ako se s jedne strane izuzmu isključiva tumačenja o unaprijed posve determiniranom procesu nastajanja tih pojava i oblika u Prirodi, (9) a s druge strane tome suprotna tumačenja o potpuno neovisnom procesu proizvoljnosti i slučajnosti, (10) preostaje prihvatljivije tumačenje da su svi oni u najvećoj mjeri upravo rezultat interakcijskoga odnosa organske i anorganske materije i određenih energetskih potencijala, koji djeluju u skladu s nizom opće poznatih zakonitosti fizičke prirode.

Kod organskih oblika nailazimo na niz čimbenika koji aktivno djeluju u tom procesu od samoga početka njihova nastajanja. Dominiraju termo-dinamički procesi (11) i opće poznati faktori selekcije i modifikacije. Osim tih tendencija javljaju se i ostali čimbenici – momenti svrhe, stabilnosti i volje. (12)

U tom postupku nastajanja osjeća se i snažno djelovanje općih prirodnih težnji prema jednostavnosti, ravnoteži i sređenosti oblika.

U procesu nastajanja graditeljskih oblika životinja-graditelja, dominira skala niza prirodnih čimbenika, kojih je osnovni karakter automatizam i stalnost u djelovanju, uz osnovni cilj punoga zadovoljenja njihovih primarnih egzistencijalnih

dence, (10) what remains is a more acceptable explanation that they (phenomena and forms) are to a great extent the result of the interactional relation of organic and inorganic matter with particular energy potentials, such that act in accordance with a number of well-known laws of physical nature.

Organic forms show a series of factors that act in the process from the very beginning of their existence. Thermodynamic processes are prevalent (11), as well as the commonly recognise factors of selection and modification. Apart from these trends, other factors also occur – the moments of purpose, stability and will. (12)

A strong impact can be seen within the process of creation, of a general natural tendency towards simplicity, balance and neatness of form.

A series of natural factors, as a key characteristics of which are automatism and permanence of activity, dominate in the process of forming builders forms of animal-builders, where the key purpose is satisfying their primary existential needs. (13) Namely, the principle of entropy, as the second law of thermodynamics, undoubtedly says that everything is subjected to the tendency of universal balance and suspension of all unnecessary tensions and divisions. (8) It has also been generally renowned that the tendencies towards simplicity and cost-effectiveness are generally present in Nature as a whole. They are manifested in the body build of living creatures – plants, animals and man himself, quite often in the definition of the form of inorganic nature and building forms of animal-builders as well.

A cross-section of the human thigh bone (femur) clearly shows trajectories of porous substance, while their distribution follows exactly the distribution of the forces of pressure and tensile load. This cost-effective distribution of bone mass offers an optimal ratio of lightness (weight) and strength,

potreba. (13) Naime, već samo načelo entropije kao drugi zakon termodinamike, nedvojbeno dokazuje da je sve podvrgnuto težnji sveopće ravnoteže i ukidanju svih nepotrebnih napetosti i podjela. (8) Također je prihvaćeno tumačenje da je težnja prema jednostavnosti i štedljivosti opće prisutna u cjelokupnoj Prirodi. Ona se ispoljava u građi živih bića – biljaka, životinja i samoga čovjeka, a nerijetko i u definiciji oblika anorganske prirode i graditeljskim oblicima životinja-graditelja.

U presjeku glave bedrene kosti čovjeka jasno su vidljive trajektorije spongiozne supstancije, a njihov raspored prati isključivo raspored sila tlačnoga i vlačnoga opterećenja. Takav štedljivi raspored mase kosti daje optimalni odnos lakoće (težine) i čvrstoće i s minimumom građe postiže se maksimalna otpornost (**slika 1**).

SLIKA 1. **Presjek glave bedrene kosti čovjeka**

FIGURE 1. ***Cross section of human thigh bone***

Fascinantni primjer matematički precizne ekonomične redukcije balastnog tkiva nenosivog materijala i zadržavanje samo neophodno potrebne nosive statičke mase za prihvat sila vanjskog i unutarnjeg naprezanja, nalazimo u primjeru stabljike žitarice. Vlat, kao nosiva konstrukcija stabljike štedljivo je definirana u vidu kružnog prstena, a mehaničko stanište koje preuzima sile opterećenja, nalazi se na njegovu obo-

while minimum constitution material offers maximum strength (**Figure 1**).

Grain stems offer a fascinating example of mathematically precise, cost-effective reduction of non-bearing ballast tissue, while keeping only unavoidable and necessary bearing static mass, which can accept the static forces of interior and exterior stress. Blade, as a bearing construction of the stem, is defined in a cost-effective manner as a circular ring, while mechanical cells, which take loading forces, are situated on the brim, which is as far as possible from the non-bearing dead central hollow of the stem (**Figure 2**). (14, 15)

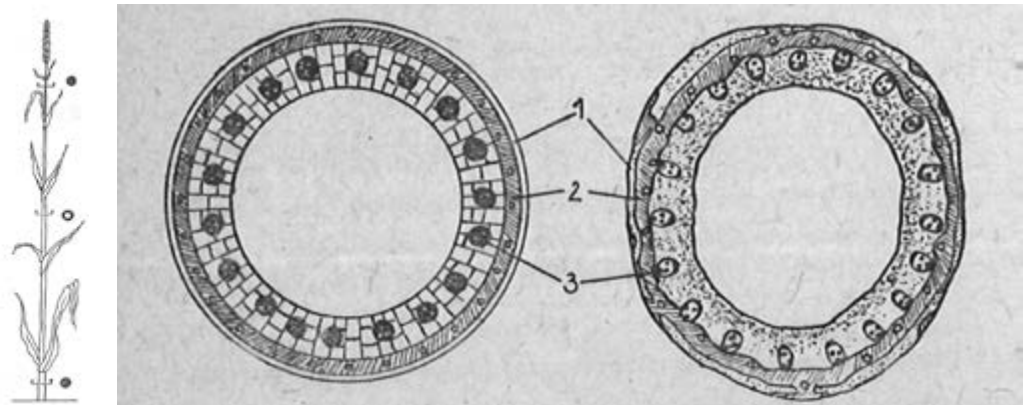
Eagle bones are a good example from the animal kingdom, as they exhibit a considerable reduction in bone mass at the "V"-stiffening, forming a natural grid-like carrier, with optimum stiffness and strength and the least possible use of the matter. Obviously, the primary aim is to construct a light and cost-effective structure (**Figure 3**). (16)

The example of the snowflake (ice crystal) illustrates, in the world of inanimate nature, pronounced poly-symmetry, a comprehensive geometric regularity and characteristics of order in the overall composition of the form (**Figure 4**). (16)

Ever since ancient times, honeycomb has, among the forms "built" by animal builders, attracted open admiration, due to its unsurpassable characteristics, the most cost-effective manner of filling in a plane with groups of hexagons pressed together. This mathematical phenomenon was also

du, što dalje od nenosive mrtve središnje šupljine stabljike (**slika 2**). (14, 15)

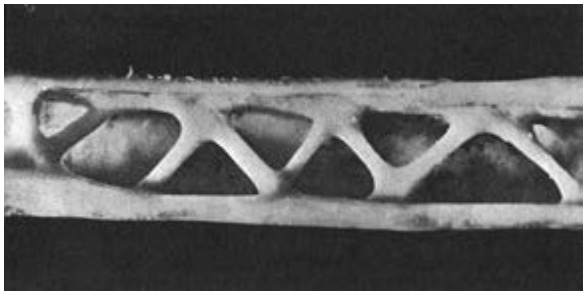
analysed by giants like Johannes Kepler and Ruđer Bošković (**Figure 5**). (17)



SLIKA 2. **Prikaz građe vlati raži (lijevo), presjek kroz vlati raži (desno); 1 – asimilacijsko staničje, 2 – mehaničko staničje, 3 – provodni snopovi**

FIGURE 2. ***Representation of rye blade (left), rye blade cross-section (right); 1 – assimilation cell, 2 – mechanical cell, 3 – wire bundles***

Na primjeru iz životinjskoga svijeta – orlove kosti, vidljiva je snažno smanjenje mase kosti na „V"-ukrućenja, koja oblikuju prirodni rešetkasti nosač, gdje je postignuta optimalna krutost i čvrstoća uz što manji utrošak tvari, s dominantnim ciljem izgradnje lagane i ekonomične konstrukcije (**slika 3**). (16)



SLIKA 3. **Detalj orlove kosti**

FIGURE 3. ***Detail of an eagle bone***

U svijetu anorganske prirode, na primjeru pahuljice snijega (kristal leda), vidljive su naglašena polisimetričnost, sveobuhvatna geometrijska pravilnost i

Analysing all of these areas of Nature, it can be concluded that, apart from a wide range of all the factors mentioned above and principles taking part in defining the forms, a considerable tendency towards cost-effectiveness and thrift in their overall arrangement can be clearly seen.

Cost-effectiveness in architectural creation

Written treatises dealing with quality in architecture realised within the scope of morphological solutions of structural-bearing part of the construction, compositional structure, or direct physical re-

karakteristika reda u ukupnoj kompoziciji oblika (**slika 4**). (16)

Od oblika „izgrađenih“od životinja-graditelja, još je u davnim vremenima pčelinje saće izazivalo neskriveno divljenje zbog svojih nenadmašnih karakteristika, najštedljivijeg načina popunjavanja ravnine skupnim priljubljenim šesterokutima. Tim su se matematičkim fenomenom bavili velikani poput Johannesa Keplera i Ruđera Boškovića (**slika 5**). (17)

SLIKA 4. **Pahuljica snijega**
*FIGURE 4. **Snowflake***

Analizirajući sva ta područja Prirode, možemo ustvrditi da se pored široke lepeze svih dosad navedenih čimbenika i načela koji sudjeluju u definiranju oblika, u značajnoj mjeri provlači i težnja prema ekonomičnosti i štedljivosti u njihovu sveobuhvatnom sređivanju.

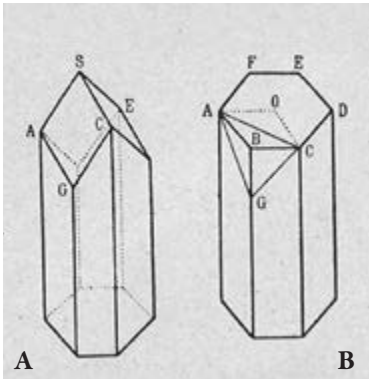
Ekonomičnost u arhitektonskom stvaralaštvu

U pisanim raspravama o kvaliteti u arhitekturi ostvarenoj unutar kruga morfoloških rješenja konstruktivno-nosivog dijela strukture, kompozicijskom ustrojstvu ili pak neposrednoj fizičkoj realizaciji arhitektonskoga djela u prostoru, ne nailazimo tako često na analize i tumačenja ekonomičnosti kao posebno izdvojealisation of a piece of architecture in space, do not often include analyses and explanations of cost-effectiveness, as a separate notion and subject of analysis. This is true, although, taking into account the historical-architectural analysis, the value and importance of cost-effectiveness within the scope of architectural creation, could be found as early as with the Roman architect-theoretician Vitruvius.

Within the practical environment of Roman civilisation, Vitruvius wrote of economising with material and with authority asked for the need to follow the standards in realising the idea of cost-effectiveness. (18)

A kind of continuation of this trend to the spirit of cost-effectiveness can also be found in the theory of architecture in the period of the Rainaissance (L. B. Alberti), which followed the reaffirmation of the rational approach of antiquity. (19)

On the other hand, “performance (executive) building” was in a constant pursuit of a maximally cost-effective approach to executing objects and solving a number of details, directly associated with the execution. At the end, this resulted in the establishment of statics as a scientific discipline, bringing about dimensions of building element masses necessary to build a piece of architecture. (20) Architecture as a science, contrary to the above, quite often neglected the problem, primarily because of the potential possibility that this principle could easily grow into a kind of limiting factor when creating pieces of architecture in space. (21)



SLIKA 5. **Geometrijski oblik stanice pčelinjeg saća (A) i postanak stanice iz prizme ravnog dna (B); matematički izvod tupoga kuta romba „alfa" (prema Ruđeru Boškoviću)**

FIGURE 5. ***The geometric shape of the honeycomb cell (A) and the origin of the cell from the flat bottom prism (B); mathematical derivation of the obtuse angle of the rhombus „alpha" (according to Ruđer Bošković)***

Oplošje stranice sastoji se od 6 trapeza i 3 romba

$$6 \text{ trapeza} = 6\,\frac{b+(b-x)}{2}\cdot a = 6ab - 3ax$$

$$3 \text{ romba} = 3 \cdot a\sqrt{3}\sqrt{x^2+\frac{a^2}{4}} = \frac{3a\sqrt{3}}{2}\sqrt{4x^2+a^2}$$

Prema tome je oplošje stranice (Sl. A)

$$P = 6ab - 3ax + \frac{3a\sqrt{3}}{2}\sqrt{4x^2+a^2}$$

$x = ?$ za $P = \min$

$$\frac{dP}{dx} = -3a + \frac{3a\sqrt{3}}{4}\cdot\frac{8x}{\sqrt{4x^2+a^2}} = 0$$

$$2x\sqrt{3} = \sqrt{4x^2+a^2}$$

$$x = \frac{a}{\sqrt{8}}$$

ako je $AC^2 = 3a^2$, a $GS^2 = 4x^2 + a^2 = \frac{4a^2}{8} + a^2 = \frac{3a^2}{2}$,

onda je

$GS^2 = \frac{1}{2}AC^2$, iz čega slijedi – $\alpha = 109^\circ 28' 16''$

noga pojma i predmeta analize. Premda, gledajući kroz povijesno-arhitektonsku analizu, na vrijednost i važnost ekonomičnosti unutar arhitektonskog stvaranja ukazuje već rimski arhitekt-teoretičar Vitruvije.

Unutar pragmatičnog okoliša rimske civilizacije u svojim raspravama o arhitekturi, Vitruvije navodi ekonomiju materijala i autoritativno upućuje na potrebu poštivanja normi vezanih uz njezino ostvarivanje. (18)

Svojevrsni nastavak priklanjanja duhu ekonomičnosti nalazimo u raspravama teoretičara arhitekture renesansnog razdoblja (L. B. Alberti), koje se javljaju

However, recent trends reveal a strong inclination to the principle of cost-effective and thrift, most often when designing mass living and office architecture, especially in creating shell or other free-standing spatial forms, the appearance of which has impacted the appearance of a new aesthetic standpoint on architectural object artistic value in general. (22)

Circle, or circular form and regular hexagon can be pointed out among morphological matrices as the most consistent expression of cost-effectiveness and thrift in designing. It is quite realistic to assume that the appearance and introduction of the circle (circular form) in architecture was, among other things, a result of seeking for a technical most cost-effective building form. (23) Circle, as a plani-

u svjetlu ponovne afirmacije racionalnog pristupa antike. (19)

S druge strane, „izvedbeno graditeljstvo" bilo je tako reći u stalnom traganju za što egzaktnijim ekonomičnim nastupom pri izvedbi djela i rješavanju niza detalja, neposredno vezanih za tu izvedbu, što je na kraju rezultiralo ustrojstvom statike kao znanstvene discipline, koja donosi dimenzije neophodno potrebne mase gradbenih elemenata da bi se djelo izgradilo. (20) Arhitektonska je znanost, suprotno tome, u najvećoj mjeri zapostavljala taj problem, zbog potencijalne mogućnosti da bi to načelo moglo prerasti u svojevrsni ograničavajući čimbenik u postupku prostorne kreacije njenih djela. (21)

No, u najnovije doba nalazimo na snažno priklanjanje načelu ekonomičnosti i štedljivosti, i to izrazito pri oblikovanju masovne stambene i uredske arhitekture, posebice pri stvaranju ljuskastih i drugih samostojećih prostornih oblika, čija je pojavnost utjecala i na oblikovanje novoga estetskog stava o likovnoj vrijednosti arhitektonskoga djela uopće. (22)

Od morfoloških matrica, kao najdosljedniji izraz ekonomičnog postupanja i štedljivosti u oblikovanju, možemo izdvojiti krug, tj. krugoliki oblik i pravilni šesterokut. Realno se pretpostavlja da je do nastanka i uvođenja kruga (kružnog oblika) u arhitekturi došlo, između ostalog, i u traganju za tehnički što ekonomičnijim graditeljskim oblikom. (23) Krug kao planimetrijski lik izražava u karakteru svoje definicije naglašenu usklađenost s bitnim određenjima pojma ekonomičnosti: 1. sve metric shape, expresses by the character of its definition obvious compliance with key features of the notion of cost-effectiveness: 1. All the points of its perimeter are at the same distance from the center; 2. Only a single dimension is required to construct it – its radius; 3. The perimeter line of a circle is shorter, compared to other regular geometrical shapes, as related to the surface it encloses.

In the language of architecture, it can be said that, compared to other forms, circular one is structurally the simplest, and most cost-effective in execution, as for the necessary amount of building material. (24) If the same circular form is elevated from ground-plan and regarded in its spatial, 3-D rotational variant – as a globe or sphere, the same advantage can be noted – favourable relation between the enclosed space and outer perimeter. (25)

Careful distribution of the ceiling mass in the form of a spherical calotte or some related form, results in an even more cost-effective architectural form - a dome or cupola. (26) This morphological development enables enclosing and covering more of the inner space, with a reduced amount of necessary building material for its realisation.

Primary cost-effectiveness becomes increasingly obvious when dome-shaped structure development is analysed, augmented by the development of new materials, to culminate recently in the definition of thrift. (27) Dome is absolutely the most effective form, as related to the minimal amount of material to get the effect of enclosing space. Dome represents one of the most consistent expressions of applying the authority of cost-effectiveness in defining an upper closing zone of the architectonic space. (28) This high degree of thrift and simplicity is, among other factors, the reason for the early implementation of a circle in architecture and its broad application in various socio-economic formations.

točke njegova oboda jednako su udaljene od središta; 2. za njegovu konstrukciju dovoljna je samo jedna veličina – njegov polumjer; 3. u usporedbi s ostalim pravilnim geometrijskim likovima, u odnosu na površinu koju zatvara, obodna linija kruga je najkraća.

Prevedeno na jezik arhitekture proizlazi da se u odnosu na ostale, kružni oblik iskazuje kao strukturalno najjednostavniji, a glede izvedbe najštedljiviji u odnosu na potrebnu količinu građe. (24) Ako taj isti kružni oblik uzdignemo iz tlorisne vodoravne ravnine i promatramo ga u njegovoj prostornoj, trodimenzionalnoj rotacijskoj varijanti – kugle ili sfere, ponavlja se navedena povoljnost odnosa zatvarajućeg prostora i vanjskog oboda. (25)

Rasporedom mase svoda u obliku sferne kalote ili njoj srodnom obliku, dobiva se još štedljiviji arhitektonski oblik od svoda – kupola. (26) Tim morfološkim napretkom omogućeno je zahvaćanje i prekrivanje još više unutarnjeg prostora uz smanjenje potrebne građe za njegovu realizaciju.

Promatrajući razvoj kupolastih oblika i usporedno tome pojavnost novih materijala, afirmacija primarne ekonomičnosti sve je intenzivnija, da bi u najnovije doba kulminirala u definiciji svoje štedljivosti. (27) Naime, kupola drži neosporni primat u odnosu na kriterij korištenja minimalne količine materijala prema dobivenom efektu zatvaranja prostora. Kupola predstavlja jedan od najdosljednijih izraza primjene autoriteta ekonomičnosti u definiranju gornje zatvarajuće zone arhitektonskog prostora. (28) Upravo u

Qualitative expression of cost-effectiveness and rational thrift, as related to the length of the enclosing perimeter and inner surface obtained thus, compared to regular plane curves, is inversely proportional to the increase of their geometrical complexity. The advantage of the curve which forms a regular circle is quite obvious intuitively as well (**Figure 6**).

Mathematic derivation of the perimeter and surface interdependence at the comparative view of circle, ellipse, square, triangle and polygon, is an exact contribution to the unambiguous proof that architectonic forms exhibiting the shape of a circle in their horizontal cross-section and ground-plan projection, have a more favourable coefficient of thrift and cost-effectiveness, when physically defined, as compared to the forms that exhibit any other shape (square, triangle, etc.) (**Figure 7**).

Regular hexagon, as well as a circle, finds their ideographic origin in the workings of Nature itself. However, while the circular form draws its full power through an independent, detached setup, a hexagon is to a high extent dependent on multiple occurrences of the same form in a plane. Only regular hexagons, equilateral triangles and squares, of all the regular polygons, cover the whole area of a plane, with no remainder. When the extent of the forms mentioned is concerned, hexagons cover the largest area as well (**Figure 8**).

Ancient Split and the Early Middle Ages

When analysing the impact of Rome at the Croatian coast we can see that *„Roman antique acted with the full force of its civilising and political mission at our geographical area, and has left significant traces of high urban culture"*. (29) Looking at Split as an antique heritage at the Adriatic eastern coast, it should be noted that it continued its life with the

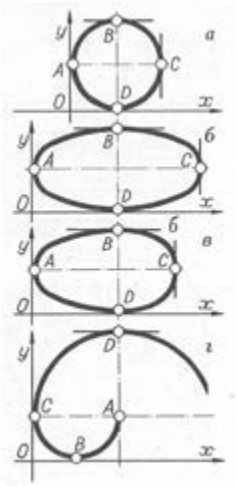
tom posjedovanju visokoga stupnja kvalitete štedljivosti i jednostavnosti, moguće je između ostalog, naći razlog ranog uvođenja kruga u arhitekturu i njegove široke primjene u najrazličitijim društveno-ekonomskim formacijama.

Kvalitativna ispoljenost ekonomičnosti i racionalne štedljivosti, glede odnosa veličine zatvarajućeg oboda i unutarnje dobivene površine, u odnosu na pravilne ravninske krivulje, obrnuto je razmjerna s narastanjem njihove geometrijske složenosti. Nadmoćnost krivulje koja tvori lik pravilnoga kruga i intuitivno je posve očita (**slika 6**).

Matematički izvod međusobne zavisnosti opsega i površine kod usporednog prikaza kruga, elipse, kvadrata, trokuta i mnogokuta, egzaktni je prilog jednoznačnom dokazu da arhitektonski oblici, koji u svojim vodoravnim presjecima i tlocrtnoj projekciji iskazuju lik kruga, imaju povoljniji koeficijent štedljivosti i ekonomičnosti kod svog fizičkog definiranja, od oblikâ koji sadrže neke druge likove (kvadrat, trokut i sl.) (**slika 7**).

Kao za kružnicu i krug tako i za pravilni šesterokut možemo zapaziti da vuku svoje ideografsko podrijetlo iz samih uradaka Prirode. No, dok kružni oblik svoju punu snagu emanira kroz samostalni postav, šesterokut je u mnogo čemu ovisan od višestruke pojavnosti tih istih likova u ravnini. Od pravilnih mnogokuta samo pravilni šesterokuti, jednakostranični trokuti i kvadrati, pokrivaju čitavu ravninu bez ostatka. U odnosu na opseg promatranih likova, šesterokuti obuhvaćaju i najveću površinu (**slika 8**).

downfall of Roman empire influence and onset of the epoch of migration of peoples. Split was spared from devastation, particularly by the Eastern Goths in the first half of the 6th century, the Avars at the beginning of the 7th century, of course, the Slavs. The fact is that most of the towns in coastal Croatia ceased to exist. However, some of them succeeded in preserving their urban identities, such as Zadar, Trogir and Kotor, while some appear as successors of demolished towns, such as Split (Aspalathos) a successor of Salona and Dubrovnik (Ragusium) as a successor of Epidaurus.



SLIKA 6. **Ravninske krivulje i odraz graditeljske štedljivosti**

FIGURE 6. ***Plane curves and reflection of thrift***

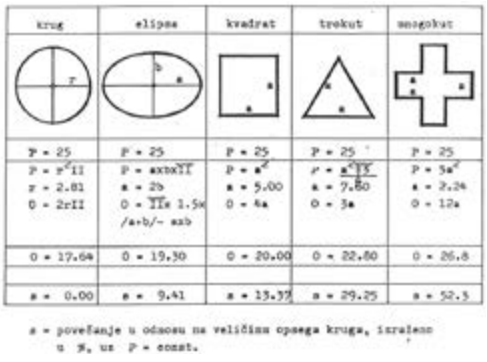
The inhabitants of antique Salona, demolishing of which meant an interruption of all life there, found shelter, as Toma archdeacon noted, at least most of them, under the protection of the walls of Diocletian's palace. Thus, the downfall of Salona and the migration of its inhabitants to Split made this town an heir of Salona's cultural and urban achievements.

Antički Split i rani srednji vijek

Analizirajući utjecaj Rima na hrvatskom priobalju uviđamo: *„na našem geografskom području rimska je antika djelovala punom silinom svoje civilizatorske i političke misije, te je ostavila značajne tragove visoke urbane kulture“.* (29) Promatrajući Split kao antičko naslijeđe na istočnoj obali Jadrana, treba naglasiti da je on padom utjecaja Rimskog carstva dalje nastavio svoj život u epohi seobe naroda, jer je bio pošteđen razaranja osobito Istočnih Gota u prvoj polovici 6. stoljeća i Avara početkom 7. stoljeća i naravno, Slavena. Naime, većina hrvatskih gradova uz more prestala je egzistirati, no neki su očuvali svoj urbani identitet poput Zadra, Trogira i Kotora kao i oni koji se javljaju kao nasljednici porušenih gradova poput Splita (Aspalathos), kao nasljednika Salone, i Dubrovnika (Raousion) kao nasljednika Epidaura.

Stanovništvo antičke Salone, čije je rušenje značilo prekid života grada, kako bilježi Toma arciđakon, sklonilo se u najvećem broju među zidine Dioklecijanove palače. Tako je padom Salone i odlaskom njezinih stanovnika u Split, taj grad postao nasljednikom njezinih kulturnih i urbanih tekovina.

O Splitu se može govoriti kao o gradu koji je baštinio urbane tradicije nekoga drugoga porušenoga grada. Split je povijesni nasljednik porušene Salone, iako ih dijeli različitost lokacijske dispozicije. Carska Dioklecijanova palača bila je i prije sporadično naseljavana, ali je padom Salone jugozapadno smješten Split (Aspalathos) u potpunosti preuzeo njezinu ulogu prema Bizantu i prema ranim hr-



SLIKA 7. **Pravilni geometrijski likovi i faktor ekonomičnosti**

FIGURE 7. ***Regular geometric figures and cost-effectiveness factor***

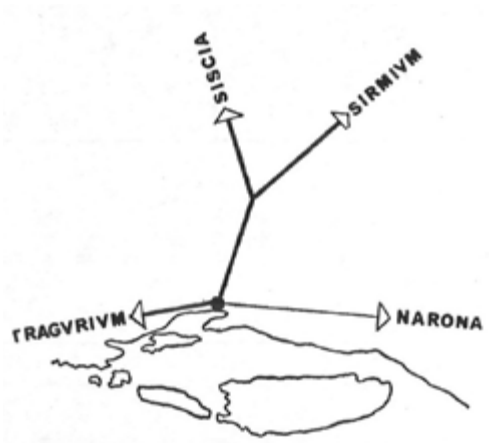
SLIKA 8. **Geometrijske sheme međusobno povezanih ravninskih likova**

FIGURE 8. ***Geometric schemes of interconnected plane figures***

Split can also be considered a town that inherited the urban traditions of another demolished town. Split is a historical successor of demolished Salona, although their locations are separated. Imperial Diocletian's palace had been inhabited sporadically. However, with the downfall of Salona, Split (Aspalathos), located in the southwest of the palace, completely took its role, in relations with Byzantium and early Croatian rulers (**Figure 9, 10**). (30) Diocletian's palace gradually later transformed from a place of refugees to a medieval urban entity.

Split was spared from numerous demolitions in the course of the turbulent migration of nations in Europe (**Figure 11, 12**). Upon the full affirmation of the Croatian people from the transition of the VI

vatskim vladarima (**slike 9, 10**). (30) Dioklecijanova se palača od prvobitnog refugija postupno kasnije transformirala u srednjovjekovno urbano središte.



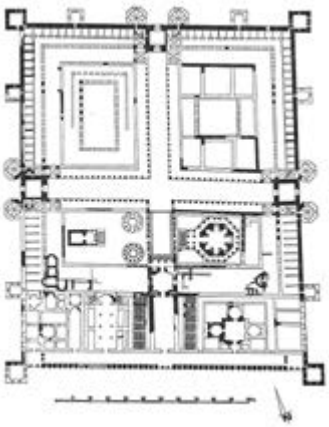
SLIKA 9. **Povezanost antičkih komunikacija Salone (30)**

*FIGURE 9. The **connection of ancient communications of Salona (Suić)***

U tijeku turbulentne seobe mnogih naroda u Europi, Split je ostao pošteđen brojnih razaranja (**slike 11, 12**). Punom afirmacijom hrvatskoga naroda na prijelazu VI. u VII. st. do prijelaza XI. u XII. st. Hrvati razvijaju vrlo intenzivnu kulturnu i umjetničku djelatnost u okviru koje se grade brojni arhitektonski objekti. U početnom su razdoblju to jednostavne građevine, a u razvijenoj fazi (IX., X. i XI. st.) grade se brojni vrijedni sakralni objeki, počevši od jednobrodnih bazilika i jednostavnih centralnih objekata pa do razvijenijih tipova trobrodnih bazilika i složenih centralnih objekata. (31)

Tu je potrebno naglasiti da snaga tradicijske konstante novonadošlih Slavena-Hr-

to the VII century until the transition of the XI to the XII century, Croats developed intensive cultural and artistic activities, including building numerous architectonic objects. In the beginning, those were



SLIKA 10. **Dioklecijanova palača u Splitu (30)**

*FIGURE 10. **Diocletian's palace in Split (Suić)***

simple buildings, while in the later, developed phase (IX, X and XI c.) a number of valuable sacral buildings, starting with single-nave basilicas and simple central objects, to sophisticated types of three-nave basilicas and complex central objects. (31)

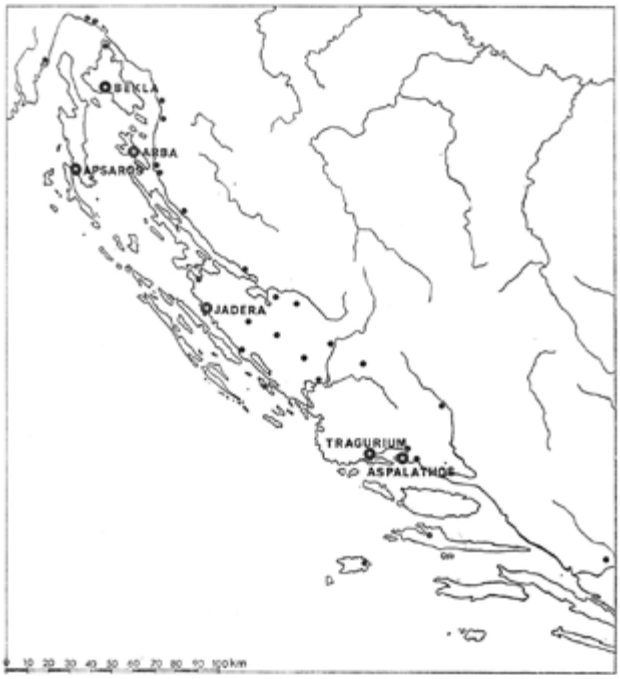
It should be noted that the power of the traditional constant of newly-arrived Slavs-Croats left a mark on the artistic expression of this early Croatian historical period, with ever-present reflections of Roman and Byzantine influence from the past times. (31)

Early Croatian Sacred Architecture and the Split Area

When analysing the buildings from the early Croatian period, it is necessary to consider cost-ef-

vata daje pečat umjetničkom izrazu toga starohrvatskoga povijesnoga razdoblja u kojem se nalazi i odraz rimskoga i bizantinskoga utjecaja iz prošlih vremena. (31)

fectiveness in light of the capacities of the time and realities of an underdeveloped, modest cultural environment and ambiental-geographical values of, conditionally speaking, isolated area (**Figure 13**).



SLIKA 11. **Karta porušenih i pošteđenih rimskih gradova od seobe naroda (Suić)**

*FIGURE 11. **Map of destroyed and spared Roman cities from the migration of peoples (Suić)***

SLIKA 12. **Dioklecijanov mauzolej u Splitu (Mohorovičić)**

*FIGURE 12. **Diokletian's mausoleum in Split (Mohorovičić)***

Starohrvatska sakralna arhitektura i područje Splita

U razmatranju zdanja iz starohrvatskoga razdoblja, potrebno je gledati ekonomičnost u svjetlu tadašnjih mogućnosti i datosti toga još nedovoljno razvijenoga, skromnoga kulturnoga miljea i ambijentalno-geografskih vrijednosti, uvjetno rečeno, jedne izolirane sredine (**slika 13).**

Building activity considerably flourished in the area of Dalmatia during the period of Croatian national rulers. *„The stage of early Croatian architecture is the territory of the early Croatian state – ninth to the eleventh century."* (32)

Defining sacral building as a material expression of their new perceiving and attitude to life in the confines of Christian doctrine, can be seen through a broad scope of various forms and geometric pat-

U vrijeme hrvatskih narodnih vladara dolazi do izrazitog bujanja graditeljske aktivnosti na području tadašnje Dalmacije. *„Pozornica starohrvatske arhitekture je teritorij stare hrvatske države, vrijeme – deveto do jedanaesto stoljeće."* (32)

Definiranje sakralnih zdanja kao materijalnog izraza njihova novog spoznavanja i gledanja na život u sklopu kršćanskoga nauka, javlja se u širokoj paleti najraznovrsnijih oblika i geometrijskih predložaka. No, unatoč toj morfološkoj različitosti, moguće je provesti relativno konciznu klasifikaciju tih zdanja u odnosu na matricu tlocrtne dispozicije.

U analizi starohrvatskih crkvica podizanih do XI. vijeka, Karaman (33) navodi da *„nisu građene u obliku pačetvorinaste bazilike na tri broda, koji je Crkva širila svojim ugledom po zapadu Europe, već često pokazuju raznovrsne tlorisne osnove – na trolist, četverolist, šesterolist, na križ i tako dalje"*. A u pogledu definiranja uspravnog volumena tih građevina, Karaman govori da su *„starohrvatske crkvice pokrivene svodovima i kupolicama, u vrijeme kada je monumentalno crkveno graditeljstvo na zapadu Europe upotrebljavalo gotovo isključivo drveni strop"*. (33)

Osim tih posebnih morfoloških značajki izgrađenih zdanja, pozornost svakog istraživača privlači skromnost u veličini – horizontalni i vertikalni gabaritni doseg starohrvatskih crkvica je krajnje suzdržan. U literaturi možemo naići na znakovit naziv za ta zdanja – „male katedrale". (32)

Starohrvatsko graditeljstvo sakralne funkcije možemo morfološki razlikovati kroz dvije dominantne grupe. Jednu bi činiterns. However, despite this morphological variety, it is possible to make a relatively concise classification of these buildings, in relation to the matrix of ground-plan disposition.

SLIKA 13. **Pogled na Split**
*FIGURE 13. **View of Split***

Karaman (33) said in the analysis of early Croatian small churches built before the XI c. that *„they were not built in the rectangular shape of a three-nave basilica, which the Church proliferated using its reputation throughout the west of Europe, but often exhibit various ground-plan bases – three-leaf, four-leaf, six-leaf, cross et cetera"*. On defining the vertical volume of these buildings, Karaman said that *„early Croatian small churches were covered with arches and small domes, at the time when monumental ecclesiastical building in western Europe used wooded ceilings almost without exception"*. (33)

Apart from these special morphological characteristics of the buildings erected, researchers' attention is drawn to the modesty of size – the horizontal and vertical size of early Croatian small churches is utterly unassuming. Literature often, quite significantly, calls them „small cathedrals". (32)

Early Croatian sacral buildings can be morphologically recognised through two dominant groups.

le bi male presvođene crkvice u modeliranju kojih preteže kružna matrica, dok bi drugu grupu oblikovale monumentalne zgrade naglašene pravolinijske ortogonalnosti. (34) Te dvije osnovne morfološke skupine u općoj tipologiji crkvene arhitekture – centralne i longitudinalne građevine – gotovo su podjednako zastupljene u predromaničkoj crkvenoj arhitekturi u Dalmaciji. (35)

Šesterokonhni ili šesterolisni oblik najizrazitiji je tip centralnih građevina ranosrednjovjekovne arhitekture Dalmacije. Karakterizira ga šesterolisni tlocrt, poznat do sada na sedam primjera u Dalmaciji, od kojih se tri nalaze na splitskom području – crkva Sv. Trojice u Splitu, crkva Sv. Marije u Trogiru i crkva Sv. Mihovila u Brnazima kod Sinja (**slike 14-16**). (35)

Sve te navedene građevine imaju zajednički šesterolisni tlocrt i središnju kupolu sa šest uokolo postavljenih konhi. Sve su gotovo istih dimenzija i izgrađene u rustikalnoj tehnici gradnje.

O tome da su racionalnost upotrijebljenoga građevnog materijala kao i opća ekonomičnost u modeliranju bili vodeći čimbenici tih prethodnih oblika gradske arhitekture, opisuje Andre Mohorovičić u traktatu *„O analizi pučke arhitekture"* kada kaže: *„Faktor lokalnog nalaza materijala, ekonomičnost i mogućnost obrade igraju u ovom slučaju glavnu ulogu kod izbora i primjene materijala. U spontano kreiranoj pučkoj arhitekturi elementi tehničke i ekonomske komponente svakako su prioritetni, dapače u početnoj fazi razvoja isključivi i odlučujući."* (36)

Morfološki predlošci starohrvatske sakralne arhitekture imaju još jednu zanimlji-

One would be small domed churches modeled predominantly by a circular matrix, while the other group would be monumental buildings with pronounced rectilinear orthogonality. (34) These two basic morphological groups in the general typology of ecclesiastical architecture – central and longitudinal buildings – are present in almost equal number in pre-Romanic ecclesiastical architecture in Dalmatia. (35)

Hexagon of six-leaf shape is a most prevalent type of central buildings in early medieval architecture in Dalmatia. It is characterised by a six-leaf ground-plan, recognised at seven different sites in Dalmatia, three of them situated at Split area – the church of Holy Trinity in Split, the church of St. Mary in Trogir and the church of St. Mihovil in Brnaze near Sinj (**Figure 14-16**). (35)

All the above buildings had a common six-leaf ground-plan and a central dome with six conches situated around it. They were of almost identical dimensions and were built employing rustic building techniques.

Andre Mohorovičić in his treatise *„On the analysis of folk architecture"* confirmed that rationality of the building material used, as well as general cost-effectiveness in modeling, were leading factors in constructing these early forms of city architecture, saying: *„The issue of locally available material, cost-effectiveness and the possibility of working the material, play in this case a major role in selecting and using the material. The elements of technical and economic components are obviously the highest priority in spontaneously created folk architecture, indeed, in the initial development phase they were exclusive and decisive."* (36)

Morphological patterns of early Croatian sacral architecture are characterised by another interesting feature – multicoloured apses or conches. The inner space of the forms analysed consists of a central

SLIKA 14. **Sv. Trojica u Splitu**
FIGURE 14. ***Holy Trinity in Split***

SLIKA 15. **Sv. Marija u Trogiru**
FIGURE 15. ***St. Mary in Trogir***

vost – višebrojne apside ili konhe. Unutarnji prostor promatranih oblika sastoji se od centralne glavne mase valjkastog prostora na koju se nadovezuje niz manjih poluvaljkastih (ili tri četvrtine valjkastih) prostora, smještenih u radijalno postavljenim konhama. Raščlamba toga jedinstvenoga prostora putem konha ili apsida jedinstveno je i specifično graditeljsko rješenje. Budući da je morao ostati očuvan fokus interesa u samom centru, što je neizbježno kod svih „introvertnih" građevina centralnog tipa (a izbjeći bilo kakvu pojavu longitudinalnog usmjeravanja prostora), rubno po kružnici postavljene pojedinačne apside organski

main cylindrical mass, to which a number of smaller semi-cylindrical (or three-quarter cylindrical) spaces are attached, located in radially situated conches. The breakdown of this unique space by means of conches or apses is a unique and completely specific building solution. As the focus of interest had to be preserved in the center itself, which is unavoidable with all „introvert" buildings of central type (while any longitudinal directing of the space has to be avoided), on the perimeter of the circle individual apses are situated, which organically „flourish" from the central mass of space, with no need for interspace or unnecessary physical partitions. (37)

These are rather modest architectonic assemblies, when the number of spatial elements is con-

„bujaju“ iz te centralne mase prostora, bez iziskivanja ikakvih međuprostora ili nepotrebnih fizičkih pregrada. (37)

SLIKA 16. **Sv. Mihovil u Brnazima kod Sinja**

FIGURE 16. ***St. Mihovil in Brnaze near Sinj***

Prema broju upotrijebljenih prostornih elemenata, to su skromni arhitektonski sklopovi, koji s minimalnim brojem elemenata uspješno konstituiraju prostorno vrijedan i nadasve originalan arhitektonski oblik. (32)

Jedna od prevladavajućih vanjskih vizualnih karakterisika tih zdanja njihova je izrazito mala veličina, s obzirom da je promjer središnjeg prostora iznosio prosječno šest metara, a promjer čitavog objekta kao i njegova visina oko deset metara.

Šesterokonhni oblik te ranosrednjovjekovne hrvatske arhitekture nalazimo i izvan Dalmacije, a unutar njezina opsega Split je pored Zadra bio drugo važno žarište te arhitekture (**slika 17**).

Geometrijsko-eksperimentalna analiza tlorisa splitskih šesterolista u odnosu na čimbenik ekonomičnosti

Već sâm alternativni naziv šesterolist za šesterokonhi vijenac apsida, ukazuje da je

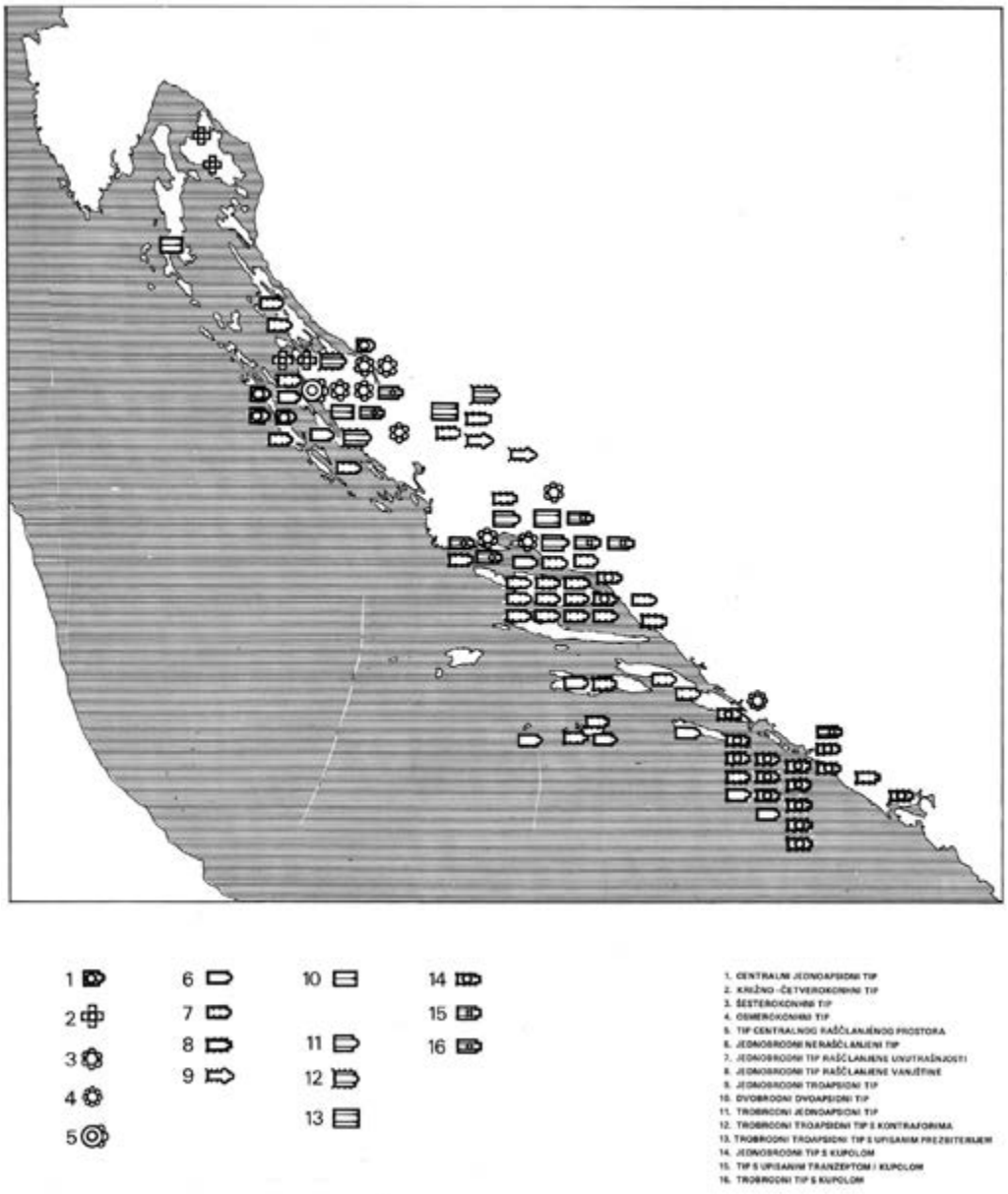
sidered, as they successfully design spatially valuable and primarily original architectonic forms, with a minimum number of elements. (32)

One of the outstanding outer visual characteristics of these buildings is their pronounced small size, as the diameter of the central space is six meters on average, while the diameter of the whole object, as well as its height, amounts to ten meters.

The hexaconch shape of this early medieval Croatian architecture can also be found in Dalmatia, while in Dalmatia Split is, together with Zadar, an important hotspot of this architecture (**Figure 17**).

Geometric-experimental analysis of the ground-plan for the Split „six-leaf “ in relation to the cost-effectiveness factor

The alternative name „six-leaf “ for the hexaconch crown of apses itself indicates that the phytomorphic component is clearly expressed and almost intuitively recognised. According to the grand division of rectilinear, rectangular and curved, circle-like forms, where the first are attributed to man's creativity and second to organic Nature, artistic compatibility of early Croatian hexaconch small churches with natural forms, particularly of the plant-phytomorphic circle. An experiment with the aim to prove the presence of the principle of cost-effectiveness and the trend of rational thrift will be organised with the aid of a geometrical scheme of ideal circle and interconnected regular hexagons, as a matrix the basis of which is mathematically provable cost-effectiveness within the domain of Nature. As these artistic patterns can be found outside of human construction, it is correct to call them their precedents. This is particularly so as circular and circle-like shapes can be found in plant structures, in shells, in the construc-



SLIKA 17. **Rasprostranjenost osnovnih tipova ranosrednjovjekovnih crkvica u Dalmaciji (T. Marasović)**

FIGURE 17. ***Distribution of basic types of early medieval churches in Dalmatia (T. Marasović)***

tu fitomorfna komponenta jasno izražena i gotovo intuitivno prepoznata. Prema velikoj podjeli na pravolinijske, pravokutne i zavojite, krugolike oblike, od kojih prve pripisujemo ljudskom stvaralaštvu a druge organskoj Prirodi, ističe se likovna kompatibilnost starohrvatskih šesterokonhnih crkvica s oblicima prirode, osobito vegetabilno-fitomorfnoga kruga. Eksperiment u svrhu dokazivanja prisutnosti načela ekonomičnosti i tendencije racionalne štedljivosti, izvršiti će se uz pomoć geometrijske sheme idealnog kruga i međusobno povezanih pravilnih šesterokuta, kao matrica koje su nositelji matematički dokazive ekonomičnosti unutar domene prirode. Kako te likovne obrasce nalazimo izvan ljudskoga graditeljstva, opravdano ih je smatrati njihovim presedanima. Osobito zato što kružne i krugolike oblike nalazimo u građi biljaka, školjaka, ptičjih gnijezda i slično, a matricu šesterokuta kod prostorne rešetke radiolaria i u jednom od najfascinantnijih uradaka u Prirodi – u građi sača pčela. (3)

Krug je u pogledu zahvaćanja unutrašnje površine u odnosu na vanjski obod vodeća figura u građi bilo kakvog oblika, jer iziskuje najmanje građe za svoje zatvaranje, a međusobno poredani šesterokuti jedini su od svih ostalih pravilnih geometrijskih likova koji popunjavaju ravninu bez ikakva ostatka balastnog prostora. (38)

A) Matrica kružnih oblika

Promatrajući crkvicu Sv. Marije u Trogiru, uviđamo da u dispoziciji tlocrta obris kružnice nije iskazan u strogo pravilnom

tion of bird's nests and the like, while the hexagon matrix can be found in the spatial grid of radiolaria and in one of the most fascinating workpieces of Nature – in the structure of honeycomb. (3)

The circle is, regarding the ratio of covering the inner area and the length of the outer parameter, the best figure in constructing any shape, as it asks for the least amount of building material to be enclosed, while interconnected hexagons are the only ones, among all the other regular geometric figures, that fill-in the plane with no residual ballast space. (38)

A) Circular matrix

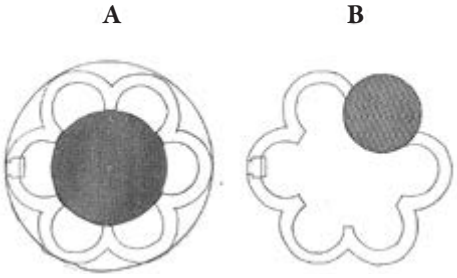
If we analyse the church of St Mary in Trogir, we can see that in its ground-plan disposition the shape of the circle is not geometrically strictly regular. However, the circle is clearly outlined in its essence. It can be seen in the shape of circular inner space (A), as well as in the shape of semi-circular, on the inner side three-quarter circular conches or leaves (B), **Figure 18**. The reflection of a circle can also be seen in a geometric image of the intersection of the central space circle and circles belonging to circumferential spaces of conches (**Figure 19**).

The existence of symmetry and rhythm in these circle-like compositions leads to the indirect conclusion that the trend to cost-effectiveness is strongly pronounced in their composition. Regardless of the fact that in designing early Croatian churches of this group in the Split area there is no strict, geometrically regular pattern in execution, symmetric division in ground-plan disposition is indisputable and is expressed as poly-symmetry. Six radial axes can be distinguished in total, theoretically dividing the space into two parts of equal area surface. Two groups of axes are clearly distinguishable. In one, the axes pass through apse vertexes and central focus point (A) and in the other axes also pass

geometrijskom izrazu. Međutim, kružnica, odnosno krug, je u njegovoj biti izrazito izražena. To se očituje u obliku kružnoga središnjeg prostora (A), i u obliku polukružnih, iznutra 3/4-kružnih konha ili listova (B) (**slika 18**). Odraz kruga nalazimo i u geometrijskoj slici zone međusobnog presijecanja kruga centralnog prostora i krugova obodnih prostora konhi (**slika 19**).

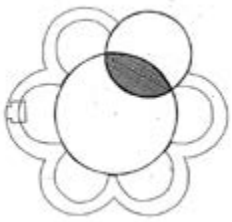
through the centre of the composition, but through the points of apses, the side touches the center line as well (B), dividing the ground-plan mass sparingly into two parts (**Figure 20**).

As an outer component of the ground-plan, rhythm is, regardless of often underlined irregularities in the size of circularly situated apses, also in principle clearly expressed in small Split churches – through the interchange of the same area units, as well as in mutual distance of their sequences. The



SLIKA 18. **Grafička analiza tlocrta Sv. Marije u Trogiru, prema dominantnoj matrici kruga (autor)**

FIGURE 18. ***Graphic analysis of the floor plan of St. Mary in Trogir, according to the dominant circle matrix (author)***



SLIKA 19. **Grafička analiza tlocrta Sv. Marije u Trogiru, prema interferenciji kruga centralnog prostora i kruga konhe (autor)**

FIGURE 19. ***Graphic analysis of the floor plan of St. Mary in Trogir, according to the interference of the central space circle and the conches circle (author)***

Postojanje simetrije i ritma u tim krugolikim kompozicijama navodi nas na posredni zaključak da je u njihovom komponiranju težnja ka emonomičnosti izrazito zastupljena. Bez obzira što pri oblikovanju starohrvatskih crkvica te grupe promatranih primjera na splitskom području nema strogoga, geometrijski pravilnog uzorka u izvedbi, simetrična podjela u tlocrtnoj dispoziciji nesporna je i javlja se u vidu poli-simetrije. Pritom se može razli-

aps crowns of the churches in question are developed in the interspace of two concentric circles (A). Although there is, even here, certain irregularity in executing their radii, we can conclude that the distance between conche vertexes – S is equal to the outer radius – R (B), and also that rhythm is generally quite clearly pronounced in the form of the corpus, as a phenomenon of juxtaposition of approximately identical apse surfaces (C and D) (**Figure 21**).

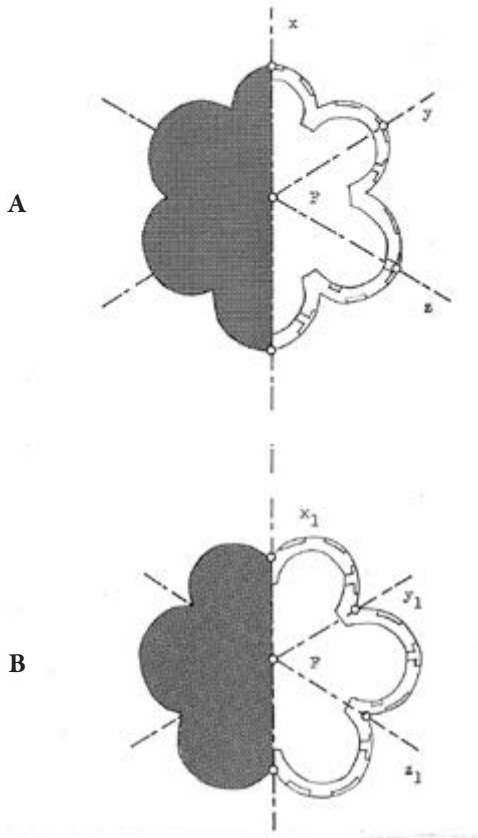
The above analyses of cost-effective work reveal another fascinating solution – basic precedents

kovati ukupno šest radijalnih osi, koje tlocrt teorijski dijele na dva površinski jednaka dijela. Mogu se posve jasno razlikovati dvije grupe osi. Jednu, gdje osi prolaze tjemenima apsida i centralnom fokusnom točkom (A) i drugu, gdje osi također prolaze kroz središte kompozicije, ali i točkama simetrala bočnoga dodira apsida (B), dijeleći tako štedljivo tlocrtnu masu na dva dijela (**slika 20**).

Kao vanjska komponenta tlocrta, bez obzira na često naglašavanje nepravilnosti u veličini kružno postavljenih apsida, ritam se također principijelno jasno iskazuje kod splitskih crkvica – u izmjeni realno istih površinskih jedinica, i u njihovom međusobnom razmaku nizanja. Vijenac apsida promatranih crkvica razvija se u međuprostoru dva koncentrična kruga (A). Premda i tu postoji određena nepravilnost u izvedbi njihovih polumjera, moguće je zaključiti da je razmak između tjemena konhi – S, jednak vanjskom polumjeru – R (B), i da je u obliku korpusa principijelno veoma jasno izražen ritam, kao fenomen nizanja približno identičnih površina apsida (C i D) (**slika 21**).

U navedenim analizama ekonomičnog postupanja nalazimo još jedno fascinantno rješenje – principijelne presedane koje nalazimo u samoj prirodi i to u građi samoga čovjeka. Naime, morfologija ljudskoga mozga, osobito njegova vanjska ovojnica je „smežurana" pa stoga ima znatno povećanu površinu bez negativnog utjecaja na neželjeno povećanje volumena. Analognu matricu ekonomičnosti nalazimo kod starohrvatskih crkvica splitskoga područja, kao i svih ostalih

found in Nature and in the constitution of human body itself. As human brain morphology shows, it is, and especially the meninges, „wrinkled", which significantly increases its surface with no detri-



SLIKA 20. **Grafička analiza simetričnosti tlocrta crkvice Sv. Trojice u Splitu (autor)**

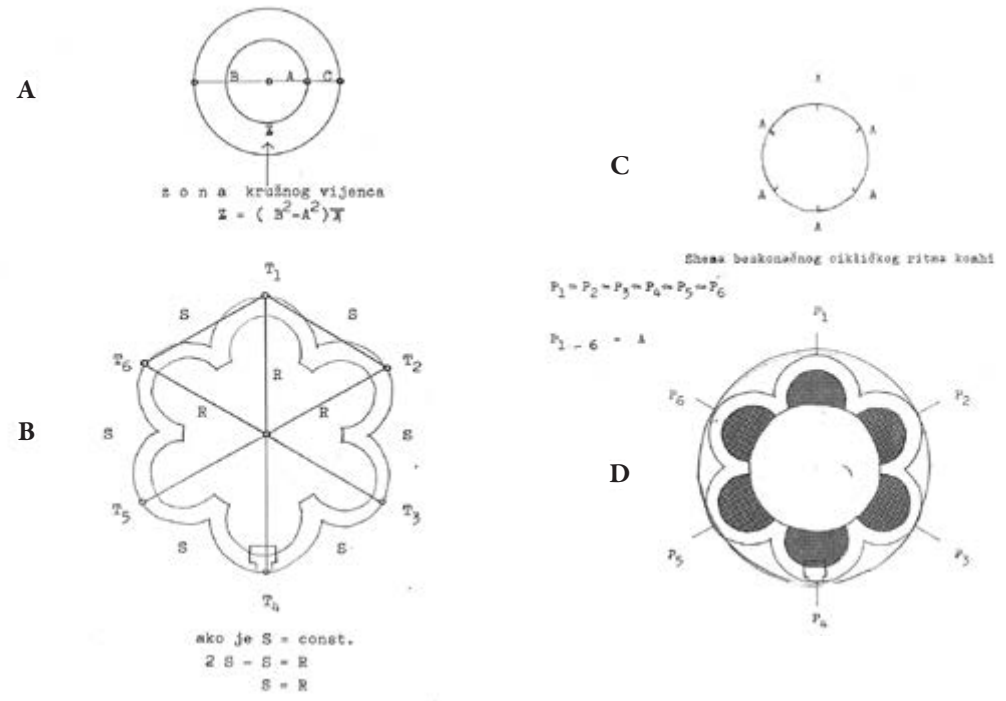
FIGURE 20. ***Graphical analysis of the symmetry of the ground-plan of the church of Holy Trinity in Split (author)***

mental impact on the uncalled-for increase in volume. A similar matrix of cost-effectiveness could be found with early Croatian churches in the Split region, as well as with all the others of molticonche

višekonhnog tipa. Naime, geometrija kao egzaktna disciplina jasno tumači da se površina jedne obodne plohe znatno povećava, ako se ta ploha mjestimice izboči ili udubi. S druge strane, površina ili prostor koji tako „deformirana" ploha obujmljuje, ne podliježe tom povećanju, jer unatoč nizu promjena na njegovom obodu, prostor zadržava približno prvobitnu veličinu.

type. Geometry, as an exact discipline, clearly says that the surface of one circumferential plane increases significantly if the plane is locally bulged or dented. On the other hand, the surface or space that such a „warped" plane encompasses, does not increase at the same time, as despite a number of changes in the circumference, the space retains approximately its original value.

The ground-plan of St. Mary church in Trogir (A), as well as the ground-plan of a hypotheti-



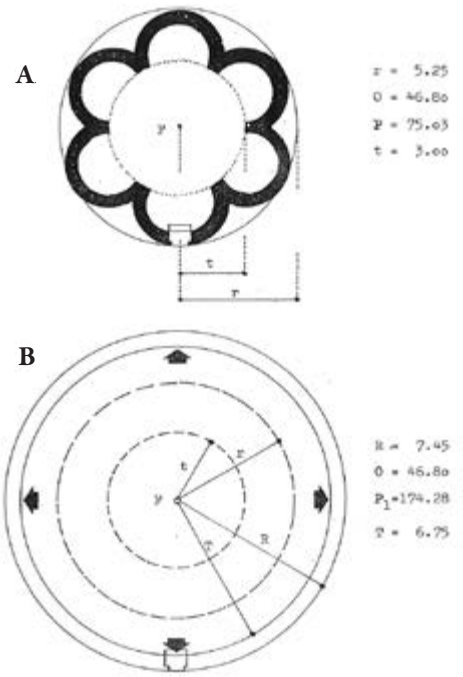
SLIKA 21. **Grafička analiza ritma u tlocrtu crkvice Sv. Marije u Trogiru (autor)**
FIGURE 21. ***Graphic analysis of the rhythm in the ground-plan of the church St. Mary in Trogir (author)***

Tlocrt crkve Sv. Marije u Trogiru (A) i tlocrt hipotetskog modela (B), s opsegom koji odgovara razvijenoj površini apsida crkvice (ukupni opseg građevine),

cal model (B), with the circumference of the developed surface of church apses (total building circumference), prove mathematically the principle of cost-effectiveness. Namely, for the same cir-

matematički potvrđuju načela ekonomičnosti. Naime, za jednaki O (opseg), hipotetski model imao bi više nego dvostruko veću tlocrtnu površinu (232%), a unutarnji polumjer tambura kupole također bi se značajno povećao (225%) (**slika 22**).

U nizu pojedinačnih analiza pojave načela ekonomičnosti kroz primijenjeni oblik kruga, kod starohrvatskih crkvica centralnoga šesterolisnog tipa, nezaobilazno je i oblikovanje njihovih konhi ili apsida. Povijest arhitektonskih oblika poznaje pojam apsida kao arhitektonske forme još iz antičkog doba kao polukružni završetak onovremenih bazilika, da bi od IV. stoljeća u kršćanskim crkvama bile preuzete kao bitni sastavni element njihova prostora. (39) Prema svojoj geometrijskoj shemi, apside se u kasnijim razdobljima javljaju u obliku kružnih segmenata, kvadrata i pravilnih poligona. (39)



SLIKA 22. **Grafička analiza vanjskoga zatvarajućeg plašta Sv. Marije u Trogiru (A) i pripadajućega hipotetskoga modela razvijenih konhi (B) (autor)**

FIGURE 22. ***Graphic analysis of the outer cloak of St. Mary in Trogir (A) and the associated hypothetical model of the developed conches (B) (author)***

cumference, the hypothetical model would have more than the double ground-plan surface (232 %), while the inner radius of the dome would also be significantly increased (225 %) (**Figure 22**).

Within the series of individual analyses of the cost-effectiveness principle through the applied circular shape, the analyses of early Croatian churches of central, six-leaf type, unavoidably point at the design of their conches or apses. The history of architectonic forms recognised the term apse as an architectonic form as early as antique times, defining it as semi-circular termination of basilicas at that time. Apses have been taken by Christian churches since the IVc., as a key constituent element of their space. (39) Apses later appear, according to their geometrical scheme, in the form of circular segments, squares and regular polygons. (39)

The analysis of their comparative values, as related to cost-effectiveness and rationality of their physical definition, compared to the apses of the analysed six-leaf buildings in Split, indicates that, with the same *P* (inner enclosed surface) the perimeter, or circumference, of the outer apses shell, designed *in the form of a polygon,* especially with

Analiza njihovih usporedivih vrijednosti glede ekonomičnosti i racionalnosti njihove fizičke definicije, u odnosu na apside promatranih šesterolatičnih splitskih zdanja, pokazuje da je uz isti P (unutarnja zatvarajuća površina) opseg vanjskih ovojnica apsida oblikovanih *u vidu poligona*, osobito kvadratne matrice, redovito nepovoljniji od opsega koji u tlocrtu konhi iskazuju lik kruga, tj. kružnice (**slika 23**).

B) Matrica pravilnih šesterokuta

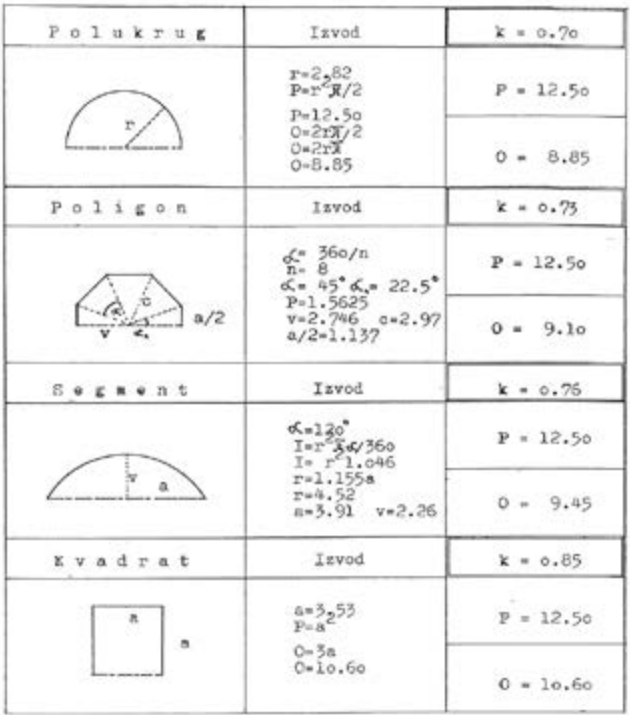
U kompoziciji starohrvatskih crkvica središnjega šesterolisnog tipa uočava se jedan posebno kompleksni prostorno-arhitektonski problem, koji proizlazi iz međusobnoga povezivanja prostora s kružnom matricom, a predstavlja nesumnjivu specifičnost jer se krugovi kao likovi ne mogu međusobno povezati bez ostatka međuprostora (koji se u ovom primjeru nije smio iskazati, jer bi nepovratno narušio koncepciju jednoprostornosti građevine).

U pokušaju otkrivanja ekomoničnosti postojećega rasporeda koji obiluje krugolikim oblicima, u geometrijsku je analizu uvedena, kao pomoćno ispitno sredstvo, matrica međusobno povezanih pravilnih šesterokuta, kao teorijski najuspjeliji uzorak u rješavanju problema ekonomičnog pokrivanja zadanog dijela ravnine.

square matrix, almost always less favourable than the circumference when the conches ground-plan is circular, or in the form of a circle (**Figure 23**).

B) Matrix consisting of regular hexagons

The composition of early Croatian small churches of central six-leaf type exhibits a particular complex spatial-architectonic problem, arising from the interconnection of spaces with a circular matrix. It is quite specific since circles as shapes cannot be connected to each other with no residual interspace (which was not supposed to be exhibited as it would irretrievably ruin the concept of a single-space building).

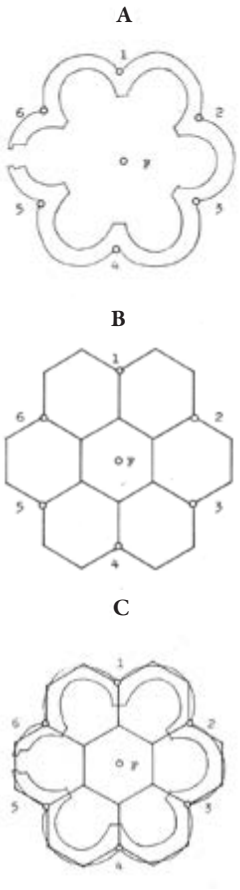


SLIKA 23. **Komparativni prikaz oblika konhi u odnosu na povečanje njihova opsega, uz P = konstantno (autor)**

FIGURE 23. ***Comparative representation of conch shapes with respect to increasing their circumference, with P = constant (author)***

Matematičko-geometrijskim eksperimentom prekrivanja tlocrtne dispozicije starohrvatske šesterolisne crkvice (A) mrežom međusobno povezanih pravilnih šesterokuta (B), dobiven je vrijedni nalaz (C) iz kojeg se jasno očituje da je međusobno povezivanje središnje mase promatranog zdanja s vijencem njegovih polukružnih apsida (apsidiola, konhi), konstrukcijski veoma blisko najracionalnijoj matrici povezivanja istovrsnih ravninskih likova u zadani oblik (**slika 24**).

Kako je ta matrica međusobno povezanih pravilnih šesterokuta u svom najvećem dijelu manifestacija djelovanja načela štednje u njenoj morfogenezi, u pogledu najštedljivijeg omjera upotrijebljenog materijala za njeno definiranje, dobiveni nalaz trebao bi predstavljati pouzdanu potvrdu da i u morfogenezi promatrane građevine načelo štednje i ekonomičnosti ima značajnu ulogu.



SLIKA 24. **Tlocrt crkvice Sv. Marije u Trogiru i mreža pravilnih šesterokuta (autor)**

FIGURE 24. ***Ground plan of the church Sv. Maria in Trogir and a network of regular hexagons (author)***

Zaključak

Provedene pojedinačne analize u ovom radu, gdje su teze o postojanju načela ekonomičnosti u morfogenezi starohrvatskih crkvica središnjega šesterolisnog tipa na području Splita, potkrijepljene matematičko-geometrijskim eksperimentima kojima su bili podvrgnuti ti oblici, dobiveni su ovi zaključci:

1. Štedljivi registar likovnih elemenata

U svjetlu činjenice da svako kvalitetno arhitektonsko djelo putem svojega vanjskoga morfološkog izraza jasno odraža-

Trying to discover the cost-effectiveness of the actual distribution, abounding in circle-like shapes, we have introduced in our geometrical analysis, as an auxiliary testing tool, the matrix of interconnected regular hexagons, as a theoretically the most successful example in solving the problem of cost-effective covering of a particular part of a plane.

va ciljeve i ambicije svojih graditelja i profil tadašnjeg društva, razvidno je da se ta umjetnička „poruka" može različito definirati primjenom isto tako različitog registra likovnih elemenata.

Nastojanje da se osigura jedan kontemplativni, posvećeni prostor, neometan dinamikom svakodnevnog života, koji će potpuno zadovoljavati potrebe onovremenog čovjeka za njegovom duhovnom dimenzijom, jasno i nedvosmisleno izražava sam taj oblik arhitektonskog djela.

Kod splitskih šesterolisnih crkvica raspoznaje se prisutnost čimbenika ekonomičnosti i racionalne štedljivosti u jednoj izrazito specifičnoj ulozi. Naime, upravo suprotno od načina da se s mnoštvom različitih likovno-arhitektonskih znakova iskaže taj segment arhitektonske vrijednosti djela, ovdje je upravo štedljivo raspolaganje elementima arhitektonskih oblika pridonijelo većoj jasnoći izražavanja te metaforičke dimenzije djela.

Morfološka matrica fokusirana je isključivo na lik kruga i kružnice, kojom se kreira tlocrtna dispozicija i vertikalni gabarit djela.

2. Ekonomičnost u odabiru i uporabi materijala

Lako je uočljivo da su zidna platna promatranih zdanja prostorno definirana kao krute, kompaktne površinske mase, izgrađene od nepravilnih komada lomljenog kamena. Općenito uzevši, u razmatranju razdoblja starohrvatske sakralne arhitektonske umjetnosti nailazimo na tu pojavu „endemske" isključivosti u uporabi građevnog materijala. Stari su Hrvati „gradili

Mathematical-geometric experiment that included covering a ground-plan disposition of an early Croatian six-leaf church (A) by a network of interconnected regular hexagons (B), resulted in a valuable find (C), which clearly indicated that the interconnection of the central mass observed with the circle of its semi-circular apses (apsidioles, conches), was structurally quite close to the most rational matrix of connecting plane figures of the same type in a given shape (**Figure 24**).

Since the matrix of interconnected regular hexagons is mostly a manifestation of the workings of the principle of cost-effectiveness in its morphogenesis, as to the most economical ratio of the material used to define it, the result obtained should represent a reliable proof that the principle of thrift and cost-effectiveness play a major role even in morphogenesis of the building in question.

Conclusions

Individual analyses done within the scope of this study, where the thesis of the presence of the cost-effectiveness principle in the morphogenesis of early Croatian small churches of central, six-leaf type in the region of Split, supported by mathematical-geometric experiments performed on the given forms, resulted in the following conclusions:

1. Thrifty register of artistic elements

Having in mind the fact that every high-quality architectonic work, through its outer morphological expression, clearly reflects the goals and ambitions of the builder and the profile of the society of the time, it is quite obvious that this artistic „message"can be differently defined when applying a different register of artistic elements.

The ambition to provide a contemplative, consecrated space, undisturbed by everyday life dynamics, such that would completely satisfy the

od prvog početka svoje crkve od kamena. Oni su to činili u vrijeme, kada su ostali slavenski narodi, još dizali svoje prve bogomolje u drvu, koje se lako troši i propada". (33) Kako prirodne datosti okoliša bogata kamenim materijalom, a oskudna drvetom, to priklanjanje lako dostupnoj građi nepobitni je dokaz o ekonomičnom promišljanju i postupanju onovremenih graditelja.

3. Statičko jedinstvo jezgre i obodnih konhi

U istraživanju nosivog dijela korpusa koji bi u vidu konstrukcije prenosio sva javljena unutarnja i vanjska opterećenja tih građevina, dolazimo do nalaza, a on nije izdvojen u vidu posebnog elementa, već je sadržan u samoj definiciji korpusnog plašta, kojem se osim osnovne funkcije zatvaranja unutarnjeg prostora, dodaju i funkcije pune statičke stabilnosti izgrađenog korpusa i potpornja nadvišenoga valjkastog tambura i kupole. Tu je složen arhitektonsko-statički program riješen s minimumom upotrijebljenih graditeljskih sredstava.

4. Posredni dokazi o štedljivosti u oblikovanju

O postojanju snažnoga latentnoga momenta ekonomičnosti u općoj konstituciji i oblikovnom sređivanju graditeljskih oblika starohrvatskih predromaničkih crkvica, jasno potvrđuju upravo neka novija istraživanja, koja su za svoju glavnu analizu imala posve drugačiju temu. (40) Ispitivanjem morfogeneze tih sakralnih zdanja s funkcionalnom tezom o apsolutnom autoritetu kozmičkih sila i doga-

needs of contemporary man for his spiritual dimension, clearly and unambiguously is reflected by the form of the piece of architecture studied.

The factors of cost-effectiveness and thrift with Split six-leaf small churches are recognised in a particular and quite specific role. Contrary to the idea that a multitude of various artistic-architectonic signs could present this segment of architectonic value, in the case of these churches thrifty use of the architectonic form elements contributed to better clarity of expression and better presented metaphoric dimensions of these pieces of architecture.

The morphological matrix is focused exclusively on the circular shape and form, using them to create the ground-plan disposition, as well as the vertical size of the building.

2. Cost-efficiency in the selection and use of the material

It is easy to note that wall canvases in the objects observed are spatially defined as stiff, compact surface masses, made of irregular pieces of broken stone. Generally, this phenomenon of „endemic" exclusiveness in using building materials can be seen when the period of early Croatian sacral architectonic art is observed. Early Croats „used stone in building their churches from the very beginning. They did it at the time when other Slavic peoples used wood, which is easily spent and deteriorates, to build their temples". (33) As the natural environment was rich in stone material, and lacked wood, this inclination to use easily available building material is an obvious proof of cost-efficient deliberation and action of the builders at the time.

3. Static unity of the core and circumferential conches

Investigation of the bearing corpus, which through construction transfers all inner and outer loads, leads to the conclusion that it is not detached

đanja pri ustrojstvu njihova oblikovnog sklopa (iako bez nekog šireg dokaznog analitičkog postupka), jasno se zastupa teza o štedljivoj uporabi i ekonomičnom korištenju oblika. Naime, pretpostavlja se da postojeći oblici u graditeljskoj kompoziciji nisu bili raspoređivani isključivo putem nekoga prevladavajućeg formalističko-apstraktnog reda, već je tu bio snažno izražen cilj da se s „minimumom sredstava ostvari opsežan graditeljski program". (40)

Jasno je da takve sekundarne analize doprinose rasvjetljavanju uloge načela ekonomičnosti kod promatranih crkvica starohrvatske arhitektonske baštine.

Stoga se može zaključiti da su eksperimenti izvedeni na tlocrtnim dispozicijama starohrvatskih arhitektonskih šesterolista na području Splita, potvrdili da je isto prirodno načelo ekonomičnoga grupiranja više istovrsnih manjih prostora u zajedničku cjelinu, preslikano u tim arhitektonskim zdanjima. Te starohrvatske crkvice izrastaju kao djela značajno usklađena s datostima svoga povijesnog vremena i općih prirodnih zakonitosti pripadajućeg prostora.

Upravo se kod šesterolatičnih tipova crkvica, kroz vanjsku oblikovnu manifestaciju aktivnog djelovanja načela ekonomičnosti u sveukupnom ustrojstvu tih djela, jasno iskazuje genij hrvatskoga predromaničkoga stvaralaštva, gdje je taj organski racionalizam nastao primarno iz nužde za egzistencijalnim opstankom u tim prostorima dugi niz godina, da bi kasnije izrastao u najvišu estetsko-likovnu vrijednost tih djela.

as a separate element but is contained in the definition of the corpus mantle itself, which apart from the basic function of enclosing the inner space, also performs the function of full static stability of the outer tambour and dome. This complex architectonic-static problem has been solved using the minimum amount of building material.

4. Indirect proofs of thrift in designing

Some recent investigations that were concerned with completely different topics (40) clearly confirmed the thesis that there was a strong latent moment of cost-effectiveness in the general construction of early Croatian pre-Romanic small churches. Investigations of morphogenesis of these sacral objects, with the functional thesis of the absolute authority of cosmic forces and phenomena in creating their design assembly (although with no broader analytical procedure to prove it), clearly supported the thesis on thrifty and cost-effective use of the forms. It is reasonable to suppose that the existing forms in building composition were not distributed only by some prevailing formalistic-abstract order, but also by a strongly pronounced will of „using minimum resources to realise a comprehensive building program". (40)

These secondary analyses obviously contribute to clarifying the role of the principle of cost-effectiveness in the churches observed that represent early Croatian architectonic heritage.

It can be seen that the experiments performed on ground-plan dispositions of early Croatian architectonic six-leaves in the Split region confirmed that the same natural principle of a cost-effective grouping of a number of identical small spaces into a joint unit, was copied in these architectural objects. These early Croatian small churches have grown as pieces of architecture considerably harmonised with the realities of its historic period and the general natural laws of the region in question.

Razvidno je kako je upravo načelo ekonomičnosti i opće graditeljske štedljivosti kod promatranih starohrvatskih crkvica središnjega šesterolisnog tipa na splitskom području, značajno pridonio punoj spontanosti izražavanja svih onih unutarnjih težnji i vjerovanja čovjeka onoga vremena, putem odabranih oblika, kao i da se to „značenje" prenese kroz tako daleku vremensku distancu u svom prvobitnom, iskrenom i neizmijenjenom obliku.

It is exactly the six-leaf church type that, by its outer design including the active impact of the cost-effectiveness principle in its overall structure, clearly exposes the genius of Croatian pre-Romanic creation, where this organic rationalism was born primarily through a necessity for the existential survival in the region for a long period of time, to grow only later into the highest aesthetic-artistic value of these objects.

It is obvious that the principle of cost-effectiveness and general building thrift in the early Croatian small churches of the central six-leaf type observed contributed significantly to the full spontaneity of expressing all the inner aspirations and beliefs of the man at that time, through selected forms, as well as to the success in transferring this „meaning" through such a long period of time in its primary, earnest and unchanged form.

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