

## **RAZVOJ BETONA KROZ POVIJEST**

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*Pregledni članak*

### ***Sažetak***

*Beton kao trajni građevinski materijal najčešće je u uporabi u graditeljstvu kod izgradnje gotovo svih vrsta građevina u niskogradnji i visokogradnji. U samim začetcima njegovog korištenja kao slobodan materijal već je omogućavao stvarati nove oblike. Kroz njegovu povijest razvoja, sve se više težilo usavršavanju tehnologije spravljanja, iznalaženje novih vrsta, boljih karakteristika kao i uklanjanju nedostataka betona, kako bi zauzeo vodeće mjesto pri odabiru materijala za gradnju. Prema statističkim podacima u Europi godišnje se proizvede preko 750 milijuna kubičnih metara betona dok svjetska proizvodnja premašuje šest milijardi kubičnih metara.*

***Ključne riječi:*** beton, materijal, povijest, građevine

## **DEVELOPMENT OF CONCRETE THROUGHOUT HISTORY**

### ***Summary***

*Concrete as a durable building material is most often used in construction in the construction of almost all types of buildings in low-rise and high-rise construction. In the very beginnings of its use as a free material, it already made it possible to create new forms. Throughout its history of development, there was an increasing effort to improve the technology of making, finding new types, better characteristics as well as removing the defects of concrete, in order to take a leading position in the selection of materials for construction. According to statistical data, over 750 million cubic meters of concrete are produced annually in Europe, while world production exceeds six billion cubic meters.*

***Keywords:*** concrete, material, history, buildings

## 1 UVOD

Beton je po svojim fizikalnim, mehaničkim i estetskim svojstvima u očvrslom stanju sličan stijeni, odnosno kamenu. Stoga možemo reći da on nije ništa drugo, nego jednostavno i jeftino proizveden umjetni kamen. Najčešća formulacija za beton je da je to mnogokomponentni, poludisperzni, umjetni kameni građevinski materijal, sastavljen od tvrdog poznatog kao krupnog agregata, međusobno vezanih cementnim kamenom, nastalim hidratacijom i očvršćivanjem cementa kao veziva. Zapreminski gledano 70 - 80% zapremine betona čini agregat, koji se dobiva iz prirode jednostavno iskopom šljunka i pijeska ili drobljenjem stijene, što ga čini jeftinim. Osim tih obaveznih komponenti u sastav betona mogu ulaziti i dodaci (aditivi) koji mu daju posebna svojstva (zaptivači, aeranti, plastifikatori, regulatori vezivanja, sredstva protiv mraza...). Tijekom procesa očvršćivanja beton razvija određena svojstva od kojih su najbitnija tlačna i vlačna čvrstoća, veoma mala propusnost vode te kemijska i volumenska stabilnost. (Begović, D. i Štirmer, N. (2015): Teorija i tehnologija betona, Građevinski fakultet, Zagreb)

## 2 RAZDOBLJE PRIJE NOVE ERE

Obično se susrećemo sa tezom da je beton nastao u IX stoljeću. Međutim arheološka istraživanja pokazuju da je bio u primjeni još u Rimskom carstvu, pa čak i nekim civilizacijama kamenog doba.

Povijest betona seže do najmanje 6500. godine prije nove ere, kada je Nabatea od onoga što sada poznajemo kao Siriju i Jordan upotrijebio preteču suvremenog betona za izgradnju struktura koje preživljavaju sve do danas. Pretpostavlja se da je Nabateu izumio rani oblik hidrauličkog betona koji se otvrdnjava kada

je izložen vlazi korištenjem vapna. Tako su izgradili betonske podove, stambene strukture i podzemne cisterne.



Slika 1. Al-Khazneh (riznica), Petra<sup>55</sup>



Slika 2. Renesansna grobnica, Petra<sup>56</sup>

Uporabu betona susrećemo i od 3000 godina prije nove ere gdje su Egipćani koristili blato pomiješano sa slamom kako bi povezali osušene cigle. U ovom razdoblju proizvodnju betona susrećemo i kod Azijata, Hebreja i Egipćana, te dalje kod starih Grka i Rimljana.

Proučavanjem sačuvanih građevina i njenih ostataka kao i pisanih dokumenata posebice rimskog graditelja Vitruvija koji je pisao u I stoljeću prije nove ere „De Architectura“ opisuje beton kao umjetni kamen koji su Rimljani proizvodili i koristili pod nazivom „opus signium“. Prvi pravi beton sličan današnjem susrećemo kod starih Rimljana koji su oko 300. godina prije nove ere koristeći za vezivno sredstvo pucolanski

<sup>55</sup> Internet; <https://www.wikipedia.org/>

<sup>56</sup> Internet; <https://www.wikipedia.org/>

cement iz Puzzola kraj Napulja počeli proizvoditi beton.

Korištenjem betona kao građevinskog materijala arhitektura Rimskog carstva dobiva svoj procvat, stvarajući moguće strukture i dizajne koji se nisu mogli graditi koristeći samo kamen koji je bio glavni element rane rimske arhitekture.

Tako su stubovi i lukovi kao glavni elementi estetski ambicioznih građevina postali mnogo lakši za gradnju. Takvim su betonom izgrađeni mnogi putevi, rimske toplice, Colosseum i Pantheon u Rimu kao i akvedukt Pont du Gard u južnoj Francuskoj koji je donosio vodu gradu Nimesu, Francuska. (Bromwich J. (2006): Roman Remains of Southern France: A Guide Book. Routledge, str. 110)



Slika 3. Most preko rijeke Gard, Nimes, Francuska<sup>57</sup>

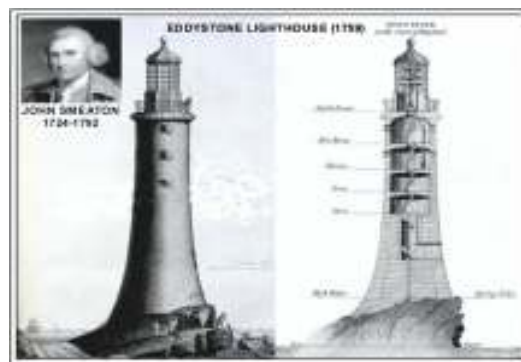


Slika 4. Panteon, fotografija iz 19. stoljeća<sup>58</sup>

Nakon više od 2000 godina, rimske betonske konstrukcije još uvijek su na svom mjestu i odolijevaju svim vremenskim uvjetima. Uspoređujući beton starih Rimljana i beton današnjice, može se uočiti velika razlika u kvaliteti. Prema studiji koju je proveo tim sa Sveučilišta Utah, rimski beton radio se od mješavine vulkanskog pepela, vapna, odnosno kalcijeva oksida, morske vode i vulkanskog kamenja. Za razliku od suvremenog betona, takva mješavina se koristila za izgradnju luka, lukobrana i brana, u kontaktu s vodom postajala je sve čvršća. Znanstvenici tvrde da je to posljedica kemijske reakcije morske vode s vulkanskim materijalima u kojima se formiraju novi minerali koji jačaju beton.

### 3 SREDNJI VIJEK

Padom Rimskog Carstva 476. godine proizvodnja betona je zaboravljena do 14. stoljeća kada je počela ponovna uporaba živog vapna i pucolana tj. sve dok 1414. nije pronađen rukopis koji opisuje tu tehniku do u detalj, te ponovno dolazi do interesa za proizvodnju betona. Godine 1756. britanski inženjer John Smeaton izradio je prvi moderni beton (hidraulički cement) dodavanjem šljunka kao grubog agregata i miješanjem opeke u cement. Smeaton je razvio novu formulu za beton kako bi izgradio treći svjetionik Eddystone, te je tako došlo do ogromnog pomaka u korištenju betona u modernim strukturama.



Slika 5. Svjetionik Eddystone<sup>59</sup>

<sup>57</sup> Internet; <https://www.wikipedia.org/>

<sup>58</sup> Internet; <https://www.wikipedia.org/>

<sup>59</sup> Internet; <https://www.case.international/>

## 4 RAZVOJ BETONA U IX. VIJEKU

Moderna znanstvena iskustva počinju 1818. godine, kad je Vicat otkrio uzroke hidrauličkih svojstava nekih vrsta veziva.

Godine 1824. engleski izumitelj Joseph Aspdin iz Leedsa izumio je Portland Cement, koji je ostao dominantan oblik cementa kao jednog od sastojaka pri proizvodnji betona. Aspdin je stvorio prvi pravi umjetni cement spaljivanjem zemaljskog vapnenca i glina zajedno. Iako nije bio dovoljno pečen bio je jači cement od proizvedenog običnog zdrobljenog vapnenca.

Francuzi Cointeraux i Lebrun 1837. godine su sagradili prvu poznatu stambenu zgradu od betona. Pronalazimo i podatak da je G.A. Ward 1837.godine sagradio betonsku kuću u Americi.

Tek 1845. godine Isaac Johnson, pečenjem mješavine gline i vapnenca sve do nastajanja klinkera, uspio je dobiti portland-cement prema boji tog očvrslog cementa sličnoj boji vapnenca iz okolice Portlanda, koji se i kao određena vrsta cementa i danas koristi.

Godine 1849. njemački istraživači Pettenkofer i Fuchesproveli su i objavili prvu preciznu kemijsku analizu portland cementa, te označili početak ere proizvodnje portland cementa kao hidrauličkog veziva za proizvodnju betona. (Tomičić I, 1996, Betonske konstrukcije, Zagreb.)

## 5 PRONALAZAK ARMIRANOG BETONA

Kako je već rečeno da je beton umjetni kamen koji ima vlačnu čvrstoću bitno manju od tlačne čvrstoće, sredinom 19 stoljeća dolazi do otkrića armiranog betona,

jednog od povijesnih koraka sadašnjice. Njegov pronalazak se pripisuje različitim pronalazačima.

1850.g. Francuz Lambot izradio je čamac od žičane mreže obložene mortom, te se prema nekim autorima smatra izumiteljem armiranog betona.

1867.g. Francuz Monier vrtlar iz Francuske patentirao je izradu velikih betonskih lonaca. Kasnije je patentirao i rezervoare, cijevi, montažne ploče i svodove. Navedene patente 1879.godine otkupio je njemački graditelj G.A.Wayss, koji ih je promovirao pod nazivom Wayss-Monier sistem te je sa svojim tvrtkama izgradio veliki broj građevina u Njemačkoj i Austriji, ali i u Americi. Ovaj sistem naišao je na veliku primjenu, pa se i danas u praksi za tanke prefabricirane betonske ploče često koristi naziv monierka. 1950 Francuzi su slavili stogodišnjicu armiranog betona te su samim tim prioritet u pronalaženju dali Lambotu a ne Monieru.



Slika 6. Lambotov čamac<sup>60</sup>



Slika 7. Monierove posude<sup>61</sup>

<sup>60</sup> Internet; <https://www.marc-andre-dubout.org/>

<sup>61</sup> Internet; <https://www.wikipedia.org/>

## 6 PRVE ARMIRANO BETONSKE GRAĐEVINE

Kronološki možemo poredati prve armirano betonske građevine i to:

- Francois Coignet je 1852.godine prvi je počeo izvoditi zidove u stanogradnji ojačane željeznim žicama, a kasnije i ploče, te je i objavio radove o teoriji armiranog beton.
- Wilijam Wikinson gradi prvu stambenu kuću izgrađenu korištenjem armiranog betona u Engleskoj 1854.godine.
- Nijemac Matias Koeneen je 1866. godine armirao betonske ploče tako što je armaturu postavio u vlačnu zonu i značajno umanjio količinu suvišnog betona iz vlačnih dijelova konstrukcije.
- Prva armiranobetonska zgrada sagrađena je 1875.g. u Port Chesteru u New Yorku, a sagrađio ju je W.E. Ward Godine .
- 1889. godine izgrađen prvi ab most
- 1891. godine George Bartholomew izlio prvu betonsku cestu u SAD ta cesta još postoji

Jedno od bitnih imena izumitelja armiranog betona zauzima Francuz Henebique te se i on smatra začetnikom primjenjive metode proračuna armiranobetonskih konstrukcija, teorije i tehnologije. Godine 1892. patentirao je je novi tip rebrastih stropova i uveo u praksu armiranobetonske pilote. Svoje patente pod nazivom Hennebique betonsystem izvodio je sa svojim tvrtkama po cijeloj Europi i svijetu.

Prva armirano-betonska zgrada na kojoj je novi materijal postao ujedno uz konstrukcijski element i element pročelja zgrade izgrađena je 1903.godine.bila je stambena zgrada Augusta Perreta, Rue Franklin 25, Pariz. Projektirao je i crkvu Notre Dame u Le Raincyju kod Pariza i tada je po prvi put oblikovano pročelje kao lagana filigranska betonska rešetka, dok je

nosivost građevine dobijena izvedbom stupova u unutrašnjosti objekta.



Slika 8. Prva AB stambena zgrada<sup>62</sup>



Slika 9. Katedrala Notre Dame u Le Raincyju kod Pariza<sup>63</sup>

U sustavu logističke potpore Oružanih snag Bosne i Hercegovine funkcioniра koncept povratne i usputne logistike. U ovom konceptu se primjenjuje u svrhu unaprijeđenja efikasnosti i promociji

<sup>62</sup> Internet; <https://fr.wikipedia.org/>

<sup>63</sup> Internet; <https://sites.google.com/>

korisničke usluge i obnavljanju raspoloživih potencijala.

Ne mogu se zaboraviti ni Frank Lloyd Wright u SAD-u (crkva Unity, Oak park, 1904.), Thomas Edison koji je 1908. godine izgradio jeftine i udobne betonske kuće u gradu Union u New Jerseyu, koje postoje još i danas i slovenski arhitekt i dizajner Jože Plečnik (kripta crkve Sv. Duha u Beču, 1910.) te Max Littman (Škola anatomije, München, 1906.) koji su također koristili novi materijal. 1913. godine izgrađena je Milenijska dvorana Maxa Berga u poljskom Wroclawu (tada Breslau) koja je svojom kupolom nakon 18 stoljeća premašila kupolu Pantheona u Rimu, te time je beton postao materijal budućnosti. Trideset i dva rebra poduprla su kupolu raspona 65 metara, a na vrhu se nalazio svjetlarnik. Bila je to prva reprezentativna građevina kojom iznutra i izvana u potpunosti dominira beton. (gradimo.hr/clanak/povijest-betona/)



Slika 10. Dvorana u poljskom Wroclawu (tada Breslau) <sup>64</sup>

1914. Le Corbusier je projektirao kuću Domino koja je imala AB elemente: stupove, ploče katova i stubište jednake za sve vlasnike stanova u zgradi. Sve ostalo je svaki pojedini korisnik mogao ispuniti s materijalima i na način prema svojim specifičnim željama. Le Corbusier je i dalje eksperimentirao s betonom kao materijalom te ostavio za povijest arhitekture crkvu Notre Dame du Haut u Ronchampu. Ovu crkvu je projektirao i izveo 1965. godine i ona u potpunosti odudara od njegova projekta iz 1929. godine, čuvene vile Savoye.



Slika 1. Crkva Notre Dame du Haut u Ronchampu <sup>65</sup>

1916. Na aerodromu Orly u Parizu sagrađen je hangar za avione kao ljuska debljine 90 centimetra i raspona od 75 metara, autora Eugenea Freyssineta.

<sup>64</sup> Internet; <http://arkikultura.com/>

<sup>65</sup> Internet; <http://galerija.metropolitan.ac.rs/>

1921. Einsteinov toranj u Postdamu Ericha Mendelsohna, primjer monolitne naglašenosti beton

1923. Kubizam je u to vrijeme bio nova forma u slikarstvu koja se prelila i na arhitekturu, mnogi su projektanti slijedili taj trend, među njima i Mies van der Rohe s paviljonom Barcelona.

1924. Sagrađen je Planetarium u Jenni, projekt trojice autora Bauersfelda, Dyckerhoffa i Widmanna

Od važnijih metoda proračuna potrebno je izdvojiti metodu proračuna armiranobetonskih konstrukcija po dopuštenim naprezanjima (klasična metoda) koju je razvio Francuz De Tedeschi na prijelazu iz 19. u 20. stoljeće. Ona se temelji na linearnom odnosu naprezanja i deformacija u betonu i armaturi.

Francuza Eugene Freyssinet smatramo začetnikom prednapetog betona i razvoja prednapetih konstrukcija velikog raspona. koji je 1928. godine patentirao prednapeti beton i izveo prvu uporabu konstrukciju od prednapetog betona.

Od 1932. do 1936. godine A. F. Lolejt i grupa stručnjaka uvode u primjenu tzv. prijelomnu metodu proračuna armiranobetonskih konstrukcija u bivšem SSSR-u, koja se smatra prethodnicom današnje metode graničnih stanja.

1936. godine izgrađene prve velike betonske brane, Hooverova i brana Grand Coulee i još postoje

1937. i 1940. godine lučni Most na Đurđevića Tari lučni most, imao je najveći betonski luk u Europi i jedan od najvećih svjetskih armiranobetonskih drumskih mostova na svijetu.



Slika 2. Lučni Most na Đurđevića Tari<sup>66</sup>

## GRAĐEVINE NOVIJEG DOBA

Glamurozna arhitektonska izražavanja posebice nakon 2. svjetskog rata, sve više su pridavale značaju betona kao građevinskog materijala, posebice zgrade javne namjene, velike sportske dvorane i nezamislivo veliki broj drugih objekata projektiran je i građen betonom. Tako su od betona građene razne forme, zakrivljene i dinamičke plohe krovova i fasada, složeni geometrijski oblici do tada neviđeni (tzv. ljsuke koje su omogućavale natkrivanje bez međuoslonaca) i drugo. Polovicom 20. stoljeća, prvo u Njemačkoj, a kasnije i šire počela je proizvodnja pojedinih betonskih elemenata u radionicama i da se kao gotov element dopreme na gradilište.

Ovdje bi spomenuli najznačajnije:

- Palazzetto dello Sport, Rim, Pier Luigi Nervi 1957.
- Dvorana u Tokiju, Kenzo Tange, 1964.
- 1967. Prva sportska građevina s betonskom kupolom, Assembly Hall, izgrađena na Sveučilištu u Illinoisu, u urbanom području Urbana-Champaign. 1967. U Münchenu je sagrađena ljsuka koja je prekrila 20 tisuća kvadrata prostora sve od predgotovljenih elemenata, a na sličan način započeta je i gradnja stambenih zgrada koja je bila brža i jednostavnija.
- Aerodromi (JFK u New Yorku, Eero Saarinen, 1962.)

<sup>66</sup> Internet; <https://marjanhajnal.wordpress.com/>

- 1970. Vlaknasto ojačani beton fibrobeton se po prvi put pojavljuje u uporabi operne kuće (Sidney, Jorn Utzon 1973.).
- 1975. Izgrađen CN toranj u Torontu u Kanadi, najviša zgrada izgrađena lijevanjem cementa u pomične forme.



Slika 13. CN toranj u Torontu u Kanadi<sup>67</sup>



Slika 3. Prva sportska građevina Assembly Hall<sup>68</sup>

- 1990. Zgrada na adresi 311S Wacker Drive u Chikagu postavlja novi rekord najviše ab zgrade
  - 1992. Izgrađena najviša zgrada od armiranog betona, na adresi S. Wacker Dr. 311 u Chicagu.
  - 1999. Polirani beton predstavljen u SAD od strane firme HTC
  - 2004. Izumitelji koriste posebna svjetlo emitirajuća vlakna napravljena od strane mađarskog arhitekta Aron Losonczi i stvaraju prvi translucetni beton
  - 2016. Prva potpuno funkcionalna zgrada napravljena od 3d printanog betona-The Office of the Future zgrada u Dubajju
- 1985. Prvi put uveden silikatni prah kao pozzolanski aditiv. Beton „najviše čvrstoće“ upotrijebljen u izgradnji Union Plaze u Seattleu.

## ZAKLJUČAK

Ni jedan izgrađeni objekat ne može se zamisliti a da kao materijal nije korišten beton. Kao građevinski materijal postao je uporabljiv na razne načine još u Rimskom carstvu, pa čak i nekim civilizacijama kamenog doba.

Od Nabatea što sada poznajemo kao Siriju i Jordan preko Azijata, Hebreja i Egipćana, te dalje kod starih Grka i Rimljana, gdje susrećemo korištenje betona za izgradnju struktura koje preživljavaju sve uvjete, do modernih, glamuroznih objekata u kojima beton kao materijal zauzima vodeće mjesto. Kroz povijest njegova proizvodnja se usavršavala. Uporabom armiranog betona koji je u konstrukciji preuzeo vlačna opterećenja količina betona je znatno umanjena. Proizvodnjom predgotovljenih betonskih elemenata, koji se samo montiraju na gradilištu do objekata napravljenih od 3d printanog betona ovaj materijal doživljava svoj procvat razvoja.

Kroz sam razvoj tehnologije betona može se reći da su začeci korištenja betona kao

<sup>67</sup> Internet; <https://unsplash.com/>

<sup>68</sup> Internet; <https://uihistories.library.illinois.edu/>



materijala ipak u Francuskoj te da su prvi veliki graditelji betonskih konstrukcija bili upravo Francuzi i njihova Francuska škola gradnje betonskih konstrukcija jedna od najpoznatijih u svijetu po svom oblikovanju, inovativnom statičkom sustavu i velikim rasponima. (Galić J. (2016): Betonske konstrukcije, Zagreb). Naravno ne mogu se zaboraviti niti Njemački i Engleski izumitelji, kao i projektanti suvremenih građevina izgrađenih od betona u SAD-u, Kini, Japanu i drugim zemljama.

Iz sveg predhodnog zaključujemo da je beton jedan od vodećih materijala u graditeljstvu od samih začetaka civilizacije do današnjih vremena. Njegova primjena omogućila je projektantima maksimalnu slobodu rada na projektiranju svih objekata, a investitorima glamurozni izgled i ispunjenje njihovih želja.

## LITERATURA

- 1) Bromwich J. 2006, Roman Remains of Southern France: A Guide Book. Routledge
  - 2) Đukan P. i Tomljanović, Z. 2001, Betonski radovi, Zagreb, Institut Građevinarstva Hrvatske
  - 3) Gukov I, 2019, Betonske konstrukcije I predavanja Gukov Zagreb
  - 4) Galić J, 2016, Betonske konstrukcije, Zagreb
  - 5) Kovač B., Brana, P. i Vidaković, D. 2006, Tehnologija građenja, Osijek
  - 6) Krstulović P. 2000, Svojstva i tehnologija betona. Split, Građevinsko – arhitektonski fakultet Split
  - 7) Neville A.M. 2011, Properties of concrete. Technology & Engineering
  - 8) Radić J.i suradnici 2006, Betonske konstrukcije priručnik, Zagreb
  - 9) Tomić I, 1996, Betonske konstrukcije, Zagreb
- <http://www.cemex.hr/Povijestcementai-betona.aspx> (3.1.2023.)
  - <http://www.casopis-gradjevinar.hr/> (5.1.2023.)
  - [www.egradnja.ba/vijesti/14102020/evo-lucija-betona-kroz-historiju](http://www.egradnja.ba/vijesti/14102020/evo-lucija-betona-kroz-historiju) (5.1.2023.)
  - <http://www.gradimo.hr/clanak/povijest-betona/37675> (9.1.2023.)
  - [www.jutarnji.hr](http://www.jutarnji.hr) (9.1.2023.)
  - <https://mdc.arq.br> (9.1.2023.)
  - <https://www.wikipedia.org/> (10.1.2023.)
  - <https://www.case.international/> (10.1.2023.)
  - <https://www.marc-andre-dubout.org/> (10.1.2023.)
  - <https://fr.wikipedia.org/> (10.1.2023.)
  - <https://sites.google.com/> (10.1.2023.)
  - <http://arkikultura.com/> (10.1.2023.)
  - <http://galerija.metropolitan.ac.rs/> (10.1.2023.)
  - <https://marjanhajnal.wordpress.com/> (10.1.2023.)
  - <https://unsplash.com/> (10.1.2023.)
  - <https://uihistories.library.illinois.edu/> (10.1.2023.)

## 1 INTRODUCTION

In terms of its physical, mechanical and aesthetic properties, concrete in its hardened state is similar to rock, i.e. stone. Therefore, we can say that it is nothing but simply and cheaply produced artificial stone. The most common formulation for concrete is that it is a multi-component, semi-dispersed, artificial stone building material, composed of hard aggregate known as coarse aggregate, bound together by cement stone, created by hydration and hardening of cement as a binder. By volume, 70 - 80% of the volume of concrete is aggregate, which is obtained from nature simply by digging gravel and sand or crushing rock, which makes it cheap. In addition to these mandatory components, the composition of concrete can include additives that give it special properties (sealants, aerants, plasticizers, binding regulators, antifreeze agents, etc). During the hardening process, concrete develops certain properties, the most important of which are compressive and tensile strength, very low water permeability, and chemical and volumetric stability. (Begović, D. i Štirmer, N. (2015): Concrete theory and technology, Faculty of Civil Engineering, Zagreb).

## 2 PERIOD BEFORE THE NEW ERA

We usually come across the thesis that concrete was created in the 19th century. However, archaeological research shows that it was still in use in the Roman Empire, and even in some Stone Age civilizations. The history of concrete goes back to at least 6500 BC, when the Nabateans of what we now know as Syria and Jordan used the precursor to modern concrete to build structures that survive to this day. Nabateau is believed to have invented an early form

of hydraulic concrete that hardens when exposed to moisture using lime. So they built concrete floors, residential structures and underground cisterns.



Picture 4 Al-Khazneh (Treasury), Petra<sup>69</sup>



Picture 2 Renaissance tomb, Petra<sup>70</sup>

The use of concrete dates back to 3000 BC when the Egyptians used mud mixed with straw to connect dried bricks. In this period, we also meet Asians, Hebrews and Egyptians, and further on with the ancient Greeks and Romans, who produced concrete.

By studying preserved buildings and their remains as well as written documents, especially the Roman builder Vitruvius who wrote in the 1st century BC "De Architectura" describes concrete as an artificial stone that the Romans produced and used under the name "opus signium". The first real concrete similar to today's is encountered by the ancient Romans, who started producing concrete around 300 BC using pozzolanic cement from Puzzolo near Naples as a binding agent.

<sup>69</sup> Internet; <https://www.wikipedia.org/>

<sup>70</sup> Internet; <https://www.wikipedia.org/>

By using concrete as a building material, the architecture of the Roman Empire flourished, creating possible structures and designs that could not be built using only stone, which was the main element of early Roman architecture. Thus, columns and arches, as the main elements of aesthetically ambitious buildings, became much easier to build. Many roads, Roman baths, the Colosseum and the Pantheon in Rome, as well as the Pont du Gard aqueduct in southern France, which brought water to the city of Nimes, France, were built with such concrete. (Bromwich J. (2006): Roman Remains of Southern France: A Guide Book. Routledge).



Picture 5 Bridge over the Gard River, Nimes, France<sup>71</sup>



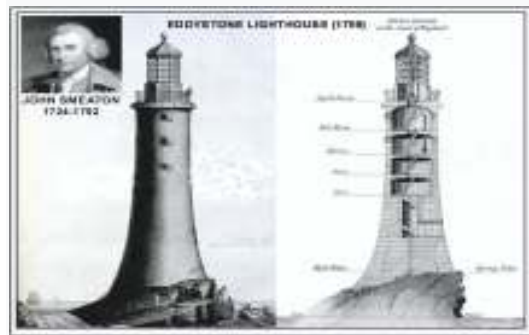
Picture 6 Pantheon, photograph from the 19th century<sup>72</sup>

After more than 2000 years, the Roman concrete structures are still in place and withstand all weather conditions. Comparing the concrete of the ancient Romans and the concrete of today, you can

see a big difference in quality. According to a study conducted by a team from the University of Utah, Roman concrete was made from a mixture of volcanic ash, lime or calcium oxide, seawater and volcanic stones. In contrast to modern concrete, such a mixture was used for the construction of arches, breakwaters and dams, in contact with water it became more and more solid. Scientists claim that this is a consequence of the chemical reaction of seawater with volcanic materials in which new minerals are formed that strengthen the concrete.

### 3 MIDDLE AGES

With the fall of the Roman Empire in 476, concrete production was forgotten until the 14th century, when quicklime and pozzolana began to be reused, i.e. until 1414, when a manuscript was found that describes this technique in detail, and interest in concrete production reappeared. In 1756, British engineer John Smeaton made the first modern concrete (hydraulic cement) by adding gravel as a coarse aggregate and mixing bricks into the cement. Smeaton developed a new formula for concrete to build the third Eddystone Lighthouse, marking a huge breakthrough in the use of concrete in modern structures.



Picture 7 Eddystone Lighthouse<sup>73</sup>

<sup>71</sup> Internet; <https://www.wikipedia.org/>

<sup>72</sup> Internet; <https://www.wikipedia.org/>

<sup>73</sup> Internet; <https://www.case.international/>

#### **4 DEVELOPMENT OF CONCRETE IN IX CENTURY**

Modern scientific experiences begin in 1818, when Vicat discovered the causes of the hydraulic properties of some types of binders.

In 1824, English inventor Joseph Aspdin from Leeds invented Portland Cement, which remained the dominant form of cement as one of the ingredients in concrete production. Aspdin created the first true artificial cement by burning terrestrial limestone and clay together. Although it was not sufficiently fired, it was a stronger cement than the ordinary crushed limestone produced.

In 1837, Frenchmen Cointeraux and Lebrun built the first known residential building made of concrete. We also find information that G.A. Ward built a concrete house in America in 1837.

It wasn't until 1845 that Isaac Johnson, by firing a mixture of clay and limestone until clinker was formed, managed to obtain Portland cement according to the color of that hardened cement, similar to the color of limestone from the Portland area, which is still used as a certain type of cement today. In 1849, German researchers Pettenkofer and Fuchs performed and published the first precise chemical analysis of Portland cement, marking the beginning of the era of Portland cement production as a hydraulic binder for concrete production. (Tomičić I, 1996, Concrete structures, Zagreb).

#### **5 THE DISCOVERY OF REINFORCED CONCRETE**

As it has already been said that concrete is an artificial stone whose tensile strength is significantly lower than its compressive strength, reinforced concrete was

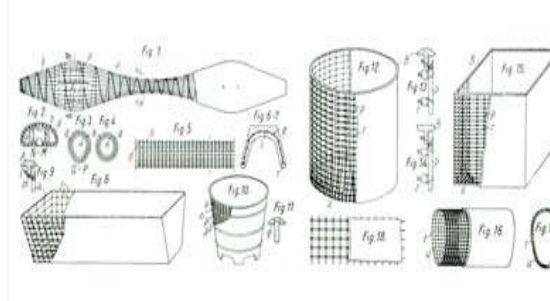
discovered in the middle of the 19th century, one of the historical steps of the present. Its invention is attributed to different inventors.

1850 The Frenchman Lambot made a boat out of wire mesh coated with mortar, and according to some authors, he is considered the inventor of reinforced concrete.

1867 French gardener Monier from France patented the production of large concrete pots. Later, he also patented tanks, pipes, mounting plates and vaults. In 1879, the mentioned patents were purchased by the German builder G.A. Wayss, who promoted them under the name Wayss-Monier system and with his companies built a large number of buildings in Germany and Austria, but also in America. This system was widely used, so even today in practice the name monierka is often used for thin prefabricated concrete slabs. In 1950, the French celebrated the centenary of reinforced concrete and therefore gave priority in finding Lambot and not Monier.



Picture 8 Lambot's boat<sup>74</sup>



Picture 9 Monierove posude<sup>75</sup>

<sup>74</sup> Internet; <https://www.marc-andre-dubout.org/>

<sup>75</sup> Internet; <https://www.wikipedia.org/>

## 6 THE FIRST REINFORCED CONCRETE BUILDINGS

Chronologically, we can arrange the first reinforced concrete buildings as follows:

- In 1852, Francois Coignet was the first to build residential walls reinforced with iron wires, and later with panels, and published works on the theory of reinforced concrete.
- William Wikinson builds the first residential house built using reinforced concrete in England in 1854.
- German Matias Koeneen reinforced concrete slabs in 1866 by placing the reinforcement in the tensile zone and significantly reducing the amount of excess concrete from the tensile parts of the structure.
- The first reinforced concrete building was built in 1875. in Port Chester, New York, and was built by W.E. Ward Years.
- In 1889, the first ab bridge was built
- 1891. George Bartholomew poured the first concrete road in the USA, that road still exists.

One of the important names of the inventors of reinforced concrete is the Frenchman Henebique, who is also considered the originator of the applicable calculation method of reinforced concrete structures, theory and technology. In 1892, he patented a new type of ribbed ceilings and introduced reinforced concrete piles into practice. He performed his patents under the name Hennebique betonsystem with his companies all over Europe and the world.

The first reinforced concrete building where the new material became both a structural element and an element of the facade of the building was built in 1903. It was the residential building of Auguste Perret, Rue Franklin 25, Paris. He also designed the

church of Notre Dame in Le Raincy near Paris, and then for the first time the facade was shaped as a light filigree concrete lattice, while the load-bearing capacity of the building was obtained by the performance of columns in the interior of the building.



*Picture 10 The first AB residential building<sup>76</sup>*



*Picture 11 Notre Dame Cathedral in Le Raincy near Paris<sup>77</sup>*

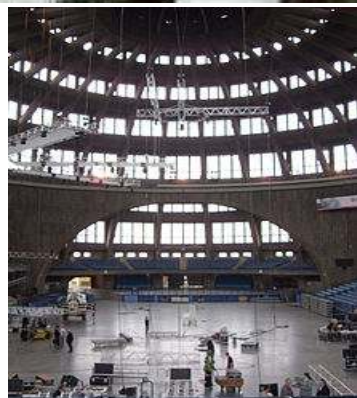
Nor can we forget Frank Lloyd Wright in the USA (Unity Church, Oak Park, 1904), Thomas Edison, who in 1908 built cheap and comfortable concrete houses in the city of Union, New Jersey, which still exist

<sup>76</sup> Internet; <https://fr.wikipedia.org/>

<sup>77</sup> Internet; <https://sites.google.com/>

today, and Slovenian architect and designer Jože Plečnik (Crypt of the Church of the Holy Spirit in Vienna, 1910) and Max Littman (School of Anatomy, Munich, 1906) who also used the new material.

In 1913, Max Berg's Millennium Hall was built in Wroclaw (then Breslau) in Poland, with its dome surpassing the dome of the Pantheon in Rome after 18 centuries, thus concrete became the material of the future. Thirty-two ribs supported the 65-meter span dome, and there was a skylight at the top. It was the first representative building completely dominated by concrete inside and out. (gradimo.hr/clanak/povijest-betona/)



*Picture 12 Hall in Polish Wroclaw (then Breslau)<sup>78</sup>*

In 1914, Le Corbusier designed the Domino house, which had AB elements: columns, floor slabs and a staircase equal for all apartment owners in the building. Everything else could be completed by each

individual user with materials and in a manner according to their specific wishes. Le Corbusier continued to experiment with concrete as a material and left the Notre Dame du Haut church in Ronchamp for architectural history. He designed and built this church in 1965, and it is completely different from his project from 1929, the famous Villa Savoye.



*Slika 13 Church of Notre Dame du Haut in Ronchamp<sup>79</sup>*

In 1916, an airplane hangar was built at the Orly airport in Paris as a 90-centimeter-thick, 75-meter-span shell, by Eugene Freyssinet.

1921 Einstein Tower in Potsdam by Erich Mendelsohn, an example of monolithic emphasis on concrete.

1923. At that time, Cubism was a new form in painting that spread to architecture, many designers followed that trend, among them Mies van der Rohe with the Barcelona pavilion.

<sup>78</sup> Internet; <http://arkikultura.com/>

<sup>79</sup> Internet; <http://galerija.metropolitan.ac.rs/>

1924. The Planetarium in Jena was built, a project of three authors Bauersfeld, Dyckerhoff and Widmann.

Among the more important calculation methods, it is necessary to single out the method of calculation of reinforced concrete structures according to permissible stresses (classical method) developed by the Frenchman De Tedeschi at the turn of the 19th and 20th centuries. It is based on the linear relationship between stress and deformation in concrete and reinforcement. We consider the Frenchman Eugene Freyssinet to be the originator of prestressed concrete and the development of large-span prestressed structures who patented prestressed concrete in 1928 and built the first usable structure from prestressed concrete.

From 1932 to 1936, A. F. Lolejt and a group of experts introduced the so-called groundbreaking method of calculating reinforced concrete structures in the former USSR, which is considered the predecessor of today's limit state method.

In 1936, the first large concrete dams were built, the Hoover Dam and the Grand Coulee Dam, and they still exist.

In 1937 and 1940, the Arch Bridge on the Đurđevića Tara arch bridge had the largest concrete arch in Europe and one of the largest reinforced concrete road bridges in the world.



*Slika 14 Arch Bridge on Đurđevića Tara*

## 7 BUILDINGS OF THE RECENT AGE

Glamorous architectural expressions, especially after the Second World War, increasingly attached importance to concrete as a construction material, especially public buildings, large sports halls and an unimaginably large number of other buildings were designed and built with concrete. Thus, various forms were built from concrete, curved and dynamic surfaces of roofs and facades, complex geometric shapes never seen before (so-called shells that enabled covering without intermediate supports) and more. In the middle of the 20th century, first in Germany, and later more widely, the production of individual concrete elements began in workshops and to be delivered to the construction site as a finished element.

Here we would mention the most important ones:

- Palazzetto dello Sport, Rome, Pier Luigi Nervi 1957.
- Hall in Tokyo, Kenzo Tange, 1964.
- 1967 First concrete domed sports building, Assembly Hall, built at the University of Illinois, in the urban area of Urbana-Champaign in 1967.
- In Munich, a shell was built that covered 20,000 square meters of space, all from prefabricated elements, and the construction of residential buildings was started in a similar way, which was faster and simpler.
- Airports (JFK in New York, Eero Saarinen, 1962).
- 1970 Fibre-reinforced concrete fiber concrete appears for the first time in the use of the opera house (Sidney, Jorn Utzon 1973).
- 1975 The CN Tower was built in Toronto, Canada, the tallest building built by pouring cement into movable forms.



*Slika 15 CN Tower in Toronto,  
Canada<sup>80</sup>*



*Picture 16 The first sports building Assembly  
Hall<sup>81</sup>*

- 1985. For the first time, silicate powder was introduced as a pozzolanic additive. The "highest strength" concrete used in the construction of Seattle's Union Plaza.
- 1990 The building at 311S Wacker Drive in Chicago sets a new record for the tallest ab building.
- 1992. The tallest building made of reinforced concrete was built, at the address S. Wacker Dr. 311 in Chicago.
- 1999. Polished concrete presented in the USA by HTC
- 2004. Inventors use special light-emitting fibers made by Hungarian

architect Aron Losonczi and create the first translucent concrete.

- 2016. The first fully functional building made of 3d printed concrete - The Office of the Future building in Dubai.

## CONCLUSION

Not a single built object can be imagined without concrete being used as a material. As a building material, it became usable in various ways as early as the Roman Empire, and even in some Stone Age civilizations.

From the Nabataeans, which we now know as Syria and Jordan, through the Asians, Hebrews and Egyptians, and further on with the ancient Greeks and Romans, where we encounter the use of concrete to build structures that survive all conditions, to modern, glamorous buildings in which concrete as a material takes a leading place. Throughout history, its production has been perfected. By using reinforced concrete, which took the tensile loads in the construction, the amount of concrete was significantly reduced. From the production of prefabricated concrete elements, which are simply assembled on the construction site to objects made of 3D printed concrete, this material is experiencing its development boom.

Through the development of concrete technology itself, it can be said that the beginnings of using concrete as a material were in France and that the first great builders of concrete structures were precisely the French and their French school of concrete construction is one of the most famous in the world for its design, innovative static system and large ranges. (Galić J. (2016): Concrete structures, Zagreb). Of course, we cannot forget the German and English inventors, as well as the designers of modern buildings built

<sup>80</sup> Internet; <https://unsplash.com/>

<sup>81</sup> Internet; <https://uihistories.library.illinois.edu/>



from concrete in the USA, China, Japan and other countries.

From all of the above, we conclude that concrete is one of the leading materials in construction from the very beginnings of civilization to the present day. Its application allowed designers maximum freedom of work on the design of all buildings, and investors a glamorous look and the fulfillment of their wishes.

## LITERATURE

- 1) Bromwich J. 2006, Roman Remains of Southern France: A Guide Book. Routledge
  - 2) Đukan P. i Tomljanović, Z. 2001, Betonski radovi, Zagreb, Institut Građevinarstva Hrvatske
  - 3) Gukov I, 2019, Betonske konstrukcije I predavanja Gukov Zagreb
  - 4) Galić J, 2016, Betonske konstrukcije, Zagreb
  - 5) Kovač B., Brana, P. i Vidaković, D. 2006, Tehnologija građenja, Osijek
  - 6) Krstulović P. 2000, Svojstva i tehnologija betona. Split, Građevinsko – arhitektonski fakultet Split
  - 7) Neville A.M. 2011, Properties of concrete. Technology & Engineering
  - 8) Radić J.i suradnici 2006, Betonske konstrukcije priručnik, Zagreb
  - 9) Tomičić I, 1996, Betonske konstrukcije, Zagreb
- <https://www.case.international/> (10.1.2023.)
  - <https://www.marc-andre-dubout.org/> (10.1.2023.)
  - <https://fr.wikipedia.org/> (10.1.2023.)
  - <https://sites.google.com/> (10.1.2023.)
  - <http://arkikultura.com/> (10.1.2023.)
  - <http://galerija.metropolitan.ac.rs/> (10.1.2023.)
  - <https://marjanhajnal.wordpress.com/> (10.1.2023.)
  - <https://unsplash.com/> (10.1.2023.)
  - <https://uihistories.library.illinois.edu/> (10.1.2023.)
- <http://www.gradimo.hr/clanak/povijest-betona/> (3.1.2023.)
  - <http://www.cemex.hr/Povijestcementai-betona.aspx> (3.1.2023.)
  - <http://www.casopis-gradjevinar.hr/> (5.1.2023.)
  - [www.egradnja.ba/vijesti/14102020/evo-lucija-betona-kroz-historiju](http://www.egradnja.ba/vijesti/14102020/evo-lucija-betona-kroz-historiju) (5.1.2023.)
  - <http://www.gradimo.hr/clanak/povijest-betona/37675> (9.1.2023.)
  - [www.jutarnji.hr](http://www.jutarnji.hr) (9.1.2023.)
  - <https://mdc.arq.br> (9.1.2023.)
  - <https://www.wikipedia.org/> (10.1.2023.)