NASELJENI MOSTOVI: UMJETNOST I ZNANOST (boje li se arhitekti dizajna mostova)

INHABITED BRIDGES: ART AND SCIENCE Are architects afraid of designing bridges?

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1 ISTORIJAT PRIMENE IT PRI PRORAČUNU KONSTRUKCIJA MOSTOVA - 45 GODINA ISKUSTVA

Kad smo učili/studirali predmet Mostovi na Građevinskom fakultetu Sveučilišta u Zagrebu, nisu postojali niti CAD alati, niti kompjuteri, ni kompjuterski programi kojima se mogla (bez, ili s malo muke) proračunati konstrukcija (statika) mostova. Crtalo se doslovce olovkom i „perom“ i tušem, trokutima i T-šinom, a računalo tzv. šiberom, log-tablicama ili ručno. Mukotrpan rad. Mogu s ponosom istaći, da sam ja, onda kao asistent, uveo 1971. kompjutersko proračunavanje statike i dinamike mostova na predmetu Masivni mostovi prof. K. Tonkovića. To se uradilo, mora se priznati, uz njegovo prećutno odobrenje. A prije toga sam uveo kompjutersko proračunavanje konstrukcija na tadašnjem Međufakultetskom sveučilišnom studiju prometa u mojem predmetu Nosive strukture (sjećate li se još FE programa STRESS). Zajedno smo kolege ing. Zdunić, ing. Bandić (iz kompjutorskog centra bivšeg RC Jugomont/Jugobetona) i kolegom ing. Đurekom iz tadašnjeg RC ETF-a, na IBM 1130, proveli 1971. sve statičke proračune svih programa vježbi mostova u dvije radne noćne „šifte“, rada na stroju. To je bilo vrijeme tzv. bušenih kartica i onih zelenih fortranskih upisnih listova. Prije faze modeliranja proračunskog modela, održali smo u dva popodnevna sata brzi (crash) tečaj iz statike konačnih elemenata (matričnog proračuna, kojeg se nije onda poučavalo i proučavalo) i osnova modeliranja proračunskih modela, te osnova upisa podataka (input data) za proračun računalom.

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1 HISTORY OF IT APPLICATION IN CALCULATING BRIDGE STRUCTURES – 45 YEARS OF EXPERIENCE

When we studied the subject of Bridges at the Faculty of Civil Engineering, University of Zagreb, there were no CAD tools, computers and computer programs to facilitate the calculation of bridge structures (statics) and make it a rather effortless task. The drawings were literally made by pencils and "pens" and ink, triangles and T-rails, while structures were calculated using slide rulers, log tables or manually – a painstaking work indeed. I can proudly point to the fact that back then (in 1971), as a fellow assistant, I was the one who introduced the computerized calculation of statics/dynamics of bridges at the subject of Massive Bridges headed by professor K. Tonković. This was done; it should be admitted, with his tacit approval. Before that, I introduced the computerized calculation of structures at the Intercollegiate university study of traffic in my subject of Supporting Structures (do you remember the FE STRESS program!?). In 1971, with the participation of eng. Zdunić, eng. Bandić (from the computer centre of the former RC Jugomont/Jugobeton) and eng. Đurek from the former RC ETF, we conducted all statistical calculations of the bridge-program exercises in two "night shifts", working on an IBM 1130 machine. It was the era of the so-called punch cards and those green FORTRAN coding sheets. Before the modelling phase of computational model, in two afternoon hours we held a crash course from the static of finite elements (matrix calculation, which had not been taught and studied at

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To sam kasnije detaljno opisao u mojim skriptama Nosive strukture I - STRESS rješavač inženjerskih problema (1975). Poslije su slijedili drugi napredniji programi: SAP, SD2A, SD2B, SAPIV, ICES STRUDL II, i drugi. Korištenje tih programa kao ALATA doprinosi oslobađanju vremena za druge KREATIVNE poslove studija. Nažalost, u to vrijeme nije bilo interneta, WEB-a, modema, komuniciralo se sa strojem (RC) bušenim karticama, nije bilo dostupnih grafičkih displeja, niti plotera, rezultati analiza printali su se na izlaznim listinama, a rezultati su se iz njih očitavali, a „podaci“ su se između fakulteta i RC prenosili pješice ili tramvajem, rijetko autom! Ali, postojao je entuzijazam! Danas nezamislivo. Kasnije su se pojavila razna „egzotična“ desktop računala pa onda i PC računala i grafički displeji. Godine 1980. nabavljen je FE grafički CAD orijentiran FE program COSMOS/M. Ne treba ni spominjati CAD i presudni utjecaj CAD-a na oblikovanje objekata i proračunskih modela. Napisani su i prvi domenski (za proračun i dizajn drvenih konstrukcija) orijentirani ekspertni sustavi. Nabavljena je GURU AI ljuska, a potom u Wardova NeuroShell – ANN ljuska. Danas se studenti služe daleko naprednijim paketima programa i raznim online apletima (ima ih i na tabletima) i na WEB-u. Nažalost, ne u dovoljnoj mjeri. Danas gledamo u kinima 3D filmove, no uskoro će biti nezasmlivo išta projektirati bez korištenja virtualne realnosti (VR). Može biti i holograma. Korištenjem tih naprednih programskih paketa, studenti i inženjeri u praksi mogu se (ili će se moći) posvetiti kreativnijim inženjerskim zadacima – osmišljavanju konstrukcija. Te promjene će

that time), the basics of modelling of computational models, and the basics of writing data (input data) for computer based calculation. Later I have described this in detail in my textbooks Bearing Structures I-STRESS resolver of engineering problems (1975). This was later followed by other advanced programs: SAP, SD2A, SD2B, SAPIV, ICES STRUDL II, and others. Using these programs as a TOOL saves time for other CREATIVE works of study. Unfortunately, back then there were no Internet and modems; the communication with the machine (RC) unfolded using punched cards. There were neither graphic digital displays nor plotters available. The results of analyses were printed on the output template, from which results were then read, while "data" between the faculty and the RC were transferred on foot or by tram, and seldom by car! But we were enthusiastic! Today, this is inconceivable. Later, various "exotic" desktop computers appeared, and then came the PC and graphic displays. It was in 1980 when the graphic CAD-oriented FE program called COSMOS/M was written. It is pointless to mention CAD and its decisive influence on creating structures and computation models. The first domain-oriented (for calculating and designing timber structures) expert systems were also developed. We installed the GURU AI shell, and then the Ward NeuroShell - ANN shell. Nowadays, students have far more advanced program packages and various online applets (available also for tablets) at their disposal, but unfortunately to insufficient degree. Today, we watch 3D movies in theatres, but soon, designing anything without the use of virtual reality

Sl. 1. Transport 5 Mb IBM hard diska 305 RAMAC HDD (1956), [24]
Fig. 1. Transport of 5 Mb IBM HARD DISC 305 RAMAC HDD (1956), [24]

diktirati investitori i kreativni arhitekti. U čemu je danas razlika između konstrukcijskog proračuna preko ocean-skog linera i megagrađevine (recimo megahotela sidrenog u tlu), osim u daleko većoj složenosti i naprednijoj tehnologiji projektiranja (suradnji struka) i izvođenja kompleksa linera/kruzera. Da se o samoj organizaciji eksploatacije i ne govori. Ridikulozno bi bilo i uspoređivanje organizacije održavanja linera i građevine megahotela ili nekog složenog stambenog objekta, zastalno sidrenog/temeljenog na tlu.

Neka podsećanja na istorijske detalje, kao i poređenja sa mogućnostima današnje primene IT, date su na slikama od 1. do 4.

(and possibly holograms) will be unimaginable. Using these advanced software packages, students and engineers in practice can or will be able to focus on more creative engineering tasks – conceiving structures. These changes will be determined by investors and creative architects. Nowadays, what is the difference between the structural calculation of an ocean liner and a mega structure (say a mega-hotel anchored in the ground), except the far higher complexity and advanced technology of designing (collaboration of vocations) and constructing a complex liner/cruiser? Let alone the management of exploitation itself! Indeed, it would be ridiculous to compare the management of maintenance of a liner and a mega-hotel structure or some other complex residential building, permanently anchored/founded in the ground.

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STRUCTURE OKVIR
TYPE PLANE FRAME
NUMBER OF JOINTS 4
NUMBER OF MEMBERS 4
NUMBER OF SUPPORTS 2
NUMBER OF LOADINGS 1
JOINT COORDINATES
1 X 0.0 Y 0.0
2 X 4.90 Y 0.0
3 X 4.90 Y -4.60 S
4 X 0.0 Y -4.60 S
JOINT RELEASES
4 MOMENT Z
3 FORCE X MOMENT Z
MEMBER INCIDENCES
1 1 2
2 2 3
3 3 4
4 4 1
MEMBER PROPERTIES PRISMATIC
1 AX 0.8 IZ 0.066
2 AX 0.32 IZ 0.00426
3 AX 0.44 IZ 0.01108
4 AX 0.32 IZ 0.00426
CONSTANTS E 3000000 ALL
LOADING 1 SVE SKUPA SA VL. TEZ.
MEMBER LOADS
1 FORCE Y UNIFORM W -13.3
1 FORCE Y CONCENTRATED P -155.8 L 1.675
1 FORCE Y LINEAR WA 0. WB -33.50 LA 1.675 LB 3.2875
1 FORCE Y LINEAR WA -33.50 WB 0. LA 3.2875 LB 4.90
2 FORCE Y LINEAR WA -6.5 WB -9.60
3 FORCE Y UNIFORM W 25.15
4 FORCE Y LINEAR WA -9.60 WB -6.50
TABULATE ALL
TRACE
SOLVE
PROBLEM CORRECTLY SPECIFIED, EXECUTION TO PROCEED.

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Sl. 2. Ilustracija IT prahistorije (1972): unos podataka u program STRESS na IBM 1130 računalu, [4]
Fig. 2. IT prehistory (1972): data input in the STRESS program running on IBM 1130 computer, [4]

Danas, i jednom (nekoć) davno, ključni dio projekta, statički proračun mostova predstavljao je i još predstavlja (po mom sudu) zapravo samo minorni/zanatski i više manje rutinski/zanatsko/inženjerski udio u projektiranju mostova, kojih je ustaljeni oblik slijedio iz isključivih/pretežnih zahtjeva modova prometnih sredstava (željeznice i cestovnih vozila). Današnju statiku (proračune) efektno će zamijeniti umjetna inteligencija i ekspertni sustavi. Problemi mostogradnje se danas zapravo kriju u izvođenju građevinskih objekata. Takvi sustavi postoje već danas (Adeli, Smith). Problemi dizajna suvremenih mostova leže danas u njihovoj složenoj ostvarljivosti. Arhitekti i urbanisti su se (elegantno) uklonili tim, tada i danas još, novonametnutim zahtjevima (poznavanju novih materijala: čelika i betona, pa onda prednapetog betona, drveta i lameliranog lijepljenog drva i spregnutih konstrukcija, i svih njima „užasnih“, za njih nekreativnih

Some reminders of historical details, as well as comparisons with the capabilities of today's IT are given in Figures 1 to 4.

Both today and historically, the key part of the project, i.e. the structural analysis of bridges, actually accounted (and still does in my opinion) only for a minor/trade and more or less routine trade/engineering share of the bridge design process, the usual form of which was emanated from the exclusive/prevaling modes of transportation means (rail and road vehicles). Today's static calculations will be effectively replaced by artificial intelligence and expert systems. Problems with bridge design nowadays are actually related to their construction. Such systems are already in existence (Adeli, Smith). Problems with designing modern bridges lie in complexity of their execution. Architects and urban planners have (elegantly) dodged the newly imposed

Sl. 3. Izgled tzv. bušene kartice: nekoć komunikacijskog medija sa kompjutorom.

Prapovijest IT ere. Tehnička arheologija, [4]

Fig. 3. The punched card: sometimes communication media with the mainframe computer.

Prehistory of the IT era - technical archaeology, [4]

Sl. 4. Moorov zakon – primjer eksponencijalnog rasta kompjuterizacije i IT u zadnjih 110 godina (2014): Ray Kurzweil, [15]

Fig. 4. Moor's law – an example of the exponential growth of computerization and the IT in the past 110 years (2014): Ray Kurzweil, [15]

dokaza nosivosti konstrukcija), jer se tražila, ne samo umjetnost oblikovanja, sinteza funkcija, već „artistička“ znanstvena manipulacija „dosadnom“ numerikom i svojstvima novih materijala. Umjetnosti tu više nije bilo mjesta: ona se odražavala u oblikovanju stupova mostova, linijama intradosa, ograda mostova i rasvjetnih stupova, estetici oblikovanja poprečnih presjeka!

2 GRADNJA NASELJENIH MOSTOVA U GRADSKOM TKIVU

Naseljeni mostovi, nisu neki novum, prije bi se reklo da su odraz jednog vremena, kad se integralno razmišljalo o građevinskim objektima: poznati su kao turističke atrakcije Ponte Vecchio u Firenci, te npr. drveni most Paladija u Bassanu, istina nekoliko puta rušen i obnavljan, a naravno iz povijesnih zabilježbi i slika glasoviti London Bridge. Poznat je i naseljeni most u Erfurtu (najdulji, sedam puta spaljivan i građen od 1156). Također i manje poznat Pont de Rohan u Landerneau (sagrađen 1336.). U novije doba ponovno se sintezom konstrukterstva i arhitekture i umjetničkih vizija, pojavljuju nova i fascinantna rješenja: Calatrava, Zaha Hadid i drugi. Međutim, povijesnim su slijedom, građevinari/konstrukteri preuzeli inicijativu i razvili razne svoje tipove (pratiptove) mostova, imajući malo smisla za umjetnost, zahtjeve urbanista i konačno zahtjeve stručno neukih korisnika - investitora, za koje se mostovi i grade. Dominirala je statika/dinamika konstrukcija. I interesi raznih konvencionalnih modova transporta. Tek se nedavno ponovno javljaju tendencije obnavljanja ideja dizajna naseljenih mostova - arhitekti se vraćaju tom problemu, jer više ne postoji ograničenje „odvratne im“ numerike. Manuelne proračune zamijenili su modeliranje konstrukcije i postupci analize konačnim elementima. Pa i neki ekspertni sustavi za dizajn mostova. A tu je i CAD i odnedavno se ustaljuje i VR. Pojavljuju se sada novi problemi, ali sada u gradnji tih građevina. Pogotovo megagrađevina. Osim toga, gradnja klasičnih „jednomodalnih“ mostova uvijek je bila ograničeni leno (sve istih) korisnika - željeznice i/ili konzorcija cestovnih interesenata. U socijalizmu je, osim toga, i riječ „profit“ bila prognana, a što je zajedno s edukacijom studenata rezultiralo sadašnjem stanju stvari - zanemarivanju ekonomskih i cost-benefit analiza. Pa i kad bi se željelo promijeniti trend, to bi u kratkom roku bilo nemoguće, jer su se prošla (pred-IT) znanja edukacijom prenosila „s koljena na koljeno“. Iz generacije su odgojeni u duhu striktno podjeljenosti struka, rezultat pred-IT ere. A zašto ti objekti ne bi bili sa bitnim sadržajima (da ih ne spominjem i ne „ureknem“), i sasvim drugih formi integralne solucije, no ... i arhitekti su odgojeni u duhu striktno podjeljenosti struka, rezultat pred-IT ere. A zašto ti objekti ne bi bili sa bitnim sadržajima (da ih ne spominjem i ne „ureknem“), i sasvim drugih formi prozašlih iz potreba razvoja i korištenja (i novih) formi urbaninih tkiva. I profitabilne racionalne ekonomije

requirements (knowledge of new materials: steel and concrete, prestressed concrete, timber and laminated adhered timber, and composite structures, and all the "appalling" and "non-creative" evidences of the structure's bearing capacity), as in addition to the art of design and synthesis of functions, they also require "artistic" scientific manipulation with the "boring" numeric and properties of new materials. Here, there was no room for the art; it was reflected in shaping the bridge piers, intrados curves, bridge fences and lighting poles, aesthetics of shaping cross-sections!

2 BUILDING INHABITED BRIDGES IN THE URBAN FRAMEWORK

Inhabited bridges are unlikely a novelty, but probably a reflection of an era when the objects of civil engineering were conceived in an integral manner. They are known as tourist attractions, for example the Ponte Vecchio in Florence, the Palladium wooden bridge in Bassano (actually several times destroyed and rebuilt), and of course the famous London Bridge known from historical records and paintings. Also renowned, it is the inhabited bridge in Erfurt (it is the longest, seven times burnt up and built from 1156), and there is the less famous Pont de Rohan in Landerneau (built in 1336). Recently, by the synthesis of structural engineering and architecture and artistic vision, new and fascinating solutions have emerged: Calatrava, Zaha Hadid and others. However, over the course of history, structural/civil engineers have taken the initiative and developed their own various types (prototypes) of bridges, heeding not much the artistic value, demands of urban planners and ultimately the demands of the professionally ignorant users – investors, for which bridges are actually built. What prevailed were the statics/ dynamics of structures, as well as the interests of various conventional modes of transportation. It was not until recently that ideas of designing inhabited bridges have emerged as a tendency – architects are returning to this problem, as the "repugnant" numeric makes no longer a limitation. Manual calculations were replaced by structural modelling and procedures of finite element analysis; there are even some expert bridge-design systems. And there is CAD and recently established VR. However, new problems are emerging, but now they are related to the construction of these buildings, particularly mega structures. Besides, constructing traditional mono-modal bridges has always been the fief of the same users – railways and/or the consortium of roadway stakeholders. In addition, the word "profit" was expelled during the socialism, which, along with the education of students has led to the present state of affairs – neglecting the economic and cost-benefit analysis. Even with the good will, changes in this trend would be impossible to introduce in the short term, given that the education system enabled the previous (pre-IT) knowledge to be passed on from generation to generation. Besides, the very system of public tenders is "a vicious circle" because their terms are defined by professionals also educated based on the same pre-IT premises. The same applies to the nominated juries with guarantors also brought up in the pre-IT era. Thus, these bodies still lack architects who might be able to suggest new integral

ulaganja u investiciju? Trenutno se u Zagrebu i u Beogradu vode diskusije o potrebi uključivanja Save i Dunava u urbani razvoj. Ali (gledano odozgo) ovi postojeći i projektirani „štapici - mostovi“ preko Save i Dunava (i drugih gradskih rijeka) nikada neće spojiti jug i sjever zagrebačkog, beogradskog (i obale bilo kojeg) urbanog priobalnog tkiva. *To mogu samo naseljeni mostovi, kod kojih će sam promet biti samo jedan od mnogih modova-korisnika prostora mostova.* No, gdje se danas izučavaju ti „osebujni“ objekti? Proučavaju se samo oni izvedeni, a ti su (ponekad i grandiozna ostvarenja graditeljstva) zasnovani na premisama prošlosti jednodimenzionalnih mostova pred-IT ere. S današnjim mogućnostima ostvarenja. Za primjer jednog u širem smislu integralnog mosta, može se navesti integralni pothodnik kod željezničkog kolodvora u Zagrebu. Projektirao ga je tadašnji IPZ (prof. Tonković) i Centar 51. Zapravo je to **naseljeni most** građen u drugom mediju – u tlu, za razliku od raznih monomodalnih „pješačkih“ pothodnika, kojima su uzori odvodne kanalizacije cijevi u tlu. Te se kritike projektiranja konvencionalnih mostova nažalost ne izučavaju, te se time ne promiču nove tendencije projektiranja mostova. Navodim ovdje, kao primjer naseljenih mostova, prvonagrađeni rad poznate arhitektice Zaha Hadid, (slike 5 i 6), za novi Londonski most, [16], [17], [18]. Moćni lobiji su za sada onemogućili realizaciju, kao što će se desiti i s budućim prijedlozima (ako ih uopće bude) budućih naseljenih mostova u Zagrebu i Beogradu. Npr. kad se u Zagrebu razmišlja o proširenju rotora kod savskog mosta, i ne razmišlja se o njegovom proširenju nad Savu, o uključanju arhitekata, raspisivanju međunarodnog natječaja, možda i izvedbi kao naseljenog objekta preko ili iznad Save - to je naime interesni „leno“ prometne, građevinske i jedne sasvim druge interesne (hidrotehničke) grupacije. Također navodim i recentni prvonagrađeni rad nedavnog natječaja za novi naseljeni londonski most (Inhabited Bridge London 800 Competition, RIBA 2009), autora Laurie Chetwooda (slika 7), kao i neke druge prijedloge (slike 8-9), [18].

Otpori promjenama su monumentalni. Ugoženost raznih interesnih lina sveprisutna je strahom ugoženih interesnih grupacija neprilagodljivih protoku vremena i napretku tehnologije.

solutions, but ... brought up in the spirit of a strict division between professions; architects are also products of the pre-IT era. And why these objects would not contain major attractions (not to mention them and bringing bad luck), and quite different forms emerging from the need for developing and using (also the new) forms of urban framework? Also a profitable rational economics of investing in investments. There are current discussions in Zagreb and Belgrade about the need for inclusion of the rivers Sava and Danube in urban development. But (as seen above), these existing and projected "sticks - bridges" over the Sava and Danube (and other urban rivers) will never make a connection between the north and south of Zagreb and Belgrade (and coasts of any other) coastal urban fabric. Only inhabited bridges can do it, in which the traffic itself will be only one of many modes-users of the bridge space. But where are these "peculiar" objects studied nowadays? Only the derived objects are studied, and these (sometimes grandiose achievements of civil engineering) are based on premises of the history of mono-modal bridges dating back from the pre-IT era with nowadays capacity of realization. In a wider sense, the integral underpass at the Zagreb railway can be taken as a good example of an integral bridge. It was designed by the former IPZ (professor Tonković) and the Centre 51. In fact, it is an inhabited bridge built in different media (in soil) as opposed to the various mono-modal "pedestrian" underpasses, which are modelled after the sewer pipes in the ground. Unfortunately, this criticism towards designing conventional bridges is studied nowhere today, so it cannot promote new bridge designing tendencies. As an example of inhabited bridges let us mention here the award winning project of the famous architect Zaha Hadid (Figures 5 and 6) for new London Bridge, [16], [17], [18]. For the moment, powerful lobbies have blocked its realization, as it will happen with future proposals (if any) for inhabited bridges in Zagreb and Belgrade. For example, when someone in Zagreb considers expanding the rotor by the Sava bridge, he fails to take into account the possibility of expanding it over the Sava river, the possibility of including the architects in the project, announcing an international tender, maybe resolving the issue as an inhabited object over or above the Sava – it is namely the "fief" of the traffic, construction, and a completely different interest (hydro-technical) group. Also it is worth to mention the winning project of the recent competition for the new inhabited London Bridge (London Bridge Inhabited 800 Competition, RIBA 2009) designed by Laurie Chetwood (Figure 7), as well as some other proposals (Figures 8-9), [18].

Resistance to changes is monumental. The vulnerability of various interest areas is omnipresent fear of affected interest groups, inflexible passage of time and advancement of technology.

Sl. 5. Prijedlog za londonski naseljeni most (2009): arh Zaha Hadid, [16]
Fig. 5. Proposal for the inhabited London Bridge (2009), by Zaha Hadid (2009), [16]

Postupno će (ipak) protokom vremena doći do promjena, jer će prevladati svijest o zastarjelosti pred-IT statičkih nazora na dizajn i konstrukcije mostova. Nije sve statika! I nije sve u statičkoj konstrukciji (no recimo i dinamici ili kvazidinamici proračuna konstrukcije mosta). Takve radikalne promjene su se već desile u prošlosti naših struka. Tako su naprosto „nestale” neke forme čeličnih rešetkastih mostova, rukovođene samo upitnom „ljepotom” envelopei momentnih dijagrama globalne cjeline statičkih sustava i navodnim (fascinirajućim?) uštedama materijala. No do promjena nazora dolaziti će tek s integracijama sadržaja, gdje je globalni nazor ugodnost i profitabilnost investicije. Za to pak treba više vremena, jer se postojeće i buduće vještine dizajna mostova rađaju/perpetuiraju iz pratipova modela naučavanih na katedrama fakulteta. A taj historicizam je žilav i traje i traje...(kao i Ravelov Bolero)... Za tu integraciju predmeta treba vremena i nadasve volje, sagledavanja budućih razvojnih trendova i nadasve - kreativnosti. I, recimo, tko je ikad pozvao npr. Zahu Hadid ili Antoine Grumbach ili Richarda Rogersa ili Yona Friedmana ili Daniela Libeskinda da održi studentima i inženjerima građevine i arhitekture set predavanja / seminara (ili cijeli kolegij) o njihovim nazorima o građenju mostova!

Treba i vremena za shvatiti, da je isto tako za projekt mosta važna ekonomija održavanja i građenja, investicija novca (kapitala) u vremenu, povrat uloženog kapitala, kao što su to recimo i konvencionalni statički proračuni. Ti su ekonometrijski algoritmi (Aguilar), već odavno poznati i dobro provjereni, ali se svjesno ili nesvjesno (ili iz neznanja, ili zbog nekooperativnosti) zaobilaze, jer ugrožavaju „konvencionalni” dizajn mostova.

But, gradually as time is passing by, there will be changes, because the consciousness of the obsolescence of pre-IT static views on the bridge design will prevail. It is not all in the structural mechanics and static as well as dynamic analysis. These radical changes have already appeared in the past of our profession. For example, some forms of steel truss bridges, based only on the questionable "beauty" of envelopes on the torque diagram of the global totality of the static system and the alleged (fascinating?) material savings, have simply "disappeared". However, changes in views will only come with the integration of contents, where comfort and profitability are the global ideas. This in turn needs more time, because the current and future bridge design skills will stem/perpetuate from archetypes of models taught on faculty departments. Thus, that historicism is tough and lasts forever ... (like Ravel's Bolero) ... This integration of subjects takes time and, above all, determination, perceiving future development trends and primarily – creativity. And, say, who has ever called Zaha Hadid or Antoine Grumbach or Richard Rogers or Yona Friedman or Daniel Libeskind to present students and engineers of civil engineering building and architecture a set of lectures/seminars (or a whole course) about their views on constructing bridges!

The fact is that the economy of maintenance and construction, the investment of money (capital) in time, the return on investment are equally important for the bridge project as, say, the conventional static calculations, but understanding it takes time. These econometric algorithms (Aguilar) have long been known and well tested, but consciously or unconsciously (or out of ignorance or because of lack of cooperativeness) are avoided, because they threaten the "conventional" design of bridges.

Sl. 6. Skice za londonski naseljeni most (2009): arh Zaha Hadid, [17]
 Fig. 6. Sketches of the inhabited London Bridge (2009), by Zaha Hadid, [17]

Sl. 7. Prvonagrađeni rad na takmičenju za naseljeni most u Londonu (2009): arh Laurie Chetwood
 (Energetski samoodržavajuća i samofinancirajuća „zelena” konstrukcija), [18]
 Fig. 7. The winning work of the Inhabited London Bridge Competition (2009), by Laurie Chetwood.
 (Energetically self-sufficient and self-financing “green” structure), [18]

Sl. 8. Prijedlog za naseljeni most preko Temze u Londonu (2009): arh Daniel Libeskind, [18]
Fig. 8. Proposal for the inhabited bridge over the river Thames in London (2009), by Daniel Libeskind, [18]

Sl. 9. Prijedlog naseljenog mosta (2009): arh Chris van Niekerk, The Fold Architecture, [18]
Fig. 9. Proposal for an inhabited bridge (2009), by Chris van Niekerk, The Fold Architecture, [18]

Nesumnjivo je da su strukture naseljenih mostova daleko složenije (slike 10-12) od struktura konvencionalnih (monomodalnih) mostova. No danas nam stoje na raspoloženju daleko bolji i „moćniji“ alati za analize ulaganja novca u investicije. Od CAD-a i VR-a do moćnih sofisticiranih paketa FE programa za svakovrsne analize statike, dinamike, stabilnosti, nosivosti i ekonometrijskih paketa za cost-benefit analize složenih građevina. Te složene strukture ne mogu ostvariti samo građevinari, već su to objekti koji traže blisku suradnju više struka kao što traže i više investicijskih timova, a ne samo kao danas više/manje jednog investitora.

Undoubtedly, the structure of inhabited bridges is far more complex (Figures 10-12) than that of conventional (mono-modal) bridges. On the other hand, nowadays we have much better and "powerful" tools available for the analysis of supplying money into investments: from the CAD and the VR, through powerful sophisticated FE program packages for performing all kinds of analyses of statics, dynamics, stability, capacity, as well as econometric packages for conducting cost-benefit analyses for complex structures. Structural engineers alone cannot realize these complex structures; these objects require close cooperation across several professions and several investment teams, instead of a single investor, as it is more or less the state of affairs today.

Sl. 10. Prijedlog za nove forme mosta u Amsterdamu (2012): arh Laurel Saint-Val, [19]
 Fig. 10. Proposal for some new forms of the bridge in Amsterdam (2012), by Laurel Saint-Val, [19]

Sl. 11. Helix bridge - pješački most čiji je uzor DNK spirala, Singapoor (2010): Cox Rayner Architects, [20]
 (Uložena su velika novčana sredstva u modelska istraživanja konstrukcije mosta)
 Fig. 11. Pedestrian Helix-bridge in Singapoore, modelled after the DNA spiral (2010): Cox Rayner Architects, [20]
 (Large sums of money were invested in the bridge structure model research)

Sl. 12. Saragosa paviljon – most koji živi (2008): arh Zaha Hadid, [16]
 Fig. 12. The Zaragoza bridge pavilion - a living bridge (2008), by Zaha Hadid, [16]

3 OPASNOSTI PRIMJENE PREDIT STEČENIH I NAUČENIH ZNANJA

Naša se (stara) generacija građevinskih inženjera zapravo dosta kasno susrela s kompjuterima, a tek relativno nedavno s pametnim gadgetima, iPadima, tabletima, Google očalama, 3D printerima, pametnim telefonima i raznim apletima. Novim generacijama je manipulacija s tim alatima nešto prirodno, dio njihova odrastanja, formiranja neurona. Mi (naša, starija generacija) možda se i služimo tim alatima i uređajima, ali zasigurno to nije dio našeg živčanog sustava. Podozrivi smo i na primjene ekspertnih sustava i robotizaciju. Većina konstruktora i građevinskih inženjera podozrivo gleda na te neželjene „vradžbine“. Tu nas prestižu neke druge struke. Još veća opasnost napretku struke prijeli od tradicionalnog prijenosa znanja s generacije na generaciju putem perpetuiranog načina prijenosa prošlih pred-IT (i često nebitnih) činjenica i znanja, na nove generacije (po principu „pleti kotac kao otac“), koje trebaju i moraju (a i djelovati će) u nama sasvim nepoznatim budućim uvjetima sve više ubrzavajućeg trenda IT i svakog drugog (recimo samo tehničkog) napretka. Te će generacije današnjih studenata djelovati u uvjetima post-IT ere nailazeće 4. Industrijske revolucije i IOT (internet of things) medija. Još uvijek se nastojimo na silu oduprijeti silom: akcija jednaka reakciji. Za sada i ne pomišljamo na inteligentnu (AI) manipulaciju akciji sila na građevinu. Gdje su istraživanja bioničke strukture?

U tom ustaljenom „tradicionalnom“ načinu prijenosa znanja, zasnovanom pred mnogo desetljeća, još se uvijek goje i tradicionalne (danas zastarjele – outdated) vještine i historicistički prikazi. Sasvim nebitni i sadašnjoj i budućim generacijama građevinskih inženjera. Već sam ranije predlagao jedan radikalni „outsourcing“ tih vještina i umijeća, bitnih u prošlosti, no potpuno nebitnih i današnjici i budućnosti. Osnivanje jednog novog studija (**tehničke** ili neke adekvatnije nazvane) **arheologije** bila bi jedna mogućnost očuvanja (pa i možebitnih izučavanja) tih danas irelevantnih, a nekima i još danas „dragih“ passe vještina, teorija i razmatranja. Uvjeren sam da je slično i s drugim strukama.

Mišljenja sam da tehnički muzeji nisu rješenje, jer se u njima izlažu (mrtvi ili tehnički zastarjeli artefakti), a ne „živa“ zastarjela građa (grafički i numerički postupci, teorije, itd.), o čemu su pisane bezbrojne knjige, priručnici, elaborati, znanstveni i stručni članci, studije i doktorati! Time bi se bitno gradivo građevinskog, a i drugih fakulteta odvojilo od te „slavne“ pred-IT prošlosti, a oslobodilo predmete studija od bespotrebnog viška historicizma i odvojilo bitno od nebitnog. I usmjerilo studente inženjerstva na inženjersko osmišljanje inženjerske problematike. S druge strane, svjesni smo jednog novog trenda studiranja putem online studija na WEB-u. Pa se i legalno postavlja i pitanje današnjeg (fizičkog) razvoja sveučilišta, pri naglom razvoju svjetskih online sveučilišnih kolegija i fakultetskog i specijalističkog obrazovanja (viditi TED na YouTubeu). U koju online edukaciju bi se trebala uključiti i naša sveučilišta, fakulteti i katedre. I naravno, naši studenti. Bez ikakvog odlaganja, treba od prvih godina studija studente usmjeriti na timski rad i međufakultetsku suradnju sa srodnim i nesrodnim fakultetima u istom gradu, i fakultetima u drugim grado-

3 THE DANGERS OF APPLYING KNOWLEDGE ACQUIRED IN THE PRE-IT ERA

Our (old) generation of civil engineers has actually quite late become familiar with computers, and not until relatively recently with smart gadgets, iPods, tablets, Google glasses, 3D printers, smart phones and various applets. Manipulating with these tools is something natural to the new generation; they are part of their growth and formation of their neurons. The older generation may also make use of these tools and devices, but surely it is unlikely a part of our nervous system. We are cautious when it comes to application of expert systems and robotics. Most structural and civil engineers take these unwanted "witchcraft" suspiciously. Some other professions are outperforming us in this regard. Even greater danger to the progress of vocation is the perpetuated transfer of obsolete, pre-IT (and often irrelevant) facts and knowledge to new generations (sometimes even the irrelevant facts of the past) that should cope with the completely unknown future conditions of the increasingly accelerating IT and any other (technical) progress. These generations of today's students will work in conditions of the post-IT era of the approaching fourth industrial revolution and IOT media. We are still trying to resist force with force: action equals reaction. For now, we have failed even to consider the use of intelligent (AI) manipulation with the action of forces on the structure. Where are the studies of bionic structures?

In this routine "traditional" way of transferring knowledge established many decades ago, traditional (now outdated) skills and historic representations, totally irrelevant both to present and future generations of construction engineers, are still thriving. I have previously proposed a radical "outsourcing" of these skills and knowledge which are historically important but completely irrelevant in present and future as well. Establishing a new study course of technical (or some appropriately named) archaeology would be a possibility of preserving (and potentially studying) these skills, theories and observations, which are nowadays irrelevant, but still so "precious" to some. I am convinced that it is the same when considering other professions as well.

In my opinion, technically museums are unlikely the solution, because they exhibit dead or outdated technical artefacts instead of the "alive" outdated material (graphical and numerical methods, theories, etc.) on which countless books, manuals, reports, scientific and professional articles, studies and doctoral thesis were written! Thus, the important teaching contents at the faculty of civil engineering, as well as curricula of other faculties, will be untied from that "glorious pre-IT" past, relieving study subjects from the unnecessary excess of historicism and separating what is important from what is unimportant, thus, focusing students of civil engineering to consider engineering issues in engineering ways. Likewise, we are aware of the new trend of conducting Web-based online studies, so that one can legally raise the issue of today's (physical) growth of universities in conditions of rapid development of global online universities and high and specialized education (see: TED on YouTube). This online education should be joined also with universities, faculties and departments,

vima u zemlji i inozemstvu, usmjeriti ih na projekte a ne na predmete. A naravno, međunarodna razmjena studenata i nastavnika je samorazumijevajuća. Zaboravlja se da će ti studenti djelovati u IT i post-IT okruženju kojeg danas i ne razaznajemo i KADA ĆE I STROJEVI MEĐUSOBNO KOMUNICIRATI – (vidi njemački projekt „Industrie 4.0” i „Smart manufacturing leadership coalition” u SAD).

U pregledu (Godišnjak 2013. Građevinskog fakulteta u Zagrebu) iz mnoštva tema diplomskih radova, pa magistarskih i doktorskih teza razvidno je da je malo uključena (nimalo!) suradnja s fakultetima u zgradi (arhitektonskim, geodetskim), a sasvim razvidno je da nema i neke suradnje između Strojarskog fakulteta (gdje se analiziraju konstrukcije brodova, razni mehanizmi i aktuatori), te FER-a, bez čije suradnje nema nekog napretka u suvremenom poimanju konstrukcija i građevina, te IT-a, robotizacije i ušteda energije. Bez suradnje građevinarstva i ekonomista s Ekonomskog fakulteta, arhitekata s fakulteta i privrede, ne može biti ni napretka u dizajnu suvremenih naseljenih i rentabilnih mostova. Most mora biti (i biti će) **sinergetski** proizvod.

... i umjesto zaključka...

Nedavno su mi se sa raznih strana u zemlji i inozemstva obratili neki doktorandi arhitekture, koji obrađuju (očito njima zanimljivu) temu našeg bivšeg stručnog angažmana i prisutnosti u zemljama tadašnjeg „trećeg svijeta” ili tzv. zemalja u razvoju, u kojima su naši stručnjaci raznih grana (medicine, arhitekture, urbanizma, kemije, visokog obrazovanja, raznih grana tehničkih djelatnosti, te i svih grana građevinske djelatnosti, kao i razna poduzeća) zemalja bivše Jugoslavije sudjelovali u razvoju zemalja Afrike, Azije, Južne Amerike. Bili su prisutni (recimo Industrogradnja) na tržištu bivšeg Sovjetskog Saveza. Također se veliki broj studenata iz zemalja trećeg svijeta školovao u zemljama bivše Jugoslavije. Tema očito interesantna. Dokumentacija je međutim zagubljena i rijetko dostupna. Istraživanja rada jugoslavenskih arhitekata, građevinskih i strojarskih inženjera, koji su djelovali u nesvrstanim zemljama praktički ne postoji, jer je i dokumentiranje njihova djelovanja bila njihova posljednja misao. Oni su bili koncentrirani na tekuće poslove i napredovanje poslova. Onda se našom ignorancijom, neznanjem i primitivizmom (uz naše golemo samozadovoljstvo i tzv. samodostatnost) sve urušilo, i ta atraktivna prosperitetna tržišta urušila. Nije bilo sve i samo u ekonomskoj krizi. Urušili su se, protokom vremena, nažalost, i razni poslovni i osobni kontakti. Tema očito zanimljiva. Sada se ti istraživači zanimaju tim zanimljivim temama naše prošlosti i istraživanjima kompleksnog mehanizma kompletnog urušavanja svih tih veza.

Samo naprednom primjenom najnovijih postupaka i IT i post-IT tehnologije, i najnovijih znanja i prepoznavanja trendova razvoja, uključivanjem u međunarodnu podjelu rada, možemo ponovno postati konkurentni, biti

and certainly, our students. Without any delay, students at the first year of study should be focused on teamwork and inter-faculty collaboration with related and unrelated faculties in the same city, and faculties in other cities in the country and abroad, focusing them on projects rather than subjects. Obviously, the international student and teacher exchange is self-evident. We sometimes forget that these students will be working in the IT and post-IT environment, which are nowadays difficult to discern, when even machines will be communicating between themselves – (see the German "Industrie 4.0" project and the US "Smart manufacturing leadership coalition" project).

From the 2013 Yearbook of the Faculty of Civil Engineering in Zagreb, the multitude of graduate theses, and even master's and doctoral theses, indicate that the degree of cooperation with other faculties situated in the same building (architectural, geodesy) is poor (if any), while there is a striking lack of collaboration between the Faculty of Mechanical Engineering (where ship structures, various mechanisms and actuators are analyzed) and the FER; without this kind of cooperation there is unlikely any progress in comprehensive understanding of structures and buildings, the IT, robotics and energy savings. But without such cooperation among cited faculties and other large enterprises there is unlikely any progress in designing modern inhabited and profitable bridges. The bridge should be (and will be) a synergetic product.

... And instead of a conclusion ...

Recently, I was approached by several doctoral students of architecture both from country and abroad, who research the issue of our past professional engagement and presence into the development affairs of the "third world", or the so called developing countries, where experts from the former Yugoslav countries in various fields (medicine, architecture, urban planning, chemistry, higher education, various branches of technical activities, and all branches of civil engineering, as well as various companies) participated the development (Africa, Asia, South America). They were also present (Industrogradnja, for example) on the market of the former Soviet Union. Also a large number of students from the third world countries studied in countries of the former Yugoslavia. Obviously an interesting topic. The documentation is however lost and rarely available. There are practically no studies regarding the work of Yugoslav architects, civil and mechanical engineers, who worked in the non-aligned countries, because documenting their operations was the last thing in their minds. They were focused on current jobs and how they advanced. Then, as a result of our ignorance, arrogance and primitivism (along with our vast complacency and self-sufficiency), all have collapsed, along with these attractive and prosperous markets. It was not caused merely by the economic crisis. Unfortunately, over time, various business and personal contacts have also broken. Obviously an interesting topic. Now, these researchers pursue are busy with studying these interesting topics of our history and investigate the complex mechanism of the complete breakdown of these connections.

Only based on the advanced application of the latest

prisutni, ili bar biti zanimljivi na međunarodnom tržištu. Za tu budućnost se trebamo brzo mijenjati, uključivanjem u međunarodne projekte i međunarodnu podjelu rada. No da li smo se voljni brzo mijenjati? Gdje se može brže i bolje uspostaviti kontakte i prijateljstvo, nego li u fazi studija i međunarodnoj (i interdisciplinarnoj) problemski orijentiranoj on-line suradnji studenata u svijetu. Trebamo postati prvi u našoj grani - zašto ne?

procedures of both the IT and the post-IT technology, as well as the latest knowledge, and the recognition of development trends, including international division of labour, we may become competitive again, be present, or at least interesting to the international market. For this goal of future achievement, we need to change rapidly, and include in international projects and international division of labour. But, are we willing to change rapidly? Where can contacts and friendships establish faster and better than at the studies and in international (and interdisciplinary) problem-oriented on-line collaboration among students worldwide? We need to become leaders in our industry. Indeed, why not?

*Sl. 13. Prijedlog naseljenog mosta preko reke Arno, Firenca (2009): Gruppo Giovani Architetti Firenze, [21],
(Postupno shvaćanje potrebe „oslobađanja” treće dimenzije!)*

*Fig. 13. Proposal for the inhabited bridge over the river Arno in Florence (2009): Gruppo Giovani Architetti Firenze, [21],
(Gradually understanding the "deliberation" of third dimension!)*

Sl. 14. Prijedlog za naseljeni most u Kopenhagenu (2008): arh Stephen Holl, [22],
(Struktura sadrži ekonomski samoodrživu tehnologiju: vjetrovne turbine, fotovolatilnu oblogu nebodera. Most sadrži javne
sadržaje, urede, trgovine, terase, razne pješačke komunikacije, elevatore, liftove, staze)

Fig. 14. Proposal for a inhabited bridge in Copenhagen (2008): arch Stiphen Holl, [22], (The structure holds economic
self keeping technology: wind turbines, photo volatile skyscraper casings. There are public spaces, offices, shops,
terraces, various pedestrian communications, excavators, elevators and pathways)

Sl. 15. Prijedlog „Naseljenog vrtnog mosta između Hrišćanstva i Islama za 21. stoljeće” u Rimu (1997): Studio Bednarski
Ltd., [23]

Fig. 15. Proposal for the "Inhabited Garden Bridge between Christianity and Islam for the 21st century" in Rome (1997),
by Studio Bednarski Ltd., [23]

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REZIME

NASELJENI MOSTOVI: UMJETNOST I ZNANOST (boje li se arhitekti dizajna mostova)

Zvonimir ŽAGAR

Raspravlja se o aspektima razvoja i potrebe ponovnog sagledavanja nekih problematika građevinske i arhitektonske struke. Prvenstveno s pogleda integracija znanja u IT i post-IT (IOT) eri, koja naprosto vapi za bitnim promjenama u načinima edukacije, projektiranja i globalnih sagledavanja problematike koju naše struke rješavaju, ili bi bar trebale rješavati, ukoliko žele opstati u novom IT okruženju i biti konkurentne svjetskim trendovima. Umjetnički i ekonomski pristup nadopunjuje tehničke aspekte dizajna naseljenih mostova. Potrebno je pri tome osloboditi se pred-IT naučenog naslijeđa o projektiranju i gradnji mostova u urbanom tkivu. Općenito je potrebno probleme sagledavati sinergijski i rješavati ih interdisciplinarno i multidisciplinarno.

Ključne riječi: Građevinarstvo, arhitektura, IT, obrazovanje, povrat uloženog kapitala, mostovi, naseljeni mostovi, sinergija.

SUMMARY

INHABITED BRIDGES: ART AND SCIENCE Are architects afraid of designing bridges?

Zvonimir ŽAGAR

This paper discusses the aspects of development of the civil engineering and architectural vocation and the need for re-considering some of the problems they are facing; all this primarily from the aspect of integration of knowledge in the IT and post-IT (IOT) era, which is in desperate need for substantial changes in terms of education, design and global consideration of issues addressed, or at least have to be addressed, by our occupations, if they choose to survive in the new IT environment and if they are competitive in global trends. Artistic and economic approaches complement technical aspects of designing inhabited bridges. Additionally, the pre-IT knowledge about designing and building bridges in urban framework should be abandoned. Generally, the problems should be considered synergistically and addressed in interdisciplinary and multidisciplinary ways.

Keywords: civil engineering, architecture, IT, education, return on investment, bridges, inhabited bridges, synergy.