Innovations in construction and the practical potential of wood in student projects

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Annotation. The problems of environmental pollution on the planet, the processing of human waste, makes architects and builders look for a solution to the problems by means of architecture and new technologies in construction. The article deals with the construction of wooden and wood structures in the Western countries, in particular, the construction of high-rise buildings as an alternative to the concrete and metal constructions. Wood as a modern high-tech, reliable and environmentally friendly building material in comparison with other materials shows its advantages in many ways. Article presents separate project proposals within the framework of the International Student Competitions "Timber in the city: Urban Habitats" 2018-2019 and 2015-2016 organized by the Association of University Architectural Schools of the USA - ACSA, as well as examples of unique wooden structures designed by famous architects. The XII International Congress on Wooden Construction in Moscow Recommendations, including ones on education and the need to train relevant specialists in Russia, are examined.

The deteriorating situation of ecologies in the world, the ethical implications of: the growing scarcity of freshwater resources; diminution of energy resources and their possible replacements; destruction of pollutants throughout the world; and the processing and recycling of human waste to integrate architects, planners, builders to seek problem resolution through architecture. Today, in the European countries: Finland, Sweden, Italy, Austria, France and in USA and Canada the specialists are building high class and business apartments and public buildings with use of timber construction techniques, multistorey wooden residential blocks are established. The timber construction is a modern, reliable, high-technology and environmentally friendly building material. In Russia, as in many countries, limitations are exist number of storeys of the wooden buildings. For instance, in Finland it is not allowed to build houses with height no more than three floors, in Austria - is no more than five floors, in Canada - is no more than six floors, and in Russia - the height limitation of three floors.

The professionals dealing with the ecological problem really, comparing the pros and cons of the modern industrial timber construction and of traditional reinforced concrete and steel construction, have come to realize that architects and planners may play a leading role in the promotion of the industrial wooden housing concept. In addition, the concrete production, erection and recycling of concrete and other inventive materials causes to intensity carbon emissions and to environmental pollution. The construction of buildings with these materials are estimated to be responsible for half of all greenhouse gas emissions in the world. Wood is an important material for ensuring a sustainable
future; it has a neutral carbon footprint, it is renewable, and the manufacture of wood products has a smaller environmental impact than that of competing building materials. Carbon dioxide is remain locked in if the wood was used to make construction materials or processing into woodbased materials. Wood is the unique material and estimated to be the carbon store. 

As international practice shows, organizing and holding various competitions, events, festivals helps to receive and propose new ideas. A good examples is in the field of training young architects and town-planners in USA and Canada are regular competitions on current themes. For example, for the academic year 2018-2019, Association of Collegiate Schools of Architecture (ACSA) in USA is pleased to announce the International student design competition "Timber in the city 3: Urban Habitats” in May 2018. This was the third student design competition "Timber in the city".  

Over the year, U.S. students had worked on the design project with their teachers. Research and design work on the competition should be structured over the course one or more semesters of the 2018-2019 academic year. An intention of all ACSA competitions is to make students aware that research is a fundamental element of any design solution. 

Architecture students (two teams) from the Irkutsk National Research Technical University (INRTU) took part in this competition since the second semester of 4-course (spring of 2019 year). During the project development stage the students found that there are important gaps in skills and knowledge about wooden multistoried structures. 

It was noted in the summaries that "Timber in the City: Urban Habitats Competition", organized by the Association of Collegiate Schools of Architecture (ACSA), the Binational Softwood Lumber Council (BSLC) and Parsons School of Design, attracted more than 920 architectural students and faculty. Entrants designed proposals to imagine the transformation of our cities through sustainable buildings from renewable resources, offering efficient affordable construction, innovating with new and traditional timber materials, and designing healthy living and working environments. The winning entrants, with prizes totaling $40,000, were chosen by a panel of leading architects and professors based on the design’s ability to integrate wood as the primary structural material while meeting the needs of the local community. The competition focused on a vacant waterfront site in Queens, New York, as a vibrant and vanguard model of healthy, biophilic living for the future of the city. Students were asked to design a mid-rise, mixed-use complex that includes affordable housing, a large community wellness facility, and an early childhood education center, all interlaced with a new exterior public waterfront space. Entrants were challenged to propose construction systems in scenarios that draw optimally on the performance characteristics of not one, but a variety of wood technologies. ACSA is pleased to announce the winners of a student design competition exploring wood as an innovative building material” [1].

"First Place: Aperture
The University of Maryland’s winning submission attracted the jurors with its intelligent use of timber construction techniques. The orientation of the buildings creates a protective plaza linking the buildings to the community with a clear understanding of the urban context.

Second Place: Re-Gen Growth
The City College of New York’s winning submission stands out for its innovative use of wood, which connects spaces, structure and the user experience all together. The density of the project represents a three-dimensional occupiable city.

Third Place: Timber Living
The University of Illinois at Urbana-Champaign’s submission has a strong grasp of timber construction and how to assemble it in a clever way. The project shows an advanced integration of sustainable measures” [1].

The programs for this mixed-use development are composed to challenge students and educators to think creatively and critically about the way in which choices about building materials, and the interrelationship of interior space and the exterior environments frame long-term consequences for the health of urban environments. Housing is the largest component of the competition program and presents an opportunity to look closely at the way timber construction can be used effectively in
creating buildings based on smaller cellular units (figure 1a). A community wellness and sports facility complements the housing, and offers larger community and collective spaces that will require larger structural spans. An early childhood education center, for children from 6 weeks to 5 years old, calls attention to the critical role these institutions play in the long-term vitality and development of a community.

**The materials.** The competition challenges participants to interpret, invent, and deploy numerous methods of building systems, with a focus on innovations in wood design on a real site. For thousands of years, solid wood has been used as a building material. Modern timber products and systems have greatly expanded the potential uses of this historic material. Timber is an ideal green building material: it is well suited for a broad range of structural and aesthetic applications, it offers economical construction and high performance characteristics in strength and energy efficiency; and wood is an economic driver to maintain forests and protect jobs in rural communities.
Criteria for the judging of submissions will include: timber/wood as the primary structural material, creative and innovative use of timber/wood in the design solution, successful response of the design to its surrounding context, the creative and clear approaches to designing a healthy urban mixed use environment with timber as a central material, and successful response to basic architectural concepts such as human activity needs, structural integrity, and coherence of architectural vocabulary.

The tasks assigned during competition "Timber in the city 2015-2016" had been like tasks next competitions, especially in term to use wood to construct new settlement units. It was noted in the project summary of the competition winner that "This winning submission is outstanding for its inventive formal strategy and expressive use of timber. The concept of stacking volumes with core atria dropping down is very nice, creating a lot of visual depth and variation not typically found in New York City. The scale of the market and gallery spaces read as great urban rooms with the residential spaces floating above. The contrast of the dark wood exterior and the warm, glowing interior also add to the aesthetic interest of the building. The project takes advantage of mass timber and its natural partnership with modular construction, which pairs well with the project’s massing. The story of constructability presented through the diagrams is believable and there is a clarity to the structural assembly and delivery methods (figure 1b). Although the part of stacked volumes is appealing, it would have acoustical issues and thermal implications from the extraneous surface area. Another technical issue is that the CLT is loaded on its weak axis. Lastly, this team was progressive in
their approach to the program. There integration of communal residential spaces and areas for urban farming is great, and it is nice to see built-in, systematic environmental strategies” [2].

As for the two competitive projects carried out by the students of Irkutsk National Research Technical University (INRTU), in both cases the tasks were solved: to use natural factors efficiently, such as adjacent river, opening on Manhattan, to form a new favorable social environment that stimulates pedestrian and physical activity, to implement a number of innovations in planning, landscaping, eco-friendly construction and architecture using wooden structures.

![Figure 2](image)

**Figure 2.** Fragments of the project No.1 students of the INRTU "Timber in the city 2018-2019": (a) floor Plans for the pool and children's center and interiors; (b) apartment Plans of a residential building made of prefabricated elements. Facade.

The town-planning concept of the project No. 1 is to create a coastal boulevard with public buildings inscribed in the landscape of the river and constituting an indissoluble whole with it.

The unique architecture of Community Wellness Center with an Olympic swimming pool on the river and an Early Childhood Educational Center evokes associations with green hills of natural environment, becoming a part of the design of city embankment and of the nearby park (figure 2a). An increasing height of housing units from 7 to 9 floors represents the dynamic development of the area from the embankment to the neighborhood interior. All three objects have internal connections among themselves at the level of the 1st floor. The complex is a new type of communal residential building with shared spaces for residents. It solves the problem of disunity of residents in urban apartment buildings focusing on their common interests in sports, early childhood, carrying out joint activities, thereby improving the quality of life (figure 2b).

**Construction elements and Assemble.** Residential complex is assembled from prefabricated modules, which are installed as in LEGO. The bearing construction elements (CLT-panels) are connected using studs on the edges of the panels, which are to insert into the grooves of adjacent panels without using metal bolts or nails. Vertical communication stiffness core with staircases and
elevator shaft, internal transverse and longitudinal bearing walls are the bearing elements of the residential design.

The minimum of large openings in the inner bearing CLT panels provides structural stiffness to the building. All the construction elements meet the requirements of fire safety, thermal insulation, sound insulation and ecology. External walls are self-bearing, panels are 7-ss TL thick: 280 mm (figure 3). The pool and the multifunctional gymnasium are covered by arched structures made of glued timber beams. The floors are seven-layer CLT panels, reinforced with T-glued beams.

![Figure 3](image.png)

**Figure 3.** Fragments of the project No. 1 students of the INRTU “Timber in the city 2018-2019”. Perspective of a residential building with a pool roof. The process of installing a residential building from prefabricated elements.

Both separate constructional elements and ready-made large building blocks of a high completion level can be delivered to the construction site: blocks are supplied with electricity, communication, water. Compared with the reinforced concrete, they can be mounted two times faster and with a much more smaller number of workers. Thanks to the module’s high degree of prefabrication, complete decoration of their internal surfaces, as well as the availability of the necessary fixing elements, the panels are completely ready for installation.

The economic effect is achieved through: quick assemble in the absence of a wet process, the use of environmentally friendly renewable natural material - timber and full prefabrication of the mounted constructional elements.
Figure 4. Fragments of the project No. 1 students of the INRTU: (a) idea of the project; (b) plans and perspective of a residential building; (c) the plans of the apartments, interiors; (d) the process of installing a residential building from prefabricated elements.

The second project proposal No. 2 is based on the revival of the idea of building housing from prefabricated three-dimensional blocks of wood, where each represents a separate living room or even a three-dimensional cell for two small bedrooms. The complex composition is a narrowed in upper part multi-luminous atrium space, formed by ledges of put on each other three-dimensional modules, with an exit to the river side. Sports halls and children's facilities occupy the first floors of the complex (figure 4 (a), (b), (c), (d)).
Fast construction process. The advantage of this design is that each cell is assembled at the factory. It is delivered ready-made to the site and can be installed by a crane, which speeds up the construction process. Frames and crossbars get installed on the construction site, blocks of residential cells get attached to them. If necessary, it is possible to replace the cells.

I would like to note the original project of the Japanese architect Shigeru Ban of the seven-storey building of the Tamedia publishing house with an area of 1000 m² in Zurich. The entire internal structure of the new building of the concern "Mediengruppe Tamedia" in Zurich (beams, ceilings, even dowels for fasteners) is made exclusively of wood. This masterpiece, combining traditional materials with the latest technologies and approaches in architecture, was the result of collaboration between Swiss engineers and an outstanding Japanese architect (figure 5 (a), (b), (c), (d).

![Figure 5](image url)

**Figure 5.** New building of the publishing concern "Mediengruppe Tamedia" in Zurich, architect Shigeru Ban. Construction fragments and nodes. Example of combining traditional materials with the latest technologies.

Details of the supporting structure of the building from wooden pillars were glued together, and then processed on a milling machine with an accuracy of up to a millimeter. The finished parts were joined on the construction site in a structure which is a five stories high wooden frame. The supporting elements of the structure were connected without the use of bolts and nails. The facade is completely made of glass. This building has a "pleasant working atmosphere". When comparing CO2 emissions from the wooden building construction and buildings made of concrete and metal, it turned out that in the first case, CO2 emissions are one-third lower than when they are built from metal. The savings
when compared with concrete were about 50%. This example clearly demonstrates that on a global scale, building from wood and wood-containing materials can significantly improve the health of the planet. In addition, wood is the only renewable building material.

In March 2019, Moscow hosted the XII international Congress on wooden construction, the main theme of which was designated as: "a Wooden house is a national priority!" In 2019, the Russian Government approved the strategy for the development of the forest complex until 2030. One of the priority areas reflected in this document is wooden house construction. The regulatory framework improvement and building codes development was launched. The Ministry of industry and trade and the Ministry of construction have already developed standards for new types of building materials. It is possible to begin broad use of wooden structures is possible in the construction of public buildings. Russian companies shared their experience in implementing such projects, including large sports facilities built of wooden structures in St. Petersburg, Kazan, Moscow, Krasnoyarsk, whose architecture is unique (figure 6).

![Figure 6. Major sports wooden facilities in Russia: (a) water park in Saint Petersburg; (b) palace of water sports in Kazan.](image)

Director of Zaha Hadid Architects (Great Britain) architect Jim Severin presented at the Congress a unique project of the world's first fully wooden five-thousand-seat stadium in England. Qatar's 'Al Wakrah' stadium, which is capable of holding 40,000 spectators. the 2022 world cup venue designed...
by the late Zaha Hadid with use of the carbon-neutral of the wooden constructions, was inaugurated on Thursday May 16, 2019 (Figure 7 (a), (b)).

Figure 7. Stadiums on the design by Zaha Hadid Architects: (a) the world's fully wooden five-thousand-seat stadium in England; (b) the carbon-neutral of the wooden constructions in Qatar.

It turned out that the construction of wooden high-rise buildings is a technically simple process. Almost all the necessary materials for a wooden house are produced in Russia, but its assembly requires high qualification of construction workers. The largest in Europe OSB building slabs production plant - DOC "Kalevala" functions in Karelia, and LVL (Laminated Veneer Lumber) production for frame racks and ceilings is in the city of Torzhok (Tver region). Experts highlight three advanced technologies that are widely used in the West and that are quite applicable in Russia. CLT panels are cross-glued wooden slabs and wall panels (Cross Laminated Timber), whose properties are close to reinforced concrete, but six times lighter than reinforced concrete slabs. CLT panels thermal insulation properties are 3-5 times higher than similar properties of brick or concrete walls. Panels are assembled with bolts and screws without the use of additional equipment. This is a new technical
solution. Proper use of wood and adhesive joints can significantly increase the rigidity and strength of the plates.

Houses made of this new material are fast-built and economical. Swedish experts estimate that the construction of wooden multi-storey houses is 5-20% cheaper than the construction of concrete panel houses, since simpler tools are used, and less transportation is required. Such buildings also are energy saving: 1 sq.m energy consumption is only 65 kWh per year. In Russia, in brick houses, heating consumes 130-150 kW per 1 sq. m.

In addition, wooden buildings, even the high-rise ones, built using modern technologies, are eco-friendly and safe. As for earthquake-prone regions like ours - with estimated seismicity of up to 8 and 9 points, prefabricated wooden multi-storey buildings can withstand such earthquakes, since they are also lighter than reinforced concrete and brick. As for fire safety and reliability, wooden structures resist the effects of high temperature for at least 45 minutes from the beginning of the fire. At the high temperature (on different reanalysis data from 400$^0$ C) metal structures had reduced the bearing capacity. Low energy costs for production, transportation, installation, ease of operation and disposal confirm the advantages of wood as a building material.

Famous canadian architect Jim Heverin, who devoted his life to research and promotion of multi-storey wooden house construction, was surprised that the share of wood in Russia – the most forested country in the world – is only a few thousandths of a percent. He was also strunned by the lack of special architectural institutions in Russia and even by the absence of wooden construction training programs.

The Congress adopted a resolution to give priority to education and training of relevant specialists in Russia.

References
[1] https://www.competitions@ACSA-ARCH.org 2019 Timber in the City-competition winner 10.08.2019
[2] https://www.timberinthecity.com
[3] https://www.acsa-arch.org
[4] Maevskaya Marianna. Wooden skyscrapers. Traditional materials in innovative technologies of modern high-rise construction. Contemporary world's architecture, #11. 2018. Available at: http://www.nittiag.ru/pub/pub_cat/sovremennaya_arkhitektura_mira_11. Ed., comp. N. A. Konovalova. - Moscow-SPb.: Nestor-History, 2018.
[5] Rasuleva Yu.V., Kudasheva D.R., Titarenko A.V. (2019). The concept of a multifunctional urban xoskeleton. The Eurasian Scientific Journal, [online] 4(11). Available at: https://esj.today/PDF/18SAVN419.pdf (in Russian)
[6] https://www.archdaily.com/930422/timber-trends-7-to-watch-for-2020
[7] https://research.thinkwood.com/
[8] Baranova A A and Bobrova A A 2019 Dispersed reinforcement of cellular and fine-grained concrete based on silica fume Proceedings of Universities. Investment. Construction. Real estate 9(4) pp 694–703
[9] Petrov A V and Efimova A K 2019 Nguyen Thanh Tung. Optimisation of technology used for restoring gas-ash concrete outdoor wall panels using modified structural and heat-insulating concrete. Investment. Construction. Real estate 9(3) pp 542–549
[10] Selezneva O I, Radaev S S and Baranova A A The impact of thermal treatment on the granulometric and chemical composition of diatomite of the Kamyslov field when obtaininga liquid-glass binder Investment. Construction. Real estate 9(3) pp 550–555
[15] Peshkov A V 2019 Digitalization of the economy, implementation of national projects and development of the construction industry Investments. Construction. Real Estate: New Technologies and Targeted Development Priorities IOP Conference Series: Materials Science and Engineering 667 012074

[16] Tyuryukhanov K Yu and Pugin K G 2019 Impact of the surface of particles of moulding sand on the structural formation of asphalt concrete Proceedings of Universities. Investment. Construction. Real estate 9(3) pp 566–577

[17] Dobruskina M A, Petrov A V and Bat-Erdene Z 2019 Improving the technology of retaining walls in the Irkutsk region using gabion baskets Proceedings of Universities. Investment. Construction. Real estate 9 (2) pp 312–323

[18] Moskvitin V A., Emelyanova N A. and Mashovich A Y 2019 Experimental studies of air permeability indicators of composite "Poroplast CF" Investment. Construction, Real estate 9 (2) pp 342–353