Scientific report for Period 1

PART 1 – INFORMATION ON PROGRAM

1.1. Title of the program	**Innovative Materials and Smart Technologies for Environmental Safety**
1.2. Program acronym:	**IMATEH**
1.3. Program web page address:	http://imateh.rtu.lv
1.4. Program manager (name, surname, phone, e-mail):	Dr.sc.ing. Andris Cate, +371 26416672, and_cate@latnet.lv
1.5. Contact person (name, surname, phone, e-mail):	Dr.sc.ing. Diana Bajare, +371 29687085, diana.bajare@rtu.lv
1.6. Report for a period	from 01.01.2015 till 31.12.2015

1.7. The aim of the program and objectives:

The aim of the National Research Programme:
Contribute to the creation of world class knowledge base, which would be wide and deep enough for innovation-based economic development involving innovative materials, smart technologies and safe human living environment, by using interdisciplinary approach in solving of scientific, technologic and social problems.

National Research Programme (NRP) has a practical orientation; each of its tasks will contribute to the important sectors of the Latvian economy - Construction, Transport, Material Processing. In the same time, the main target of the research programme is to create new knowledge about use of innovative materials to ensure safe living environment, to facilitate technology transfer to the economy by contributing to the restructuration of the national economy according to the smart specialisation strategy for the long-term development in Latvia. In the framework of this programme innovative materials, technologies, recommendations and guidelines will be developed in order to build higher safety level of living environments and to raise competency of the scientists in this area as well as to improve normative acts and standards.

The following tasks have been set to achieve the target:

1. *Create and investigate multifunctional materials and composites, including composite materials for sustainable buildings, and bio-materials such as CO_2 neutral or negative fibre composite;*
2. *Create and investigate multifunctional materials and composites, including modified materials for plywood sandwich panels;*
3. *Develop new methods of risk assessment for buildings and structures to ensure their safe, efficient and sustainable operation.*
4. *Create a layered wood composite with rational structure that provides increased specific bending load-carrying capacity, reduced cost of materials and energy consumption compared to traditional wood-based materials used.*
5. *Develop methods for materials, micro-, nano-scale features and improve the quality of diagnosis;*

6. *Develop a methodology and criteria for optimization of metallic material properties to improve the surface treatment and coating to reduce friction and wear of friction pairs including interaction with metal surfaces and ice.*

The accumulated knowledge in a form of publications, recommendations, technologies, methodology and other scientific documents will be available to producers of construction materials, civil engineers, planners, as well as legislative and supervisory institutions resulting in economic development and direct improvement of human living environment safety for the existing and future infrastructure.

Highly qualified scientific staff from the Riga Technical University (RTU) and the Latvian University (LU) is involved in the NRP. High qualifications of the Programme executors are attested by scientific publications (CVs of the main executors were included in Programme proposal, Annex 1), previous, active and submitted projects (were included in Programme proposal, Annex 2), as well as membership in professional associations and other professional activities (were included in Programme proposal).

Interdisciplinary research is included in the Programme. Main executors come from various scientific directions, such as: Construction Science (Construction Materials and Technologies, Structures); Mechanics (Construction Mechanics); Material Engineering and Mechatronics, Transport (Land Transport and Infrastructure); Material Science (Wood Materials and Technology, High Temperature Materials); Mechanics of Solids, Mechanical Engineering, Chemical Engineering (High Temperature Materials and Plasma Technology).

In order to facilitate development and sustainability of the sector, 11 young scientists, 11 doctoral students and 6 master's students are involved in the NRP, the total number of young scientists being up to 70%. Part of the young researchers has performed their research in the scientific institutions abroad.

In order to increase scientific capacity of the NRP, highly qualified scientific personnel of SIA „D un D centrs" and SIA „Evopipes" is attracted. "D un D centrs" was founded by scientists and engineers coming from the former Riga Aviation University specializing in monitoring and diagnosis systems for civil aviation. The approach of "D un D centrs" to R&D includes three main components: advanced investigation techniques, integrated models of both vibration and other machine's parameters and malfunction tests. Modern data processing techniques provide high effectiveness of measurement and analysis but the testing allows to adopt the diagnosis model and to determine the limits of measured parameters' alterations. „Evopipes" was founded in 2005 for the implementation of the polymer pipe production project in Jelgava, Latvia. At the end of 2008 the company began mass production offering wide range of products. „Evopipes" is the most advanced polymer pipe production complex in Europe, which uses the latest technology achievements, with annual production capacity of 14,000 tons of pipes. The products are tested and verification of their conformity to certain criteria is done in the laboratories of the Riga Technical University and Lithuanian Institute of Power Engineering. Company collaborates with the Riga Technical University, Faculty of Civil Engineering, Institute of Heat, Gas and Water Technology.

Strategic Management Group is established for the scientific monitoring of the Programme. Strategic Management Group consists of the Programme leader and project leaders and at least two internationally renowned scientists who are assessed according to h-index, WoS, SCOPUS or publications in journals of the respective sector validated by the ministry as well as two experts from the respective industry. Two scientists (Professor and Head of Department of Bridges and Special Structures **Gintaris Kaklauskas** from the Vilnius Gediminas Technical University (VGTU) and Director of the Institute of Materials Science, Professor of the Physics Department **Sigitas Tamulevicius**, Kaunas University of Technology (KTU)) and two experts (**Raimonds Eizensmits** Chairman of the LIKA (Latvian Association of Consulting Engineers) Board (Latvia) and **Renars Spade**, Expert of the Ministry of Economics (Latvia) have agreed to be included in the group and their CVs are included in Annex 4 of programme proposal.

The main responsibilities of the Programme leader and project leaders are to plan the cash flow and prepare progress reports and payment requests as well as to demand accounting documents and to summarise data on the activities and results. An option of mutual replacement among the project members is foreseen. Regular communication among the project members is planned to achieve this, especially with the cooperation partners, as well as regular control of the execution of tasks.

Programme leader and project leaders are responsible for time frame completion control, analysis of reasons causing delay and suggestions for improvement, corrections in time frame if necessary as well as timely planning of tenders, monitoring of the document exchange system.

Programme leader is responsible for conclusion of detailed Cooperation agreement with the cooperation partners, coordination and control of performance of the contract as well as respecting of work plan and time frame, timely preparation of progress reports.

Projects leaders (Programme consists of 6 projects) are responsible for achievement of the project targets, development of relevant methodology, detailed assessment of the experimental and theoretical data and corrections in work plan if necessary. Projects leaders are also responsible for timely planning of equipment maintenance and repair works as well as purchases of spare parts.

Executors of the NRP have modern and well equipped laboratories with the exploitation period of equipment being up to 7 years, for example, some of the project executors have participated in the project "Infrastructure Development in the National Research Centre for Nanostructured and Multifunctional Materials, Structures and Technologies", where one of the activities was purchase and installation of the scientific equipment in the Riga Technical University. Involvement of the executors of the Programme in various projects with national and international funding as well as research volume and publications in scientific journals points out the suitability of the existing infrastructure for needs of the NRP. To be able to ensure research sustainability, participants of the NRP have submitted several project proposals to the EU funded project Horizon 2020 *(Apvārsnis 2020)*, for example, in call H2020-COMPET-2014, COMPET-02-2014, activity RIA, project No. SEP-210135862, acronym FUCOLAS; in call H2020-COMPET-2014, COMPET-11-2014, activity CSA, project No. SEP-210137040, acronym COSMOS2020 etc. Currently information is being gathered and possible partners being identified for submitting proposals to the new Calls for proposals, such as M-ERA.NET, which are open every year, etc.

1.8. Executive summary of the Programme

(max. two A4 pages. Summary of scientific results achieved during reporting period, their scientific and applicational significance)

The planned targets of the NRP IMATEH in general as well as for each project in the framework of the programme were fully achieved in the reporting period from 01.01.2015 till 31.12.2015. The planned tasks are completed and the main results obtained. Detailed information on the scientific achievements of each Project is given in the Section 2 of this Report,

In the framework of this Programme 25 full length scientific papers were accepted during the Period 2 (performance indicators for Project 1 are 9 full length papers, performance indicators for Project 2 are 1 full length papers, for Project 3 − 10 papers or abstracts, for Project 4 – 4 full length paper or abstracts, for Project 6 – 1 full length paper). 14 scientific papers from them are included in the data bases Scopus or Web of Science. **All published papers in full length are included in report ANNEX PP.**

Participants of NRP IMATEH took part in **32 international conferences** with oral or poster presentations and presented newest achievements of their research.

In that time period are submitted and approved 14 abstracts or full length scientific papers for international conferences which will be organised in 2016.

In the framework of programme 13 master's thesis and 18 bachelor's thesis have been defended in the Period 2.

As planned, **doctoral researchers are involved** in the Period 2 of NRP IMATEH. The following theses were prepared in addition to the research planned in the Period 2:

1. J. Justs „Ultra high performance concrete with diminished autogenous shrinkage technology", supervisor D. Bajare, planned to defend in 2016
2. J. Tihonovs „Asphalt concrete mixes from the local mineral material with high exploitation properties", supervisor J. Smirnovs, V. Haritonovs, planned to defend in 2017
3. M. Shinka „Natural fibre insulation materials", supervisor G. Shahmenko, planned to defend in 2017
4. N. Toropovs „Fire resistance of high performance concrete", supervisor G. Shahmenko, planned to defend in 2016
5. I. Paeglite "Impact of moving load on the dynamic properties of bridges", supervisor professor, Dr.sc.ing. J. Smirnovs, planned to defend in 2017;
6. A. Freimanis „Risk assessment of secure, efficient and sustainable bridge constructions", supervisor professor, Dr.sc.ing. A. Paeglitis, planned to defend in 2018;
7. R. Janeliukshtis „Development of damage identification method for the monitoring of technical condition of constructions", supervisor professor, Dr.sc.ing. A. Cate, planned to defend in 2018A.
8. Vilguts "Rational structures of multistorey buildings made of layered glued wood composite", supervisor professor, Dr.sc.ing. D. Serdjuks, planned to defend in 2018
9. G. Frolovs "Calculations of rational structures and elements of structures from wood composite materials", supervisor professor, Dr.sc.ing. K.Rocens, planned to defend in 2017;
10. A. Kukule "Work of plywood board ribs in the conditions with humidity changes", supervisor, professor, Dr.sc.ing. K.Rocens, planned to defend in 2017;
11. O. Bulderberga "Function of mechanical damage detection in polymer composite material: development and study of properties", supervisor A. Aniskevics, planned to defend in 2017
12. E. Labans "Development and improvement of multifunctional properties for sandwich structures with plywood components", scientific supervisor Dr.sc.ing. K. Kalniņš.
13. M. Ķirpļuks "Bio-based rigid polyurethane foam and nano size filler composite properties", scientific supervisor Dr.sc.ing. U. Cābulis.

U. Lencis defended the doctoral thesis „ Methodology for use of ultra sound impulse method in assessment of construction strength" (supervisor A. Korjakins) and obtained PhD in engineering (18.06.2015.).

A. Sprince defended the doctoral thesis "Methodology for determination of long-term properties and crack development research in extra fine aggregate cement composites" (supervisor A. Korjakins) and obtained PhD in engineering (10.04.2015.).

Patents:

1. Rocens K., Kukule A., Frolovs G., Sliseris J., Berzins G. LV14979 „Method for producing ribbed plates" – The Official Gazette of the Patent Office of the Republic of Latvia 20.06.2015, pp 785 – http://www.lrpv.gov.lv/sites/default/files/20150620.pdf
2. Rocens K., Frolovs G., Kukule A., Sliseris J. LV15083 "Method and equipment of production for ribbed composite plate with goffered wood-based core". – The Official Gazette of the Patent Office of the Republic of Latvia 20.12.2015, pp. 1749. – http://www.lrpv.gov.lv/sites/default/files/20151220.pdf

Deliverables under following titles are included in Annex NN:

1. Production method of innovative and advanced cement composite with microfillers materials for infrastructure projects and public buildings;
2. Production method for high performance asphalt concrete mixes from low quality components;
3. Research method for development of diagnostics of early destruction of surface of polymer composite materials using *in situ* electron emission spectroscopy;
4. Research method for development of diagnostics of early destruction of surface of polymer composite materials using destruction-induced staining;
5. A method for measuring slip under laboratory conditions.

In addition programme members were working actively on organising two scientific conferences taking place in 2015 - **IMST „Innovative Materials, Structures and Technologies" 2015,** 30.09.-02.10.2015, as well as **56th Scientific and Technical Conference for Students**, 28.04.2015 (more information on: http://imateh.rtu.lv/konferences/).

Project representatives have participated in the NRP IMATEH meeting on project progress and implementation on 26.05.2015., 2.07.2015., 9.09.2015 and 02.10.2015.

Several seminars were organised on implementation of the programme tasks in the framework of IMATEH, for example, seminar for students on 27.01.2015 in order to present aims, tasks and benefits related to the NRP Project 1 and others. More information is presented in the scientific reports of all projects.

To promote the programme, Concrete Contest (Stage 1, concrete preparation competition) will take place on16.04.2015. Teams of 3 participants will prepare concrete specimens, which will be tested on compression strength after 28 days, determining teams having the strongest specimens. Aim of the concrete contest is to encourage students to practical application of the knowledge obtained in the university and technological development.

Stage 2 of Concrete competition will take place on 12.05.2015, when the winner will be determined among 7 teams testing the specimens on compression strength.

Upon launching the NRP programme IMATEH website was created, where information on programme achievements and activities is constantly updated. On IMATEH website http://imateh.rtu.lv/ detailed information on projects1-6 is available as well as information on NRP IMATEH activities and updates.

Co-funding of the private sector for the projects included in the programmes reaches EUR 231397.34 in the Period 2. (01.01.2015 - 31.12.201515).

1.9. Results of the programme

Performance indicator	Results	
	Planned	Achieved
Scientific performance indicators		
1. Scientific publications:	**13**	**25**
number of original scientific articles (*SCOPUS*)(SNIP>1)	3	1
number of original scientific articles enclosed in magazines of the database *ERIH (A and B)* or in proceeding of conference articles	10	24
number of reviewed scientific monographs	0	0
2. In the framework of the programme:	**13**	**33**
number of defended doctoral thesis	2	2
number of defended master's thesis	11	13
number of defended bachelors'	0	18

Performance indicators of the promotion of the programme		
1. Interactive events to promote the process and results of the programme. Target groups should include students and the number of:	**23**	**53**
conferences	10	32
seminars	5	7
organized seminars	6	10
popular-science publications	2	2
exhibitions	0	0
2. Press releases	**1**	**1**
Economic performance indicators		
1. Amount of private funding attracted to the scientific institution in the framework of the programme, including:	**122 000**	**231 397**
1.1. co-funding from the private sector to implement the projects of the programme	55 000	0
1.2. income from commercializing the intellectual property created in the framework of the programme (alienation of industrial property rights, licensing, conferring exclusive rights or rights to use on a fee)	0	0
1.3. income from contractual jobs that are based on results and experience acquired in the framework of the programme	67 000	231 397
2. Number of applied for, registered, and valid patents or plant varieties in the framework of the programme:	**0**	**2**
in the territory of Latvia	0	2
abroad	0	0
3. Number of new technologies, methods, prototypes or services that have been elaborated in the framework of the programme and approbated in enterprises	**4**	**0**
4. Number of new technologies, methods, prototypes, products or services that have been submitted for implementation (signed contracts on transfer of intellectual property)	**2**	**0**

In case of deviation from planned justification of deviation and planned activities to mitigate deviation.

The planned targets of the NRP IMATEH in general as well as for each project in the framework of the programme were fully achieved in the reporting period from 01.07.2014 till 31.03.2015. The planned tasks are completed and the main results obtained. Detailed information on the scientific achievements of each Project is given in the Section 2 of this Report. Five new methods have been elaborated in the framework of the programme (Annex NN), but are not approbated in enterprises or contracts on transfer of intellectual property services are not signed with enterprises due to delaying of starting data of NRP IMATEH.

1.10. List of results of the programme

(*List of publications, conference thesis, etc.)*

Following papers have been published (full length papers are included in Annex PP):

1. Bumanis G., Bajare D., Korjakins A. Durability of High Strength Self Compacting Concrete with Metakaolin Containing Waste, Key Engineering Materials, Volume 674, 2016, 65-70

a. http://www.scopus.com/record/display.uri?eid=2-s2.0-84958213606&origin=resultslist&sort=plf-f&src=s&st1=bajare&st2=&sid=825680C2EBD50EF96A423542C8B86583.Vdktg6RVtMfaQJ4pNTCQ%3a210&sot=b&sdt=b&sl=19&s=AUTHOR-NAME%28bajare%29&relpos=0&citeCnt=0&searchTerm=

2. Bumanis G., Toropovs N., Dembovska L., Bajare D., Korjakins A. The Effect of Heat Treatment on the Properties of Ultra High Strength Concrete, In Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources" Volume 1, 2015, 22-27
   a. http://journals.ru.lv/index.php/ETR/article/view/209
3. Baronins J., Setina J., Sahmenko G., Lagzdina S., Shiskin A. Pore Distribution and Water uptake in a Cenosphere – Cement Paste Composite Material, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
   a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012011/pdf
4. Haritonovs V., Zaumanis M., Izaks R., Tihonovs J. Hot Mix Asphalt with High RAP Content, Procedia Engineering, Volume 114, 2015, 676-684
   a. http://www.scopus.com/record/display.uri?eid=2-s2.0-84946042865&origin=resultslist&sort=plf-f&src=s&st1=haritonovs&st2=&sid=8C1DC23548743E315805D68F5791B7D8.euC1gMODexYlPkQec4u1Q%3a10&sot=b&sdt=b&sl=23&s=AUTHOR-NAME%28haritonovs%29&relpos=4&citeCnt=0&searchTerm=AUTHOR-NAME%28haritonovs%29
5. Haritonovs V., Tihonovs J., Smirnovs J. High Modulus Asphalt Concrete with Dolomite Aggregates, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
   a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012084/pdf
6. Sinka M., Radina L., Sahmenko G., Korjakins A., Bajare D. Enhancement of lime-hemp concrete properties using different manufacture technologies, In Proceedings of 1st International Conference on "Bio-based Building Materials (ICBBM)", 2015
7. Sinka M., Radina L., Sahmenko G., Korjakins A., Bajare D. Hemp Thermal insulation Concrete with Alternative Binders, Analysis of their Thermal and Mechanical Properties, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
   a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012029/pdf
8. Pleiksnis S. Sinka M., Sahmenko G. Experimental justification for sapropel and hemp shives use as thermal insulation material in Latvia, In Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources" Volume 1, 2015, 175-181
   a. http://journals.ru.lv/index.php/ETR/article/view/211
9. Obuka V., Sinka M., Klavins M., Stankevics K., Korjakins A. Sapropel as Binder: Properties and Application Possibilities for Composite Materials, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
   a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012026/pdf
10. Labans E., Jekabsons G., Kalnins K., Zudrags K., Rudzite S., Kirpluks M., Cabulis U. Evaluation of plywood sandwich panels with rigid PU foam-cores and various configurations of stiffeners, In Proceedings of 3th International Conference "Optimization and Analysis of Structures", 2015, 45-52
    a. file:///C:/Users/Diana/Downloads/Edgars.pdf
11. Freimanis A., Paeglītis A. Analysis of yearly traffic fluctuation on Latvian highways, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
    a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012064/pdf
12. Paeglīte I., Smirnovs J. Dynamic effects caused by vehicle – Bridge interaction. In. Proceedings of the 5th International Scientific Conference, Volume 5, 2015, 11-14

13. Paeglītis A., Freimanis A. Modeling of traffic loads for bridge spans from 200 to 600 meters. In. Proceedings of the 5th International Scientific Conference, Volume 5, 2015, 15-23
14. Janeliukstis R., Rucevskis S., Wesolowski M., Kovalovs A., Chate A. Damage Identification in Beam Structure Using Spatial Continuous Wavelet Transform, IOP Conference Series: Materials Science and Engineering, Volume 96, 2015, 961-12
    a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012058/pdf
15. Wesolowski M., Ručevskis S., Janeliukštis R., Polanski M. Damping Properties of Sandwich Truss Core Structures by Strain Energy Method, IOP Conference Series: Materials Science and Engineering, Volume 96, 2015, 1-8
    a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012022/pdf
16. Mironov A., Doronkin P., Priklonsky A., Chate A. Effectiveness of Application of Modal Analysis for the Monitoring of Stressed or Operated Structures, Aviation, Volume 19, 2015, 112-122
    a. http://www.tandfonline.com/doi/abs/10.3846/16487788.2015.1104860
17. Vilguts A., Serdjuks D., Pakrastins L. Design Methods of Elements from Cross – Laminated Timber Subjected to Flexure, Procedia Engineering, Volume 117, 2015, 10-19
    a. http://www.scopus.com/record/display.uri?eid=2-s2.0-84941059644&origin=resultslist&sort=plf-f&src=s&st1=Serdjuks&st2=&sid=825680C2EBD50EF96A423542C8B86583.Vdktg6RVtMfaQJ4pNTCQ%3a210&sot=b&sdt=b&sl=21&s=AUTHOR-NAME%28Serdjuks%29&relpos=0&citeCnt=0&searchTerm=
18. Stuklis A., Serdjuks D., Goremikins V. Materials Consumption Decrease for Long-span Prestressed Cable Roof, In Proceedings of the 10th International Scientific and Practical Conference “Environment. Technology. Resources” Volume 1, 2015, 209-215
    a. http://dx.doi.org/10.17770/etr2015voll.231,
19. Vilguts A., Serdjuks D., Goremikins V. Design Methods for Load-bearing Elements from Cross-Laminated Timber, IOP Conference Series: Materials Science and Engineering, Volume 96, 2015
    a. http://www.sciencedirect.com/science/article/pii/S1877705815017713
20. Hirkovskis A., Serdjuks D., Goremikins V., Pakrastins L., Vatin N. Behaviour Analyze of Load-bearing Members from Aluminium Alloys, Inzhenerno-stroitel'nyj zhurnal, 86-96
21. Sliseris J., Andrae H., Kabel M., Wirjadi O., Dix B., Plinke B. Estimation of Fiber Orientation and Fiber Bundles of MDF, Materials and Structures, 2015, 1-10
    a. http://link.springer.com/article/10.1617%2Fs11527-015-0769-1
22. Frolovs G., Rocens K., Sliseris J. Comparison of a Load Bearing Capacity for Composite Sandwich Plywood Plates, In Proceedings of the 10th International Scientific and Practical Conference “Environment. Technology. Resources” Volume 1, 2015, 39-45
    a. http://journals.ru.lv/index.php/ETR/article/view/633/609
23. Kukule A., Rocens K. Prediction of Moisture Distribution in Closed Ribbed Panel for Roof, IOP Conference Series: Materials Science and Engineering, Volume 96, 2015
    a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012034
24. Frolovs G., Rocens K., Sliseris J. Glued Joint Behavior of Composite Plywood Plates with Cell Type Core, IOP Conference Series: Materials Science and Engineering, Volume 96, 2015
    a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012048
25. Butans Z., Gross K.A., Gridnevs A., Karzubova E. Road safety barriers, the need and influence on road traffic accidents, IOP Conference Series: Materials Science and Engineering Volume 96, 2015
    a. http://iopscience.iop.org.resursi.rtu.lv/article/10.1088/1757-899X/96/1/012063/pdf

Programme IMATEH members have participated in the following conferences:

1. Bumanis G., Bajare D., Korjakins A. Durability of High Strength Self Compacting Concrete with Metakaolin Containing Waste, 24th International Baltic Conference Baltmattrib, Tallinn, Estonia, November 5-6, 2015;
2. Bumanis G., Toropovs N., Dembovska L., Bajare D., Korjakins A. The Effect of Heat Treatment on the Properties of Ultra High Strength Concrete, 10th International Scientific and Practical Conference "Environment. Technology. Resources", Rezekne, Latvia, June 18-20, 2015;
3. Baronins J., Setina J., Sahmenko G., Lagzdina S., Shiskin A. Pore Distribution and Water uptake in a Cenosphere – Cement Paste Composite Material, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;
4. Haritonovs V., Zaumanis M., Izaks R., Tihonovs J. Hot Mix Asphalt with High RAP Content, 1st International Conference on Structural Integrity, ICSI 2015 Funchal, Portugal, September 1-4, 2015;
5. Haritonovs V., Tihonovs J., Smirnovs J. High Modulus Asphalt Concrete with Dolomite Aggregates, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September -2.October, 2015;
6. Sinka M., Radina L., Sahmenko G., Korjakins A., Bajare D. Enhancement of lime-hemp concrete properties using different manufacture technologies, 1st International Conference on "Bio-based Building Materials (ICBBM)", Clermont-Ferrand, France, June 21-24, 2015;
7. Sinka M., Radina L., Sahmenko G., Korjakins A., Bajare D. Hemp Thermal insulation Concrete with Alternative Binders, Analysis of their Thermal and Mechanical Properties, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September -2.October, 2015;
8. Pleiksnis S. Sinka M., Sahmenko G. Experimental justification for sapropel and hemp shives use as thermal insulation material in Latvia, 10th International Scientific and Practical Conference "Environment. Technology. Resources", Rezekne, Latvia, June 18-20, 2015;
9. Obuka V., Sinka M., Klavins M., Stankevics K., Korjakins A. Sapropel as Binder: Properties and Application Possibilities for Composite Materials, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;
10. Cabulis U., Kirpluks M., Paberza A., Fridrihsone-Girone A., Vitkauskiene I. Balance between renewable and recyclable feedstock for rigid polyurethane foams. 6th Workshop on Green Chemistry and Nanotechnologies in Polymer Chemistry, Braganca, Portugal, July 2015;
11. Kirpluks M., Kalnbunde D., Cabulis U. High functionality polyols from rapseed oil as raw material for polyurethane thermal insulation, Baltic Polymer Symposium, Sigulda, Latvia, September 16-18, 2015;
12. Labans E., Jekabsons G., Kalnins K., Zudrags K., Rudzite S., Kirpluks M., Cabulis U. Evaluation of plywood sandwich panels with rigid PU foam-cores and various configurations of stiffeners, 3th International Conference "Optimization and Analysis of Structures", Tartu, Estonia, August 23-25, 2015;
13. Paeglite I. Traffic load on bridge dynamic response, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;
14. Paeglīte I., Smirnovs J. Dynamic effects caused by vehicle – Bridge interaction, 5th International Scientific Conference of Civil Engineering, Architecture, Land management and Environment, Jelgava, Latvia, May 14-15, 2015;
15. Paeglītis A., Freimanis A. Modeling of traffic loads for bridge spans from 200 to 600 meters, 5th International Scientific Conference of Civil Engineering, Architecture, Land management and Environment, Jelgava, Latvia, May 14-15, 2015;

16. Freimanis A. Analysis of yearly traffic fluctuation on Latvian highways, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September -2.October, 2015;
17. Janeliukstis R., Rucevskis S., Wesolowski M., Kovalovs A., Chate A. Damage identification in beam structure using spatial continuous wavelet transform, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;
18. Wesolowski M., Ručevskis S., Janeliukštis R., Polanski M. Damping Properties of Sandwich Truss Core Structures by Strain Energy Method, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;
19. Janeliukstis R., Rucevskis S., Wesolowski M., Kovalovs A., Chate A. Damage identification in beam structure using mode shape data: from spatial continuous wavelet transform to mode shape curvature methods, ICoEV 2015 - IFTOMM International Conference on Engineering Vibration, Ljubljana, Slovenia, September 7-10, 2015;
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3. Haritonovs V., Tihonovs J., Smirnovs J. High Modulus Asphalt Concrete With Dolomite Aggregates, Transport Research Arena Conference, TRA 2016, Warsaw, Poland, April 18-21, 2016;
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14. Dembovska L., Bajare D., Pundiene I., Vitola L. Effect of pozzolanic additives on the strength development of high performance concrete, MBMST 16 – 12th International Conference “Modern Building Materials, Structures and Techniques”, Vilnius, Lithuania, May 26–27, 2015;

Popular-science publications:

1. Paeglītis A. Koka tilti Latvijā – vēsture un perspektīvas (Timber bridges in Latvia – history and perspective), Būvinženieris, 2015.gada decembris, Volume 47, 156-163;
2. Bajare D., Cate A., Radina L. Innovative materials and smart technologies for environmental safety, IMATEH, “Safety and security”, Riga Technical University, Volume 4, 10-12.

Leader of the programme IMATEH ________________________A. Čate __________________

(signature and transcript) *(date)*

PART 2: PROGRAMME PROJECT INFORMATION

2.1. Project No. 1

Title	***Innovative and Multifunctional Composite Materials from Local Resources for Sustainable Structures***		
Project leader's name, surname	Diana Bajare		
Degree	Dr.sc.ing.		
Institution	Riga Technical University, Institute of Materials and Structures		
Position	Professor		
Contacts	*Phone number*		+371 29687085
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2.2. Tasks and deliverables

(List all tasks and deliverables that were planned for reporting period, list responsible partner organizations, give status, e.g. delivered/not delivered)

Target: *Create and investigate multifunctional materials and composites, including composite materials for sustainable buildings, and bio-materials such as CO_2 neutral or negative fibre composite.*

The Project consists of research divided in three parts each having its own core task to be completed in the framework of NRP IMATEH:

Core task 1: *To develop high performance concrete composite materials for infrastructure projects and public buildings, focusing on their permanence (freeze resistance, corrosion resistance, etc.) and sustainability in the local climate in Latvia, which differs from the climate in other European countries with high level of relative humidity and swift temperature fluctuations around 0 ^oC in winter and autumn, etc.;*

Core task 2: *To develop compositions of bitumen composites characterised by economy, environmental friendliness and permanence using lower quality local aggregates, recycled asphalt concrete as well as warm-mix asphalt concrete technologies;*

Core task 3: *To develop CO_2 neutral composite materials made from textile plants for use in energy-efficient buildings, thus contributing to a comfortable and healthy climate inside the building.*

Time frame for the core tasks is given in Annexes 1-A, 1-B and 1-C.

In addition, specific tasks related to completing core tasks of each Project parts are defined in every Period of the Project corresponding to the calendar year.

No.	Tasks	Deliverable	Responsible partner	Status
1.1.	To create production method of high performance concrete composites (compression strength	Production method of innovative and advanced cement composite with microfillers materials for infrastructure projects and	D. Bajare, Department of Building materials and Technologies, Institute of Materials and Structures, RTU	Delivered Annex-NN

	>100MPa) for use in infrastructure and public buildings, partly replacing concrete with microfillers having local origin.	public buildings (30.09.2015) Annex 1-A		
1.2.	To develop recommendation on increase of the corrosion and freeze resistance properties for the concrete produced from the Latvian cement.	Recommendation on increase of the corrosion and freeze resistance properties for the concrete produced from the Latvian cement (31.12.2016) Annex 1-A	D. Bajare, Department of Building materials and Technologies, Institute of Materials and Structures, RTU	In progress
2.1.	To create production method for high performance asphalt concrete mixes from local low quality components.	Production method for high performance asphalt concrete mixes from low quality components (30.09.2015) Annex 1-B	V. Haritonovs, Centre of Construction Science, RTU	Delivered Annex-NN
3.1.	To develop production method for ecological composite materials from textile plants and local mineral binders.	Production method for ecological composite materials from textile plants and local mineral binders (30.03.2016) Annex 1-C	G. Sahmenko, Department of Building materials and Technologies, Institute of Materials and Structures, RTU	In progress
3.2.	To develop and write guidelines for data collection system, which is suitable for heat and humidity migration control in energy-efficient buildings .	Guidelines for data collection system (30.12.2017) Annex 1-C	G. Sahmenko, Department of Building materials and Technologies, Institute of Materials and Structures, RTU	In progress

In case of non-fulfilment provide justification and describe further steps planned to achieve set targets and results

The planned targets of the NRP IMATEH Project 1 „*Innovative and Multifunctional Composite Materials from Local Resources for Sustainable Structures"* were fully achieved in the reporting period from 01.01.2015 till 31.12.2016. The planned tasks are completed and the main results obtained.

2.3. Description of gained scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

Target of the Project 1: ***Create and investigate multifunctional materials and composites, including composite materials for sustainable buildings, and bio-materials such as CO2 neutral or negative fibre composite.***

Target of the Project 1 within the National programme IMATEH is to create innovative and sustainable materials (cement, bitumen and fibrous composites) by using local raw materials. Targets set for this reporting period are fully achieved.

Core task 1: *To conduct research on the high performance cement composite materials for use in infrastructure and public buildings stressing their durability in the Latvian climate.*

Time frame for the Core task 1 is given in Appendix 1-A.

Task for the Period 2: *To test durability of high performance cement composite materials (compressive strength >80MPa) made from local raw materials and intended for infrastructure and public buildings.*

The microfillers added to the high performance concrete mix impacts its durability. Typically concrete without microfillers is weaker with regard to its mechanical and durability properties, thus by using microfillers it is possible significantly increase the concrete quality and to obtain high performance concrete. Due to the impact of microfillers on the concrete properties it is possible to optimize the composition of concrete reducing consumption of energy-intensive and uneconomical materials. Portland cement is highly energy-intensive raw material used to produce concrete with 0.8-1.0 t CO_2 emissions on 1 t of cement clinker produced. In addition, emissions from cement production constitute 5-7% of total CO_2 emissions in the world. In 2015 emissions coming from the cement clinker production industry in Latvia were equal to 648 000 t of CO_2 which is 5% of the total amount of 12 820 000 t of CO_2.

In the Period 1 of the project economically reasonable and technologically applicable formulations of the high performance cement composite materials with compressive strength exceeding 80 MPa for use in infrastructure and public buildings from local raw materials has been developed by using microfillers available in the Baltic region and especially in Latvia. The volume and availability of these microfillers correspond to the sustainable construction principles.

The use of microfillers is aimed at reducing the costs per unit of the concrete by replacing certain amount of the cement and in the same time improving its mechanical and physical properties and improving durability indicators. In addition, it contributes to the environmental protection as reduced amount of cement per unit of the concrete favours the decrease of CO_2 emissions and use of non-renewable natural resources in the cement production.

In the reporting period high performance concrete has been prepared and impact of the microfillers on properties of fresh and hardened concrete has been determined. Concrete mixes with metakaolin containing waste, cenospheres, microsilica, disintegrated quartz sand as well as quartz and dolomite sand have been prepared; these microfillers were used to replace 5; 10 and 15% of cement in the total volume of cement mass. When replacing cement with microfillers, their impact on the workability of fresh concrete has been assessed. Workability of the self-compacting concrete and constant water/cement (w/c) ratio were kept stable by adding plasticiser to the mix. The increase in compressive strength of hardened concrete was determined after 7, 28 and 180 days including the impact of microfillers on the compressive strength indicators. In the reporting period testing of concrete durability was started and continued, including resistance to the freeze-thaw cycles (freeze resistance), resistance to the migration of chloride ions in the concrete structure (chloride test) as well as alkali silica reaction (ASR) in the concrete structure was assessed.

Core task 2: *To conduct a research on compositions of bitumen composites, where lower quality local mineral materials, recycled asphalt concrete as well as warm-mix asphalt concrete technologies were used.*

Time frame for the Core task 2 activities is given in Appendix 1-B.

Task for the Period 2: *To develop formulations of the high performance bitumen composites using reclaimed asphalt pavement (RAP) and to continue developing bitumen composites from lower quality local aggregates.*

With the rising costs of bitumen binder and aggregates, there is a growing interest in using increased quantities of reclaimed asphalt pavement (RAP) in the production of hot mix asphalt (HMA). The use of RAP has increased significantly in the last 20 years.

Road construction sector is characterised by very material-intensive processes and it has significant consumption of energy resulting in lasting effects on the environment. Use of RAP in the production of new HMA mixes is not only cost-efficient and environment friendly, it also leads to saving of non-renewable natural resources. The most visible are the financial benefits but there are other benefits as well. By recycling the asphalt pavement it is possible to reduce consumption of energy necessary for producing, transporting and using new aggregates in the construction processes, which allows directly save the environmental resources.

Other benefits form the use of recycled asphalt pavement in the production of new pavements are the following:

- reduced construction costs;
- less wasted materials;
- reduced transportation costs;
- reduced consumption of aggregates and binder;
- energy savings;
- saving of the environment (lower levels of toxic and gas emission);
- maintenance of the existing road geometry;
- lower road wear due to decreased transportation of the materials.
- Using 20–50% of the RAP in the mix allows to save 14–34% of the costs on each ton of the road pavement which is produced.

Use of RAP in the production of new HMA mixes is in the development stage in Latvia; therefore the research focuses on the trends of production, recycling and storage methods of the RAP material. Formulation for the asphalt pavement mix with high RAP content will be developed. Restoration of the RAP bitumen will be done with the lowest viscosity bitumen (B70/100 or B100/150), while local dolomite shiver will be added to the RAP aggregate. Optimisation of the amount of RAP will be based on the exploitation properties (rutting resistance, fatigue and thermal cracking resistance).

Core task 3: *To develop CO_2 neutral composite materials made from textile plants for use in energy-efficient buildings, thus contributing to a comfortable and healthy climate inside the building.*

Time frame of the Core task 3 activities is included in Appendix 1-C.

Task for the Period 2: *To develop data collection system, which is suitable for heat and humidity migration control in energy-efficient buildings.*

In order to achieve the tasks set for the Period 2, data collection system, which is suitable for heat and moisture migration control in energy-efficient buildings, has been developed. It consists of 11 sensors (5 for temperature, 5 for moisture and 1 for heat flow), which are designed for integration into the envelope structures of the experimental structures or in the structures of existing buildings, and of data collecting/processing device which allows to save data to the FTP server. The developed system has been tested in the field and laboratory settings and has been improved in order to ensure full operation of the system. Its operation in the test mode has been compared to the standard heat flow measurement system, which have led to the conclusions that the results are stable and variations do not exceed 10%.

After its improvement and approbation, the system for data collection was integrated into experimental wall panel; which was installed on the existing wall in the part intended for a window. The wall panel was made of laboratory tested mix of fibres and binder, allowing to compare the results obtained in the laboratory settings with those obtained in the field settings. The measurements started immediately after installing the panel thus allowing to assess and study the heat flow and moisture migration processes caused by the external conditions as well as caused by the vaporization of the water related to the technological processes.

In addition, the system was used to assess the current moisture migration and heat flow for the part of the wall, where heat isolation blocks made of fibre plants will be installed for improving the thermal parameters of the wall in the later stages of the project.

In the previous research it has been concluded that there is considerable potential for the production of lime-based materials with natural fibre in Latvia but its use is limited due to the insufficient strength and climate factors. In order to improve the physical and mechanical properties of materials, new compositions of fiber composite materials were created in the Period 2 of the project and their physical and mechanical properties were tested. The specimens were made from hemp shives supplied by the biggest hemp producers. In addition, the research has been continued on finding and assessing alternative mineral binders from local raw materials which could improve mechanical properties of the materials. One of the most promising solutions is gypsum-cement-pozzolanic binder which shows better strength and moisture resistance compared to the lime based binders. Sapropel is considered as an alternative for the composite material with hemp as it is an environmentally friendly renewable resource.

Both industrially produced wall panels and fiber composite materials were tested with regard to their mechanical strength using 3 point flexural test. Thermal conductivity of all experimental mixes has been determined and thermal conductivity density curve has been created. Fire resistance test of the hemp composite material plate has been performed according to the LVS EN 13823:2010.

The obtained research data were summarised and presented in conferences and conference proceedings. In addition, calculations with regard to the natural fibre composite material life cycle as well as extraction and processing of data were started during this project period.

Tasks for Period 2	Main results
1. To test durability of high performance cement composite materials (compressive strength >80MPa) made from local raw materials and intended for infrastructure and public buildings.	***Review on durability of high performance cement composite materials. 2 publications have been submitted.***

High performance concrete with improved compressive strength is a logical stage of development following the conventional concrete widely used for the construction purposes today. The improved compressive strength and durability allows building lighter structures which are more efficient compared to the ones built with traditional materials and methods; in the same time these structures comply with the safety, durability and aesthetic requirements. As production of high performance concrete typically us associated with higher consumption of cement, reduced amount of w/c, plasticizer and microfillers, it is necessary to assess the possible microfillers in order to find the most efficient ones for creating rational compositions of high performance concrete with the lowest possible consumption of cement.

In the reporting period efficiency of the microfillers and their impact on the physical and mechanical properties of the concrete were assessed as well as concrete durability parameters, such as freeze resistance, chloride migration, alkali-silica reactions, were tested. It has been concluded that microfillers (calcined kaolin clay, microsilica, cenospheres, dust coming from the cement production) can be used to partially replace cement (in certain cases even up to 15% from the cement mass) without reducing or even improving the compressive strength indicators in the same time. The most efficient microfiller with regard to the concrete strength is microsilica; replacing 15% of the cement mass with microsilica the mechanical properties increase significantly. Concrete mixes with metakaolin containing waste show equivalent compressive strength results as the control mix without microfillers, while the compositions with cenospheres and dust coming from the cement production do not improve the mechanical properties. They even decrease slightly, which can be explained with the high porosity of cenospheres and fine consistency of the dust.

In the Period 2 of the project the durability properties of the designed concrete mixes have been tested and the impact of microfillers on structural changes in materials was assessed. Concrete specimens with various microfillers were tested regarding resistance to the freeze-thaw cycles. Freeze resistance test with concrete mixes, where cement was partially replaced with metakaolin containing waste, show that replacing 10% of the cement mass is the most efficient. This concrete is able to withstand 500 freeze-thaw cycles according to the LVS 156-1:2009 with the maximum permitted loss of strength, while basic mix and the mix with 5 and 15% added did not withstand 500 cycle tests with regard to the strength. Freeze resistance for high performance concrete with microsilica and cenospheres is also tested.

Adding microfillers to the concrete mix shows positive results regarding such durability indicator as chloride migration. Basic mix without microfillers show even up to 3.5 times deeper chloride penetration compared with the mixes, where up to 15% of cement were replaced with metakaolin containing waste. The low coefficient of chloride penetration is important for the steel reinforced concrete, where it is essential to protect the steel used to reinforce concrete against the chlorine ions creating aggressive environments that leads to the corrosion and disintegration.

Alkali-silica reactions are limited, if microfillers are included in the composition of concrete. By adding 15% of microfillers it is possible to reduce more than twice the number of harmful deformations from the expansion in the concrete structures, which causes cracking and makes the concrete vulnerable to the impact of the harmful environmental factors.

Other durability tests as well as durability experiments with different microfillers were started and continued in the reporting period.

2. To develop formulations of the high performance bitumen composites using reclaimed asphalt pavement (RAP) and to continue developing bitumen composites from lower quality local aggregates.	***Recommendation on the optimisation of the bitumen composite mixing process parameters Participation in international conference with a report, 1 scientific publication.***

Formulation for the asphalt pavement mix with high RAP content is developed in the reporting period. Restoration of the RAP bitumen will be done with the lowest viscosity bitumen (B70/100 and B100/150) while local dolomite shiver was added to the RAP aggregate. Optimisation of the amount of RAP will be based on the exploitation properties (rutting resistance, fatigue and thermal cracking resistance). Development of the high modulus asphalt concrete (HMAC) compositions by using local gravel shiver.

Physical and mechanical properties of the new and RAP raw materials (bitumen and aggregate) have been determined. For the bitumen (RAP bitumen and new bitumen) softening temperature, needle penetration and fragility temperature have been determined. Obsolete bitumen (RAP bitumen) has been renovated with B 70/100 and B 100/150 bitumen. The proportion of the new bitumen and RAP bitumen has been determined for obtaining the target bitumen B50/70. Granulometry, form, surface roughness (texture), crushing resistance (abrasion), freeze resistance and water absorption of aggregates have been measured (for RAP and new dolomite shiver). The granulometric composition has been calculated using RAP aggregate and new dolomite shiver. Theoretical asphalt concrete composition (development of formulation) - amount of bitumen, additives and aggregates of various fractions - has been calculated. The experimental mixes have been prepared in the laboratory settings. Optimisation of composition has been performed with

Marshall method based on analysis of volume parameters (pores, porosity of mineral carcass, and pores filled with bitumen). In the Period 3 of the project the designed bitumen composite material compositions with RAP will be checked in pilot tests of deformative properties by using testing methods intended for the concrete exploitation properties - wheel tracking test, stiffness test and fatigue test, thermocrack formation tests as well as water sensitivity (adhesion of the bitumen and aggregate). Compositions of warm mix asphalt (WMA) will be developed in the Period 3.	
3. To design and create data collection system, which is suitable for the heat and moisture control in the structures of energy efficient buildings.	***The data collection system has been designed, data processing has been started. 1 publication has been submitted.***
In order to reach the goals set for the Period 2, data collection system, which is suitable for heat and humidity migration control in energy-efficient buildings has been developed. It was tested in the field and laboratory settings and improved accordingly. • In order to ensure separate measurements for the relative humidity of the environment and temperature on the surface of structure, which is necessary for calculating its heat conductivity, two Sensirion SHT75 sensors were added to the existing system. • Separate grounding conductor was added to the system as testing with various current sources revealed that the system not being electrically connected to earth shows possible deviations in the heat flow measurements. • Half-finished system and method for the convenient data processing has been developed. • The system is tested and regularised both in the laboratory settings with heat flow meter FOX600 and in the field settings with data logger Ahlborn Almeno 8590-9. After improvements of the system it was used to measure moisture migration and heat flow processes in the wall block immediately after its production. Natural fibers, namely hemp shives from the local producers, as well as lime based local mineral binder, were used for the production of this block. The initial data confirm the data obtained in the laboratory settings - heat conductivity coefficient and drying time are similar. In parallel, mechanical and physical properties of the fiber composite materials were measured in the Period 2. Various local raw materials, such as lime base, gypsum base, etc. together with hydraulic additives, such as metakaolin, microsilica, etc. were used for creating compositions. In addition, various types of hemp shives in different processing stages supplied by the local producers were used. The mechanical and physical properties were determined, such as compressive and flexural strength, heat conductivity, fire resistance, and compared with the properties of similar materials.	

2.4. Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

To achieve the project target, it is planned during the Period 3 of the project:

1. To continue durability testing of the high performance cement composite materials (compressive strength > 100 Mpa) made from local raw materials and intended for infrastructure and public buildings and to develop methods for increase of concrete corrosion resistance.
2. To develop formulations for the high performance bitumen composites using reclaimed asphalt pavement (RAP) (result - formulations, method. 1 publication has been submitted.)
3. To obtain and analyse data coming from the heat and moisture migration collection system as well as to develop method for calculating the natural fiber composite material life cycle.

During the Period 3 of the project it is planned to continue high performance cement composite material durability testing - determine resistance against alkali-silica reactions, sulphate resistance, freeze resistance, resistance against the destructive impact of chlorides, etc.

To continue or to start testing freeze resistance of the produced concrete specimens according to the standard LVS 206 and recommendations RILEM TC 117-FDC (CDF test). This research will involve testing of the concrete, which has passed testing with 500 standard freeze-thaw cycles by testing the specimens in 5% NaCl solution and therefore can be characterised as high-quality concrete being able to withstand the temperature fluctuations typical for the winter season in the Latvian climate, as well as surface testing in 3% NaCl solution (CDF test).

Chloride penetration depth will be determined according to NT BUILD 492 methodology. Ability of the concrete to withstand the penetration of chlorides in the concrete will be tested, which is important in the Latvian climate, especially in areas, where anti-icing or deicing compositions are used and chloride solutions are in contact with the concrete surfaces fostering corrosion of its reinforcement, concrete crushing and loss of the load bearing capacity of the load-bearing structures. Concrete resistance to the migration of chloride ions is characterised by the chloride migration coefficient.

Impact of the alkali-silica reactions on the concrete mixes will be determined according to the standard RILEM AAR-2 – method of ultra-accelerated mortar-bar test.

Sulphate resistance of concrete specimens will be determined according to the standard SIA 262/1 Appendix D: Sulphate resistance.

Recommendation for increase of the concrete corrosion and freeze resistance will be developed based on the results of durability testing (deliverable).

To conduct a research on the bitumen composites, in the Period 3 of the project bitumen composite material (HMAC and RAP) compositions will be used in the experimental testing by applying methods intended for the concrete exploitation properties - wheel tracking tests, stiffness tests and fatigue tests, thermocrack formation tests as well as water sensitivity (adhesion of the bitumen and aggregate). In addition, it is planned to develop innovative compositions of bituminous composite materials by using local gravel shiver as well as dolomite shiver from other quarries and to compare their properties with those of the various types of conventional asphalt concrete.

By developing innovative compositions of bituminous composite materials, where various types of local aggregates and imported conventional aggregates are used simultaneously, it will be possible to compare their properties to the various types of conventional asphalt concrete and to develop compositions of bituminous composite materials (formulations) using polymer-modified bitumen.

Based on the data, which are previously obtained in the laboratory settings, it is planned to develop high strength bituminous compositions with high RAP content (partly replacing the typical aggregates used in Latvia with the RAP). Likewise it is planned to use warm mix asphalt (WMA), technologies for developing formulations of the warm mix asphalt having 15 - 25°C lower workability temperatures (for easy workability) compared to the conventional asphalt concrete.

Summarising the obtained results in the end of the Period 2 of the project it is planned to prepare economic assessment and recommendations for designing, production and application of the bituminous composites, which were created in the framework of the project.

Third task for the Period 3 of the project is to obtain and analyse data coming from the heat and moisture migration collection system as well as to calculate the natural fiber composite material life cycle.

According to the defined task it is planned to obtain and collect heat and moisture migration data from the natural fiber composite materials as well as to start developing a model based on the obtained data. Data will be collected from the materials, which are applied in various settings. The initial collection of the experimental data on the heat and moisture from the wall panel will be done for assessing the processes taking place in the constant microclimate inside the building.

Sensors will be integrated in the newly built building, where natural fiber composites are used, in order to assess them in the stage after integration is completed as well as in the real conditions of exploitation. The obtained data will serve as a base for heat and moisture migration control model for the energy efficient building structures, which will verify that the created composite materials are intended for energy efficient buildings ensuring favourable climate for the human health and well-being.

Life-cycle calculations of the natural fibre composite materials are also planned in this stage. Product life-cycle model will be developed, the data about materials, energy resources and emission factors will be obtained from the literature and databases, calculations and impact assessment will be completed. It is planned that the developed method will provide easier way to assess, if the offered material is CO_2 neutral, which is one of the basic tasks of the project.

In the Period 3 of the project it is also planned to develop a method for production of ecological composite materials from the fiber plants and local mineral binders. The method will be developed by using the previously obtained information coming from the development of the fiber composite material compositions and testing of their mechanical and physical properties. The method will allow the existing and potential producers of the natural fiber composite materials to select parameters (various binders, productions technologies, etc.) to obtain the desired properties in the final product.

2.5. Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

In the project Period 2 of the Project „Innovative and Multifunctional Composite Materials from Local Resources for Sustainable Structures" **9 conferences were attended and 9 full papers were published** (see Annex PP):

1. Bumanis G., Bajare D., Korjakins A. Durability of High Strength Self Compacting Concrete with Metakaolin Containing Waste, Key Engineering Materials, Volume 674, 2016, 65-70
    a. http://www.scopus.com/record/display.uri?eid=2-s2.0-84958213606&origin=resultslist&sort=plf-f&src=s&st1=bajare&st2=&sid=825680C2EBD50EF96A423542C8B86583.Vdktg6RVtMfaQJ4pNTCQ%3a210&sot=b&sdt=b&sl=19&s=AUTHOR-NAME%28bajare%29&relpos=0&citeCnt=0&searchTerm=
2. Bumanis G., Toropovs N., Dembovska L., Bajare D., Korjakins A. The Effect of Heat Treatment on the Properties of Ultra High Strength Concrete, In Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources" Volume 1, 2015, 22-27
    a. http://journals.ru.lv/index.php/ETR/article/view/209
3. Baronins J., Setina J., Sahmenko G., Lagzdina S., Shiskin A. Pore Distribution and Water uptake in a Cenosphere – Cement Paste Composite Material, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
    a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012011/pdf
4. Haritonovs V., Zaumanis M., Izaks R., Tihonovs J. Hot Mix Asphalt with High RAP Content, Procedia Engineering, Volume 114, 2015, 676-684
    a. http://www.scopus.com/record/display.uri?eid=2-s2.0-84946042865&origin=resultslist&sort=plf-f&src=s&st1=haritonovs&st2=&sid=8C1DC23548743E315805D68F5791B7D8.euC1gMODexYlPkQec4u1Q%3a10&sot=b&sdt=b&sl=23&s=AUTHOR-NAME%28haritonovs%29&relpos=4&citeCnt=0&searchTerm=AUTHOR-NAME%28haritonovs%29
5. Haritonovs V., Tihonovs J., Smirnovs J. High Modulus Asphalt Concrete with Dolomite Aggregates, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
    a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012084/pdf

6. Sinka M., Radina L., Sahmenko G., Korjakins A., Bajare D. Enhancement of lime-hemp concrete properties using different manufacture technologies, In Proceedings of 1st International Conference on "Bio-based Building Materials (ICBBM)", 2015
7. Sinka M., Radina L., Sahmenko G., Korjakins A., Bajare D. Hemp Thermal insulation Concrete with Alternative Binders, Analysis of their Thermal and Mechanical Properties, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
   a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012029/pdf
8. Pleiksnis S. Sinka M., Sahmenko G. Experimental justification for sapropel and hemp shives use as thermal insulation material in Latvia, In Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources" Volume 1, 2015, 175-181
   a. http://journals.ru.lv/index.php/ETR/article/view/211
9. Obuka V., Sinka M., Klavins M., Stankevics K., Korjakins A. Sapropel as Binder: Properties and Application Possibilities for Composite Materials, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
   b. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012026/pdf

Participation in conferences:

1. Bumanis G., Bajare D., Korjakins A. Durability of High Strength Self Compacting Concrete with Metakaolin Containing Waste, 24th International Baltic Conference Baltmattrib, Tallinn, Estonia, November 5-6, 2015;
2. Bumanis G., Toropovs N., Dembovska L., Bajare D., Korjakins A. The Effect of Heat Treatment on the Properties of Ultra High Strength Concrete, 10th International Scientific and Practical Conference "Environment. Technology. Resources", Rezekne, Latvia, June 18-20, 2015;
3. Baronins J., Setina J., Sahmenko G., Lagzdina S., Shiskin A. Pore Distribution and Water uptake in a Cenosphere – Cement Paste Composite Material, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;
4. Haritonovs V., Zaumanis M., Izaks R., Tihonovs J. Hot Mix Asphalt with High RAP Content, 1st International Conference on Structural Integrity, ICSI 2015 Funchal, Portugal, September 1-4, 2015;
5. Haritonovs V., Tihonovs J., Smirnovs J. High Modulus Asphalt Concrete with Dolomite Aggregates, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September -2.October, 2015;
6. Sinka M., Radina L., Sahmenko G., Korjakins A., Bajare D. Enhancement of lime-hemp concrete properties using different manufacture technologies, 1st International Conference on "Bio-based Building Materials (ICBBM)", Clermont-Ferrand, France, June 21-24, 2015;
7. Sinka M., Radina L., Sahmenko G., Korjakins A., Bajare D. Hemp Thermal insulation Concrete with Alternative Binders, Analysis of their Thermal and Mechanical Properties, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September -2.October, 2015;
8. Pleiksnis S. Sinka M., Sahmenko G. Experimental justification for sapropel and hemp shives use as thermal insulation material in Latvia, 10th International Scientific and Practical Conference "Environment. Technology. Resources", Rezekne, Latvia, June 18-20, 2015;
9. Obuka V., Sinka M., Klavins M., Stankevics K., Korjakins A. Sapropel as Binder: Properties and Application Possibilities for Composite Materials, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;

In the project Period 2 of the Project „Innovative and Multifunctional Composite Materials from Local Resources for Sustainable Structures" **4 conference abstracts or full papers were prepared and submitted**:

1. L. Vitola, D. Bajare, G. Bumanis, G. Sahmenko, Evaluation of Puzzolanic Properties of Micro- and Nanofillers Made from Waste Products, 18th International Conference on Concrete, Structural and Geotechnical Engineering, 25.-26. January 2016, Istanbul, Turkey
2. D. Bajare, G. Bumanis, Chloride Penetration and Freeze-Thaw Durability Testing of High Strength Self Compacting Concrete. Materials, Systems and Structures in Civil Engineering – August, 2016, Copenhagen, Denmark
3. V. Haritonovs, J. Tihonovs, J. Smirnovs. High Modulus Asphalt Concrete With Dolomite Aggregates, Transport Research Arena Conference -TRA 2016, Warsaw, Poland, 18.04-21.04.2016
4. V. Haritonovs, J. Tihonovs, J. Smirnovs. Use of low quality aggregates in hot mix asphalt concrete, 6th Eurasphalt and Eurobitume Congress, Prague, Czech Republic, 1.06.-3.06.2016.

4 master's thesis and 13 bachelor's thesis were prepared and defended within Project

Master's thesis:

1. M.Jaungailis-Gailis „ The use of nanomaterials and nano-systems in production of building materials";
2. R.Latkovska „ Concrete deterioration in reinforced concrete structures exposed to aggressive environments";
3. N. Pleiko, „ High performance concrete with dolomite by products";
4. I. Talanovs „ Development of Innovative Construction Materials using Nano-System Basis".

Bachelor's thesis:

1. M.Luriņa „ Nanomaterial development and use in construction material field";
2. E.Namsone „ Heat insulation material made of two - component aggregate";
3. J.Jankovskis "The impact of composition and microstructure of high-performance cellular concrete on material properties";
4. I.Cikanovičs "Reinforced concrete construction reinfrocing with carbon fibre composites";
5. V.Stirāne "Various building matreials mass, density and standart mass per storage volume corectness in construction designing";
6. M.Šķēle "Evaluation of layup orientation effect on bending behaviour of fiber reinforced composite materials";
7. V.Politiko "Concrete floors with dispersed reinforcement";
8. V.Ignatjevs "Design of self-compacting concrete with recycled concrete aggregates";
9. J.Krauklitis "Ecological SCC concrete with reduced Portland cement amount and recycled concrete aggregate":
10. J.Umbrovskis "Methodology for optimal choice of wall heat insulation materials".;
11. I. Klasa "Investigation of Bitumen Structure and Properties with Atomic Force Microscope",
12. A.Riekstina "Thin layer pavement wearing course layer (AC-TL) properties and usage research";
13. Ie. Zaharava "Determination and analysis of bitumen and aggregate interaction".

The following doctoral thesis were written:

1. J. Justs „Ultra high performance concrete with diminished autogenous shrinkage technology", supervisor D. Bajare, planned to defend in 2016

2. J. Tihonovs „Aphalt concrete mixes from the local mineral material with high exploitation properties" supervisor J. Smirnovs, V. Haritonovs, planned to defend in 2017
3. M. Shinka „Natural fibre insulation materials", supervisor G. Shahmenko, planned to defend in 2017
4. N. Toropovs „Fire resistance of high performance concrete", supervisor G. Shahmenko, planned to defend in 2016

18.06.2015. U. Lencis defended the doctoral thesis „ Methodology for use of ultra sound impulse method in assessment of construction strength" (supervisor A. Korjakins) and obtained PhD in engineering.

10.04.2015. A. Sprince defended the doctoral thesis "Methodology for determination of long-term properties and crack development research in extra fine aggregate cement composites" (supervisor A. Korjakins) and obtained PhD in engineering.

Deliverables under titles "Production method of innovative and advanced cement composite with microfillers materials for infrastructure projects and public buildings" and "Production method for high performance asphalt concrete mixes from low quality components" are include in Annex NN.

The performance indicators of the programme and project promotion

Project representatives participated in the NRP IMATEH meetings on the Project progress and implementation on 26.05.2015., 2.07.2015., 9.09.2015 and 02.10.2015.

Seminar for students was organised on 27.01.2015 in order to present aims, tasks and benefits related to the NRP Project 1.

Non-technical publication "Innovative materials and smart technologies for environmental safety, IMATEH" was prepared and published in the magazine of the Riga Technical University "Safety and security", Vol. 4 p. 10-12.

In addition, the Project members were involved in organising of two scientific conferences in 2015 - IMST „Innovative Materials, Structures and Technologies" (30.09.2015-02.10.2015) as well as 56th Scientific and Technical Conference for Students (28.04.2015).

The participants of conference „Innovative Materials, Structures and Technologies (scientists, students and industry representatives from Latvia and abroad as well as representatives of the scientific committee) were informed about the project achievements and the obtained scientific results.

To promote the programme, Concrete Contest (Stage 1, concrete preparation competition) will take place on 16.04.2015. Teams of 3 participants will prepare concrete specimens, which will be tested on the compression strength after 28 days, determining teams having the strongest specimens. Aim of the concrete contest is to encourage students to practical application of the knowledge obtained in the university and technological development.

Stage 2 of the Concrete Contest will take place on 12.05.2015, when the winner will be determined among 7 teams by testing the specimens on compression strength.

Upon launching the NRP programme IMATEH website was created, where information on programme achievements and activities is constantly updated. On IMATEH website http://imateh.rtu.lv/ detailed information on Project 1 is available as well as information on NRP IMATEH activities and updates.

The co-financing coming from the private sector and income from contract work based on the results of the Project 1 constitutes Euro 231397.34 Eur in the Period 2.

Leader of the project No. 1 _______________ Diana Bajare_______ __________________

(signature and transcript) *(date)*

PART 2.– INFORMATION ABOUT PROJECT

2.1. Project Nr.2

Title	***Innovative and multifunctional composite materials for sustainable buildings***	
Project leader's name, surname	Kaspars Kalniņš	
Degree	Dr.sc.ing.	
Institution	Riga Technical University, Institute of Materials and Structures	
Position	Leading researcher	
Contacts	*Phone*	26751614
	E-mail	Kaspars.kalnins@sigmanet.lv

2.2. Tasks and deliverables

(List all tasks and deliverables that were planned for reporting period, list responsible partner organizations, give status, e.g. delivered/not delivered)

Development of sandwich panels from raw resources available in Latvia – birch plywood. Developed product should maintain stiffness/strength comparing to the conventional plywood boards meanwhile assuring weight saving and improving impact resistance, vibration damping and heat isolation properties.

Tasks of the project

- Experimental investigation of separate sandwich panel components as experimental investigation of finished prototypes
- Development of design methodology based application of FEM and validated numerical models.
- Laboratory scale sandwich panel prototyping and development of recommendations for manufacturing scale-up

Time frame for the core tasks is given in Annexes 2A

In addition, specific tasks related to completing core tasks of each Project parts are defined in every Period of the Project corresponding to the calendar year.

Nr.	Tasks	Deliverable	Responsible partner	Status
1	Plywood sandwich panels with I-type stiffeners and improved vibration damping and impact properties	Report (technology/models) 27.05.2016.	K. Kalnins, Institute of Materials and Structures, RTU	In progress
2	Quality control and characterisation of load bearing capacity	Report (method) 30.01.2017.	K. Kalnins, Institute of Materials and Structures, RTU	In progress
3	Design guidelines for plywood panels with I-type stiffeners	Report (method) 30.09.2017.	K. Kalnins, Institute of Materials and Structures, RTU	In beginning

4	Prototyping method for plywood panels with I-stiffener core	Report (method) 28.02.2017.	K. Kalnins, Institute of Materials and Structures, RTU	In beginning
5	Manufacturing scale-up	Report (recommendations) 30.12.2018.	K. Kalnins, Institute of Materials and Structures, RTU	In beginning
6	Evaluation on domestic economic impact	Report 30.12.2018.	K. Kalnins, Institute of Materials and Structures, RTU	In beginning

In case of non-fulfilment provide justification and describe further steps planned to achieve set targets and results

-

2.3. Description of gained scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

Time frame for the Core task 1 is given in Appendix 2-A.

Tasks allocated for 2nd reporting period	Core achievements
WP-1: Elaboration of physical properties of polyurethane foam for determination of thermal conductivity/vibration and impact absorption for multifunctionality of sandwich I-core panels.	***Performed experimental investigation on vibration damping and impact resistance on the plywood sandwich panels with vertical stiffeners and foam core.***

The aim of current task was to assess vibration damping and impact properties of polyurethane foam. A dedicated reference birch plywood panels and sandwich panels with various core materials as cork, polystyrene, polyisocyanurate and natural rubber has been produced and tested. A major contributor as JSC "Latvijas Finieris" and Meža Nozares kompetences centrs (Forestry competence centre of Latvia) has been given by providing a series of specific reference and various core specimens. This synergy brought a large database of plywood fracture and damage properties as well as vibration damping and impact resistance ones.

The vibration damping properties extracted from natural frequencies and modal tests of series of specimens with different core types has been achieved. A laser scanning equipment POLYTECH PSV400 has been employed. Specimens were attached to the steel frame with cables to achieve non-affecting free-free boundary conditions. Full-field mobile scanning head makes non-contact acceleration measurements on specimen surface at all frequency spectrum.

Besides acquiring natural frequencies, one advantage of modal analysis set up is a determination of modal damping factor (loss factor) according to ASTM E756. General trend in Figure 1. shows only a small increment of loss factor comparing to reference birch plywood. However more significant tendency is a decrease of loss factor for sandwich panels with foam filler, comparing with reference one. Most obvious reason for this trend is additional stiffness reinforced by foam core. Acquired results also possess high scatter of experimental values which could be reduced by increasing number of tested panels.

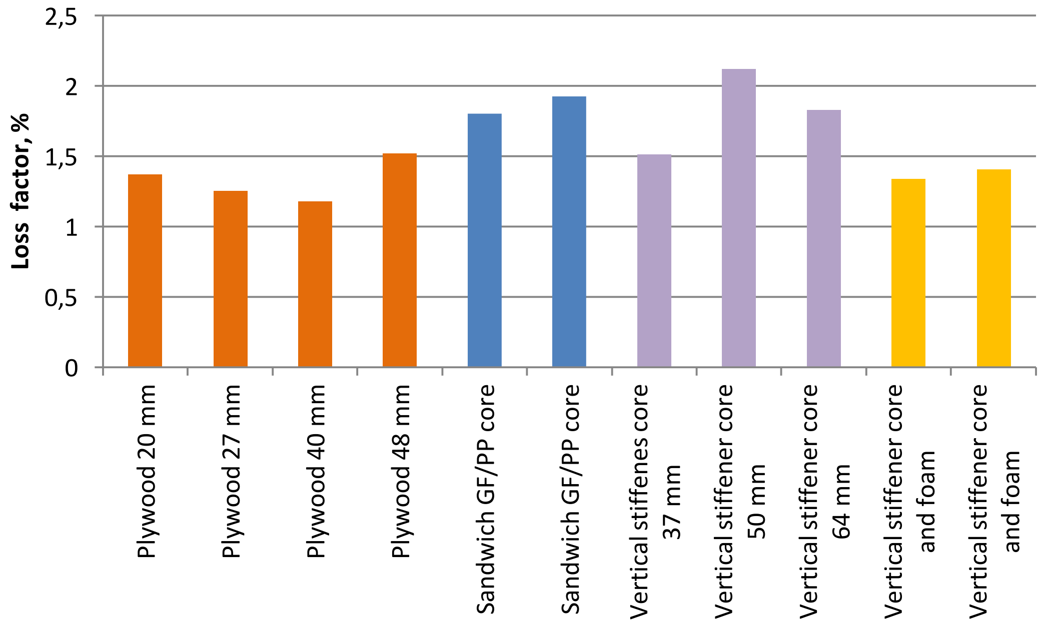


Figure 1. Loss factor for natural-frequency for reference and sandwich panels

In order to evaluate the impact load resistance of plywood sandwich panels with different core types a series of tests of low velocity impact has been conducted on INSTRON Dynatup 9250HV drop tower. Test procedure and specimen dimensions have been taken according to standard NF B51-327 - Plywood Dynamic Punching Test. The resistance to cracking and penetration should be determined by measuring the height of mass falling on square shaped specimen. Obtained results confirmed that impact resistance of specimens is heavily dependent on impact location – hit on stiffener our in between the stiffeners for stiffened sandwich panels. Much less energy is needed to perforate specimen skin between stiffeners comparing to impact directly on stiffener - difference between the impact on stiffener and between stiffeners varies at least twice. Penetration energy for rib-stiffened sandwich-specimens with and without core foam filler is at least doubled the magnitude.

WP-2: Extension of design methodology for sandwich panel design based on simulations of finite element method and optimisation of obtained physical results. Initial verification of test results and validation of produced prototypes and scale up structures.	***Validation of the numerical model by 4-point bending and thermal conductivity tests***

The aim of current task was to initiate numerical simulations in order to estimate theoretical advantages of polyurethane filled sandwich panel thermal and stiffness properties versus birch plywood.

A thermal model of the cross-section numerically represented in a 2D model with PLANE55 elements. Steady state analysis with loads applied to the temperature on lower and upper nodes of the mesh. Results in Table 1 shows that numerical analysis has a capability to forecast effective thermal conductivity; however, it shows lower values than in case of experimental tests by Linseis FHM 300 apparatus.

Table 1. Comparison of experimental and numerical results

Number of stiffeners	Effective thermal conductivity, mW/m·K		Δ,%
	Experimental result	Numerical result	
3	68.3 (0.4)	56.5	17.3
4	73.5 (2.1)	58.4	20.5

In addition a set of bending tests on INSTRON 8802 has been conducted to verify and to confirm the maturity of numerical model. The comparison of load/deflection curves is given in Figure 2 align to test set up of plywood polyurethane foam sandwich panel.

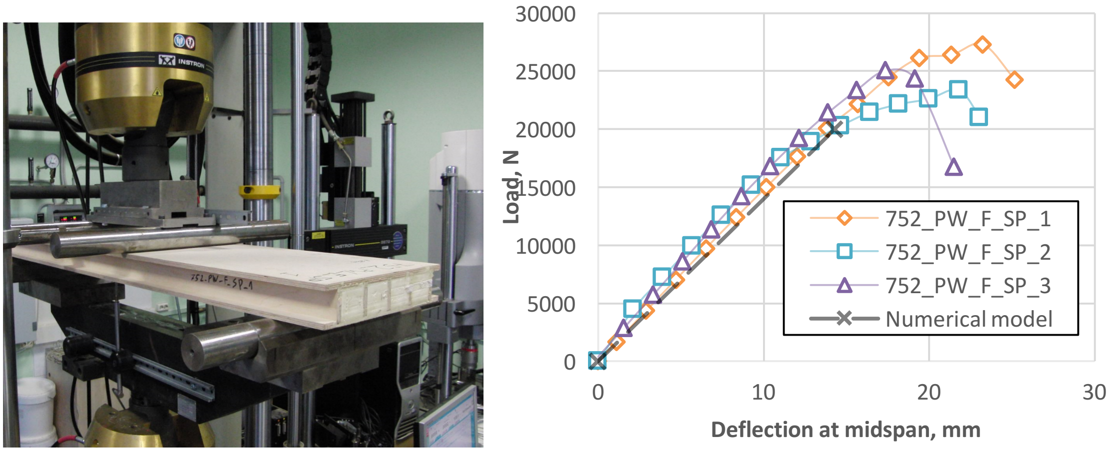


Figure 2. Test set-up and load/deflection curves for rib stiffened panels

WP-3: Laboratory scale-up prototyping of developed sandwich panels, extension of chemical composition of polyurethane foam composition for improved adhesion and workability.	***Several series of preliminary prototypes of stiffened sandwich panels with various polyurethane foam core has been produced.***

The focus of current task was to assess the most appropriate polyurethane foam applicability and corresponding recipe. Moreover in order to deliver preliminary prototypes a risk assessment was required for further improvement of production equipment and technology.

Initially a special attention was given to renewable raw materials in order to obtain high density PU foams. From thermo gravimetric (TGA) analysis of PU foam material tall oil (TO) based polyols were selected to develop two type rigid PU foams, polyurethane foams with isocyanate index 110 and polyisocyanurate (PIR) foams with isocyanate index 250. TO polyol contains teritary amine groups what gives autocatalytic properties for PU foam formulation. Such polyol is more suitable for PIR foam production, also PIR foams have higher thermal stability which is desired property for materials that will be used in potential fire hazard risk applications. The developed PU/PIR foams were analysed using TGA equipment and mass loss curves in nitrogen atmosphere were obtained. The first mass los step at 190 ºC in TGA curves is related to evaporation of liquid flame retardant - TCPP. For PU foams with isocyanate index 110 mass loss of soft segment degradation products is seen at 260 ºC. Such degradation stem is not seen for PIR foams with isocyanate index 250 because it is highly crosslinked polymer materials with small soft segment content. The degradation products of hard segments are released at 335 ºC and final release of heavy aromatics and pyrolysis products is seen at 390-470 ºC. This study confirmed that there are available solutions for fire retardant sandwich panel development.

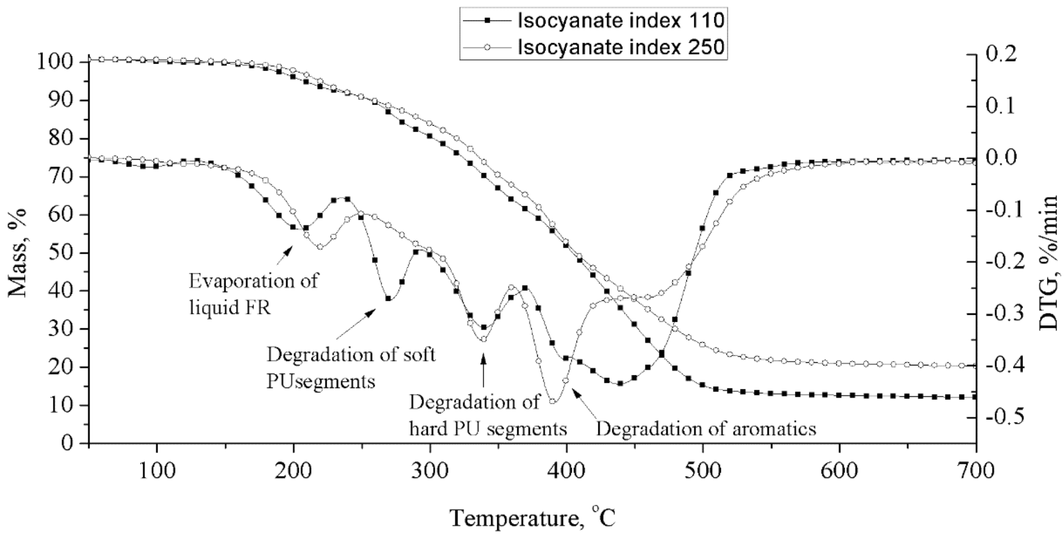


Figure 3. Thermo-gravimetric curves for specimens with different isocyanine index

PU foam (made of partially renewable components) has been filled in sandwich panels with vertical stiffeners to improve heat insulation properties. Foam mixing and filling tasks have been made on adjusted equipment in cooperation with Latvian State Institute of Wood Chemistry. The main challenge was providing of sufficient flatwise pressure to prevent face movement during chemical reaction of the foam. Achieved results (cross sections with and without foam) shown in Figure 4 shows that foam filling technology could be improved to make foam structure more uniform in next trials.

Figure 4. Sandwich panel initial prototype with and without polyurethane foam.

2.4. Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

WP-1*:* Elaboration of physical properties of polyurethane foam for determination of thermal conductivity/vibration and impact absorption for multifunctionality of sandwich I-core panels.

Main results in 2nd review period

- Produced a database of impact resistance test results for reference plywood boards.
- Produced a database of impact resistance test results of plywood sandwich panels with and without foam core filler.
- Produced a database of vibration damping properties for reference plywood panels
- Produced a database of vibration damping properties for reference plywood specimen's panels with and without foam core filler.

Further work:
- A database of various density foam core adhesion and thermal conduction properties.

WP-2: Extension of design methodology for sandwich panel design based on simulations of finite element method and optimisation of obtained physical results. Initial verification of test results and validation of produced prototypes and scale up structures.

Main results in 2nd review period
- Performed experimental validation of numerical models based of FEM.
- Evaluated and verified stiffness of rib-stiffened panels with and without foam filler.
- Performed experimental validation of thermal models based for effective thermal conductivity.

Further work direction:
- Further validation of the numerical model also introducing failure criteria
- Improving input data quality for better model performance

WP-3: Laboratory scale-up prototyping of developed sandwich panels, extension of chemical composition of polyurethane foam composition for improved adhesion and workability.

Main results in 2nd review period
- Prototyped several series of rib stiffened sandwich panels with various core wall and surface thickness. A demo movie available on IMATEH web page.
- Performed DTG tests of some foam mixtures

Further work direction:
- Improvement of foam infusion technology.
- Development of high density PU foam system with open pore structure.
- To perform adhesion tests on foam and plywood interface part specimens.

Further prototype sandwich panel specimens with open pore structure.

2.5. Dissemination and outreach activities
(Describe activities that were performed during reporting period to disseminate project results)

Publications:
1. Labans E., Jekabsons G., Kalnins K., Zudrags K., Rudzite S., Kirpluks M., Cabulis U. Evaluation of plywood sandwich panels with rigid PU foam-cores and various configurations of stiffeners, In Proceedings of 3rd International Conference "Optimization and Analysis of Structures", 2015, 45-52
   a. file:///C:/Users/Diana/Downloads/Edgars.pdf

Conferences:
1. Kirpluks M., Kalnbunde D., Cabulis U. High functionality polyols from rapseed oil as raw material for polyurethane thermal insulation, Baltic Polymer Symposium, Sigulda, Latvia, September 16-18, 2015;

2. Labans E., Jekabsons G., Kalnins K., Zudrags K., Rudzite S., Kirpluks M., Cabulis U. Evaluation of plywood sandwich panels with rigid PU foam-cores and various configurations of stiffeners, 3th International Conference "Optimization and Analysis of Structures", Tartu, Estonia, August 23-25, 2015.

Presentations:

1. K. Kalniņš K., E. Labans, U. Cābulis, M.Ķirpļuks, Synergies between Framework Programe 7 and VPP – in development of sandwich apnels. Week of innovative regions. WIRE 2015. June 3-5, Riga, Latvia
2. K.Kalnins, A.Čate - Innovative and Multifunctional Composite Materials for Sustainable Buildings, Innovative Materials for the Development of the Baltic Region National Economy, Dec.16, Rīga http://conference.birti.eu/agenda.
3. E. Labans, K. Kalniņš., Japins, G, Zudrags., K., Rudzite, S. Smart sandwich structures of plywood and GF/PP. EuroNanoForum 2015, June 10-12, Riga, Latvia

Doctoral thesis:

1. E.Labans "Integration and optimisation of multifunctionality for plywood sandwich construction". Scientific supervisor – K. Kalniņš, current status – submitted to Latvia Science Academy defence scheduled for spring 2016.
2. M. Kirpluks "Properties of Polyurethane foam composites with nano particles from renewable sources". Scientific supervisor – U. Cabulis. Estimated time of defence – spring of 2017

Master thesis:

1. D. Kalnbunde „ High functionality polyols from rapseed oil as raw material for polyurethane thermal insulation". Latvia University, master thesis in chemistry. Scientific supervisor – U. Cabulis

Web page

Updated IMATEH home page http://imateh.rtu.lv/ with detailed information about publications, attended events and main results.

Leader of the project No. 2 ____________ Kaspars Kalnins ____________

(signature and transcript) *(date)*

PART 2: PROGRAMME PROJECT INFORMATION

2.1. Project No. 3

Title	***Risk consideration for safe, effective and sustainable structures***	
Project leader's name, surname	Ainārs Paeglītis	
Degree	Dr.sc.ing.	
Institution	Riga Technical University	
Position	Professor	
Contacts	*Phone number*	+371 29269448
	E-mail	ainars.paeglitis@rtu.lv

2.2. Tasks and deliverables

(List all tasks and deliverables that were planned for reporting period, list responsible partner organizations, give status, e.g. delivered/not delivered)

Target: *Develop new methods of risk assessment for buildings and structures to ensure their safe, efficient and sustainable operation.*

The Project is divided in three parts where each part has its own core task:

Core task 1: *Investigation of the dynamic characteristics of Latvian road bridges and determination of their impact on construction reliability, to develop the new methods for assessment of structural risk, reliability and robustness;*

Core task 2: *Development of the methodology for experimental acquisition of dynamic characteristics (modal frequencies, mode shapes, modal damping) of structural elements with the presence of damage (different failure modes) for structural health monitoring;*

Core task 3: *To develop innovative smart structure with using of removable natural resources with the increased durability and reliability for structural and infrastructural purposes.*

Time frame for the core tasks is given in Annexes 3-A, 3-B and 3-C.

In addition, specific tasks related to completing core tasks of each Project parts are defined in every Period of the Project corresponding to the calendar year.

Nr.	Tasks	Deliverable	Responsible partner	Status
1.1.	Modelling of bridge and vehicle interaction, taking into account the type of the vehicle, type of the span structure, and pavement evenness	Method for investigation of vehicle and bridge interaction	A.Paeglitis, Department of Roads and bridges, Institute of Transport infrastructure engineering, RTU	In progress
1.2	Approbation of theoretical probability distribution models of bridge loads in Latvia. Analysis of traffic load data	Method of traffic data analysis	A.Paeglitis, Department of Roads and bridges, Institute of Transport infrastructure engineering, RTU	In progress
2.1	To develop method for localization of damage site and	Methodology of damage identification	S. Rucevskis, Department of Composite Materials,	In progress

	evaluation of damage size in various structural elements by using appropriate signal processing techniques experimentally measured dynamic parameter changes.	in different type of structural elements (beam, plate, sandwich)	Institute of Materials and Structures, RTU	
2.2	To develop new technologies for monitoring and diagnostics of aviation engines and various elements of rotary machines.	Recommendation on monitoring and diagnostics of dynamic systems.	S. Rucevskis, Department of Composite Materials, Institute of Materials and Structures, RTU	In progress
2.3	To develop method for pre-stress loss estimation in pre-stressed steel reinforced concrete structural elements.	Method for pre-stress loss estimation in pre-stressed steel reinforced concrete structural elements.	S. Rucevskis, Department of Composite Materials, Institute of Materials and Structures, RTU	In beginning
3.1	Data generalization for development of design procedure for load-bearing elements from cross-laminated timber.	The data were generalized for development of design procedure for load-bearing elements from cross-laminated timber during the Period 1. The considered procedures are based on the LVS EN 1995-1-1, effective strength and stifness method and transformed section method.	D.Serdjuks Department of Building Constructions Institute of Structural Engineering and Reconstruction	In progress

In case of non-fulfilment provide justification and describe further steps planned to achieve set targets and results

The planned targets of the IMATEH Project 3 „ *Risk consideration for safe, effective and sustainable structures"* was fully achieved in the reporting period from 01.01.2015 till 31.12.2016. The planned tasks are completed and the main results obtained.

2.3. Description of gained scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

Target of Project 3: ***Develop new methods of risk assessment for buildings and structures to ensure their safe, efficient and sustainable operation.***

Target of the national programme and this project is to develop new methods of risk assessment for buildings and structures to ensure their safe, efficient and sustainable operation. Targets set for this reporting period are fully achieved.

Core task 1: *Investigation of the dynamic characteristics of Latvian road bridges and determination of their impact on construction reliability, to develop the new methods for assessment of structural risk, reliability and robustness.*

Tasks for the Period 2:

1.1. Modelling of bridge and vehicle interaction, taking into account the type of the vehicle, type of the span structure, and pavement evenness.

1.2. Development of method for prediction of live load action combinations.

Time frame for the Core task 1 activities is given in Appendix 3-A.

Task Nr.1.1. vehicle interaction with bridge was analysed, dynamic amplification factor, natural frequency and damping ratio was compared. Research was done for different types of bridges in Latvia. Results show that dynamic characteristics (natural frequency, damping ratio, dynamic amplification factor) depend on bridge material, bridge type, but dynamic amplification strongly depend on pavement roughness. Pavement roughness was modelled in dynamic testing and result show that dynamic amplification factor can increase up to 2 times.

Task Nr.1.2. traffic load influence on bridge structure with span longer than 200m was analysed, because Eurocode gives traffic load model for spans up to 200m length. In this research weigh-in-motion system was used, further in text- WIM. System data was gathered from 4 WIM stations owned by VAS "Latvian State Roads". Obtained data was processed and cleaned. Load was calculated by summing up all vehicle loads and dividing them by the span length. This approach was used for spans from 200 to 600 m. Second approach was used in a real scenario. Bridge over Daugava river in Jēkabpils had a finished conceptual design hence this project was used. It was found that for most unfavourable scenario calculated traffic load was lower than ones given in Eurocode. Increasing span length loading decreased. Research was started about data WIM data cleaning to obtain more real data for further research.

Core task 2: *Development of the methodology for experimental acquisition of dynamic characteristics (modal frequencies, mode shapes, modal damping) of structural elements with the presence of damage (different failure modes) for structural health monitoring;*

Task for the Period 2: *To develop damage localization methods for structural elements.*

Time frame for the Core task 2 activities is given in Appendix 3-B.

According to the Core task 2 of the project: "The development of methodology for experimentally measured dynamic parameters (vibration frequencies, vibration modes, vibration damping coefficients) of healthy or damaged (various forms of material degradation) structural elements and its application to structural health monitoring", the planned objectives are fully met.

Damage identification methods based on vibrational response of a structure are designed for practical applications. The proposed methodology will enable the identification of structural damage invisible from the outside in different types of engineering structures. Damage indices are generalized for 1-dimensional and 2-dimensional space thus enabling damage identification in beam-type and plate-type structural elements. By employing corresponding equipment the proposed methodology can be extended for the identification of damage in real applications such as automobile and aircraft structural elements.

Core task 3: *To develop innovative smart structure with using of removable natural resources with the increased durability and reliability for structural and infrastructural purposes.*

Task for the period 2*: Development of design procedure for load-bearing elements from cross-laminated timber.*

Time frame for the Core task 3 activities is given in Appendix 3-C.

The design procedure for load-bearing elements from cross-laminated timber is in stage of development. The design procedure is based on the LVS EN 1995-1-1 and transformed section method. The design procedure is characterized by the simplicity in comparison with the gamma method, composite method, and shear analogy method. The design procedure can be used for the behaviour prediction of the load-bearing elements from the cross-laminated timber subjected to flexure or compression with the bending. The suggested design procedure will be used at the next stage of the current project for topology optimization for structure from cross-laminated timber and evaluation of it rational parameters.

Task for the period 2: *Data generalization for development of design procedure for load-bearing elements from cross-laminated timber.*

Possibility of transformed sections method used for analysis of structural members from cross-laminated timber was checked by the experiment to provide realization of core task 3 during the period 2. Eight cross-laminated timber plates were considered.

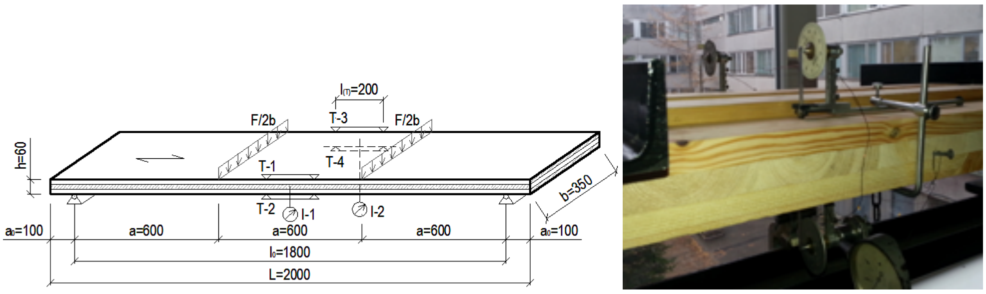
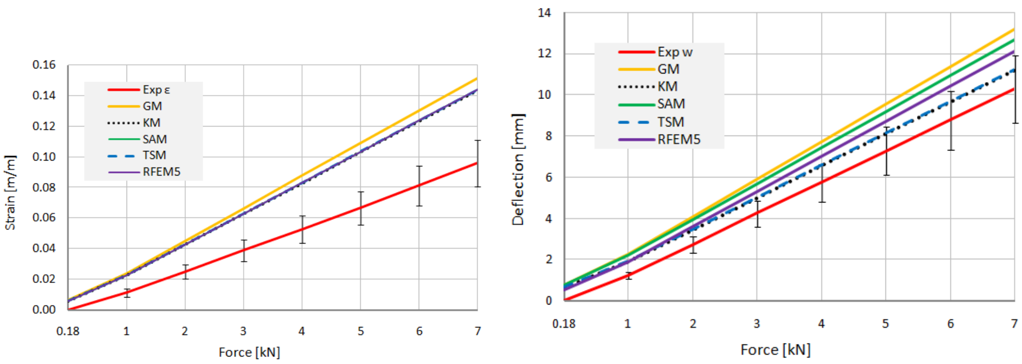


Figure 1. Loading scheme and placement of aparatus for CLT plate.

The considered plates from the cross-laminated timber were analized by the transformed sections method, gamma method, composite method, shear analogy method and FEM, which was realized by the program RFEM 5.0.



a) *b)*

Figure 2. The dependences between experimental and theoretical values of maximum normal stresses *a)* and maximum vertical displacements *b)*: vid – mean values; GM – results, which were obtained by the gamma method; KM– results, which were obtained by the composite method; SAM – results, which were obtained by the shear analogy method; TSM–results, which were obtained by the transformed section method; RFEM5 – results, which were obtained by the program RFEM 5.0.

It was shown, that the difference between the results which were obtained for the cross-laminated timber plates by transformed sections method, gamma method, composite method, shear analogy method, FEM and experiment is within the limits from 0.1 to 17.9 %.

Cross-laminated timber plate with the dimensions 2X1 m and total thickness in 95 mm was considered. The cross-laminated timber plate, which is suspended by the four corners and loaded by the statically applied uniformly distributed load, was considered as the design scheme. The plate was statically loaded by the uniformly distributed load which intensity changes within the limits from 0.46 to 5.09 kN/m2. It was shown, that the difference between the results which were obtained for the cross-laminated timber plate by transformed sections method and FEM does not exceeds 20 %.

Cross-laminated timber plate with the dimensions 2X1 m and total thickness in 95 mm was considered under the action of uniformly distributed load and axial force. The intensity of uniformly distributed load was equal to 7.5 kN/m2. The value of axial force was equal to 70 and 150 kN. It was stated, that the difference between the results obtained by the transformed sections method and FEM for the cross-laminated timber plates subjected to flexure and compression with the bending does not exceeds 10 %.

Based on the obtained results the following conclusion was enables formulated: the suggested design procedure, which is based on the LVS EN 1995-1-1 and transformed section method enables predicting the behaviour of cross-laminated timber members.

Task for the period 2: *Topology optimization for structure from cross-laminated timber and evaluation of it rational, from the point of view of it materials expenditure, parameters*

The rational parameters of the saddle-shaped cable roof prestressing, which enables to improve distribution of internal stresses and forces and to decrease expenditure of structural materials, were evaluated for the saddle-shaped cable roof with the rigid support contour, dimensions 60X60 in the plan and the height equal to 12 m in the case of statical loading. It was shown, that division of the cable net at 18 groups, which are differed by the prestressing level, enables to decrease by 19.2% cable net materials expenditure.

Tasks for Period 2	Main results
1.1. Vehicle and bridge interaction	***Dynamic amplification factor depend on the bridge type, length, vehicle speed, pavement roughness and bridge system.***
1.2. Traffic load impact on bridge superstructure	***Method allows to calculate traffic intensity for every week of the year using measured WIM data from another road.***

One of the major external loads acing on bridge superstructure is traffic load. Load value depends on vehicle type, number of axles and mass. This type of load in time variable and it is usually found by using probabilistic analysis. Real vehicle weight and number of axles can be found using Weight-in –motion measuring system. This type of measuring system is worked in road surface and it registers passing vehicle weight.

It is found that bridge dynamic characteristics depend on bridge type, passing vehicle speed, surface roughness and other factors. There are two vehicle-bridge interaction research ways: experimental and analytical. Experimental way in more time consuming and it uses devices to find necessary characteristic values and it is expensive. Whereas, analytical method is a way to evaluate vehicle-bridge interaction if method has already been experimentally approved.

Interaction models which consider energy exchange between vehicle and bridge include flowing factors:

- Model of the bridge structure;
- Model of vehicle rolling stock;
- Vehicle – bridge interaction model;
- Description of the bridge pavement condition;

- Mathematical algorithm of every model.

Vehicle models can be divided in 3 groups with increasing complexity:

- One dimensional (1D) models, consider mass and vertical displacement;
- Two dimensional (2D) models, consider vehicle protection on vertical longitudinal plane and movement is considered in the same plane;
- Three dimensional (3D) models, consider all vehicle movement axis. This method allows to consider wheel uneven contact with bridge structure.

Most common method for vehicle –bridge interaction modelling is to mathematically describe vehicle and bridge separately, but interaction is calculated using an iterative procedure where force translation and displacements are calculated for each wheel separately. Integration in time is used for vehicle equation but modal superposition used for bridge structure. Second method – considers already all system together but use of this method requires major calculation resources. This method requires to add to the matrix bridge and vehicle mass and damping ratios. This method does not allow to include bridge nonlinearities and this method does not consider vehicle-bridge no-contact situations. Wheels are always in contact with surface.

Bridge pavement unevenness is main dynamic excitation source. There are methods that allow to investigate roughness of the surface and it can be included in the model. If it is not possible to know the roughness of the surface then probabilistic theory is used and roughness profile is assumed from previous measurements.

Although it is possible to model vehicle-bridge interaction mathematically it does not give necessary information to assess structure. Much more about structure is possible to find from live scale load testing of the structure. From load testing can find dynamic amplification factor, natural frequency, damping ratio. These factors best describes moving load influence on bridge dynamic characteristics.

Although natural frequency and damping ratio can be compared with Final element method (FEM) results, dynamic action in structure in the best way is characterised by dynamic amplification factors. Dynamic amplification factor is calculated as a ratio between static and dynamic response of the (deflection or strain), and it shows how much dynamic load increase response of the structure. Dynamic load is considered in LVS 1991-2 “Traffic loads on bridges”.

Research was done for different types of bridges in Latvia. Results show that dynamic characteristics (natural frequency, damping ratio, dynamic amplification factor) depend on bridge material, bridge type, but dynamic amplification strongly depend on pavement roughness. Pavement roughness was modelled in dynamic testing and result show that dynamic amplification factor can increase up to 2 times.

Task 3.2. Period from years 2014 and 2015. Traffic load impact on bridge superstructure

In this research weigh-in-motion system was used, further` in text- WIM. System data was gathered from 4 WIM stations owned by VAS “Latvian State Roads”. Obtained data was processed and cleaned. Loads for short and medium span bridges are given in Eurocode 1991-2 “Traffic loads on bridges”, that is why loads were calculated for long span bridges (longer than 200m). Results show that available data are not enough to make conclusion hence data should be simulated. In second part of the research data on all roads were compared in order to find if data on yearly bases were analogous. If this hypotheses were true then it would be possible to make smaller periods of traffic observation (for example 2 weeks) and traffic rate on this road for the rest of the year could be calculated considering that it changes equally on the entire road. It was found that in 4 places of measurement traffic range was changing similarly enough to be generalized as a standard case for all Latvian roads.

In the beginning there were enough data from WIM stations on roads A1 72. km and A3 24. km, in total 2’670’344 vehicle data, hence load on bridges were calculated from those data. Afterward more information was gathered from measurement on roads A1 and A3, and new data from roads A7 and P80. These data were used to analyse traffic intensity uncertainty assessment. All WIM system locations are shown in Figure 1. Overall number of measurements was 8’186’871 vehicles for period 14th July 2012 to 31st March 2015. These measurements were processed and cleaned using two methods. Load calculation – focused on real vehicle weight and traffic intensity - focused on vehicle number.

For bridge load calculation, first data were cleaned according to validity codes. These codes measuring devices included in the results if in time of measurement were found an inadequacy. 3 codes were chosen out of 18 which showed inappropriate results. Asphalt thermal expansion, outside temperature influence weight measure hence there factors were considered. This method was useful, because it reduces vehicle weight variation coefficient.

Figure 1. WIM system locations

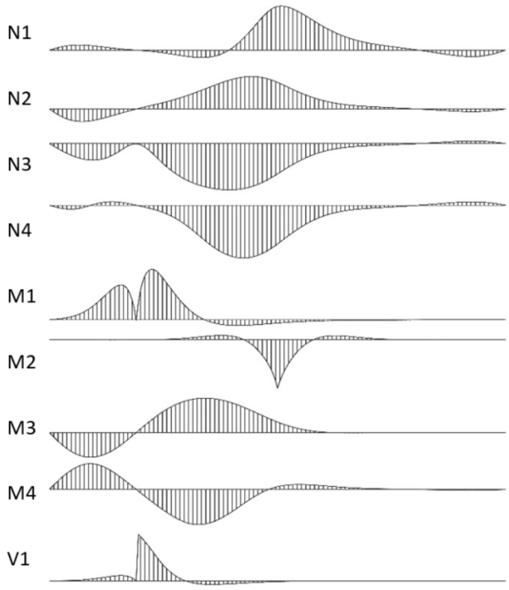


Figure 2. Influence lines of bridge in Jēkabpils

N1 – axial force in main span longest cable;
N2 - axial force in rear span longest cable;
N3 – axial force in bottom of the pylon;
N4 – axial force in middle of the pylon;
M1 – bending moment in the deck on the pylon;
M2 – bending moment in middle of the main span;
M3 – bending moment in bottom of the pylon;
M4 – bending moment in the middle of the pylon;
V1 – Shear force in the deck near pylon.

For traffic intensity variation every vehicle is important hence files were checked if there were not more than one day data in the file. Long vehicles with trailers are sometimes divides in a wrong way hence intensity increases without extra cleaning of the data. Divided vehicles are about 1% from total vehicle number and influence on overall data is small.

To simulate different traffic flows 6 scenarios were used and in all of scenarios main traffic lane was considered. Scenario 1 consisted only heavy vehicles, in others normal vehicle percentage was from 10% to 50%. Vehicles in every scenario were put in a row with constant distance of 5 m between last axle of previous vehicle and first axle of the behind vehicle.

Two different approaches were considered for long span bridge calculation. In first approach every day vehicle row was moved over constant bridge length. Load was calculated by summing up all vehicle loads and dividing them by the span length. This approach was used for spans from 200 to 600 m. Second approach was used in a real scenario. Bridge over Daugava river in Jēkabpils had a finished conceptual design hence this project was used. 9 characteristic loading sections were chosen where influence lines were found. It showed load influence on cross section depending on the load position, shown in Figure 2. Same rows of vehicle were moved over these influence lines. Load was calculated according to the equation (1):

$$q_i = max\left(\frac{\sum P*y>0}{A_{pos}}; \frac{\sum P*y<0}{A_{neg}}\right) \quad (1)$$

where qi – distributed load, P – vehicle axle load, y – axle load influence on section, A – positive or negative influence line area.

In both cases maximal load for every day was found. After evaluating probabilistic distributions a Gumbel distribution was chosen as most appropriate for one day distribution. Afterwards loads were extrapolated up to 5% probability in 50 year period. In conclusion, influence lines gives larger loads than constant span approach, but they are considered as more accurate for this bridge. Extrapolated loads were compared to loads given in Eurocode 1991-2 , and they were larger. It could be explained, because vehicle weight since 1987 has increase when loads were measured for Eurocode, but it is not certain. It is possible that our assumptions of the distance between vehicles was too conservative, however we did not have data about real distances between vehicles in rush-hours.

Since result extrapolation gives a certain inaccuracy it should be prevented using very long data gathering period or simulated data for a long period of time. To find if traffic intensity on one road can be used for another roar, 4 roads intensity distribution were analysed. Each weeks mean intensity were divided with all year mean intensity, this way road could be compared even if real intensity was different. In the end we obtained every weeks difference from all year's intensity. This approach allows to calculated traffic intensity in every week of the year from WIM data of one road taking as an example other roads intensity distribution. Namely, if on road X two weeks before Midsummer traffic intensity has been measured, but on other roads at that time intensity is only 60% from year mean intensity, then increasing measured intensity by 40% we can get all year mean intensity.

Distribution shows that on roads A7, A3 and P80 traffic distribution over year changes very similar. Exception is road A1 on which intensity in summer increases significantly, but it can be explained with music festivals that take place around Salacgrīva In conclusion, intensity can be calculated from short period data, but it should be checked for any local conditions that can increase or decrease traffic intensity.

2. Development of damage localization methods for structural elements	***Methods for damage localization in beam-type and plate-type structural elements***

In the report period studies of experimental evaluation of dynamic parameters (vibration frequencies, modes, damping etc.) for beam-type and plate-type structural elements and their application to structural health monitoring were carried out. By using appropriate signal processing techniques, dynamic parameters were used for identification of damage related parameters such as localization and size of damage in structural elements.

A Wavelet Transform (WT) technique is proposed for damage identification in beam-type structure. WT is a mathematical transformation, which represents a correlation between a tested signal and a wavelet function. In case of large correlation, large magnitude WT coefficients are obtained. Largest peaks in plots of WT coefficients vs coordinate of a structure reveal the location of damage. The identification of damage was characterized with a so-called Damage Index (DI), which,

in case of WT, is equal to the value of WT coefficients. In practice, experimentally measured mode shapes are inevitably corrupted by measurement noise causing local perturbations into the mode shape, which can lead to false peaks in damage index profiles. These peaks could be mistakenly interpreted as damage or they could mask the peaks induced by real damage and lead to false or missed detection of damage. To overcome this problem, it is proposed to summarize results for all modes. The summarized damage index then is defined as the average summation of damage indices for all modes, normalized with the respect to the largest value of each mode. Then the damage indices, determined for each element are standardized and a concept of statistical hypothesis testing is applied to classify damaged and healthy elements and to localize damage depending on the pre-defined damage threshold value. To quantify the reliability of damage identification for every wavelet, an additional term, called Damage Estimate Reliability (DER) was calculated. DER is equal to average SDI in the area of damage divided by average SDI in all parts combined. Damage Estimate Reliability result is expressed in percentage. WT method requires the analysis of wavelet function performance (in terms of DER) at every scale, thus finding the optimum scale that yields the best damage identification results, therefore an extensive study of DER vs scale behaviour for different wavelets was conducted. An additional study of the influence of number of mode shape input data points on DER values was performed. This was done in order to estimate the density of embedded sensor grid in a real time situation if structure was equipped with one. To examine limitations of the method and to ascertain its sensitivity to noisy experimental data, several sets of simulated data are analysed. Simulated test cases include numerical mode shapes corrupted by different levels of random noise as well as mode shapes with different number of measurement points used for wavelet transform. Effectiveness and robustness of the proposed algorithm were tested experimentally on: 1. two aluminium beams of different length, containing single mill-cut damage; 2. two aluminium beams of different length, containing 2 sites of mill-cut damage; 3. two polymer composite beams of different length, containing single low-velocity impact damage. All calculations were performed using MATLAB software. In the report period also an investigation aimed at detecting and localising damage in plate-like structures was begun. The advantage of the proposed method is that it requires mode shape information only from the damaged state of the structure. The damage index is defined as the absolute difference between the measured curvature of the damaged structure and the smoothed polynomial representing the healthy structure. Several sets of numerical simulations have been carried out to analyse the influence of damage severity, measurement noise and sensor spacing on the performance of the proposed damage detection method. The obtained results show that the proposed damage index provides reliable information about the location and size of the damage in case of the presence of medium severe damage, relatively accurate measurement data and relatively dense distribution of sensors. Last two drawbacks of the method can be overcome by using the latest scanning laser vibrometer systems which allow high-density transverse displacement measurements with a low degree of measurement noise. In this case the major drawback of the method is that the severity of damage has to be relatively high for successful damage detection. The obtained results also suggest that the proposed method can be applicable not only for laboratory tests but also for practical structural applications.	
3.1. Development of design procedure for load-bearing elements from cross-laminated timber.	***The design procedure for load-bearing members from cross-laminated timber, subjected to flexure or compression with the bending, was tested experimentally. The considered members differed by their statical schemes. The rational parameters of the saddle-shaped cable roof prestressing, which enables to improve distribution of internal stresses and forces and to decrease***

	expenditure of structural materials, were evaluated.
3.2. Experimental testing of design procedure for load-bearing elements from cross-laminated timber.	***The design procedure for load-bearing members from cross-laminated timber, subjected to flexure or compression with the bending, was tested experimentally. The considered members differed by their statical schemes.***
3.3. Topology optimization for structure from cross-laminated timber and evaluation of it rational, from the point of view of it materials expenditure, parameters	***The rational parameters of the saddle-shaped cable roof prestressing, which enables to improve distribution of internal stresses and forces and to decrease expenditure of structural materials, were evaluated.***

Possibility of transformed sections method used for analysis of structural members from cross-laminated timber was checked by the experiment to provide realization of core task 3 during the period 2. Two following experiments were realized. Eight cross-laminated timber plates with the dimensions 2X0.35 m and total thickness in 60 mm were considered in frames of the first experiment. The plates were created from the timber boards with cross-sections 20x110 mm. The fibers of two external layers were oriented in the longitudinal direction. The fibers of one internal layers was oriented under the angle equal to 90°relatively the direction of the fibers of external layers. The layers were glued together by the polyurethane glue under the pressure in 600 kg/m2. Pine wood with the strength class C24 is considered as a board material. A freely supported beam with the span equal to 1.9 m was chosen as a design scheme of the plates. The plates were loaded by the two concentrated forces, which divided the span at three equal parts. The total vertical load changes within the limites from 1 to 7 kN.

Cross-laminated timber plate with the dimensions 2X1 m and total thickness in 95 mm was considered in frames of the second experiment. External and internal layers were made from the timber boards with the dimensions 25x50 and 45x195 mm, correspondingly. Fiber direction of the external layers is parallel to the longitudinal axis of the plate. Fiber direction of the internall layer is oriented under the angle equal to 90° to the longitudinal axis of the plate. The layers were glued together by the polyurethane glue under the pressure in 400 kg/m2. Pine wood with the strength class C18 is considered as a board material. The cross-laminated timber plate, which is suspended by the four corners and loaded by the statically applied uniformly distributed load, was considered as the design scheme. The plate was statically loaded by the uniformly distributed load which intensity changes within the limits from 0.46 to 5.09 kN/m2.

The considered plates from the cross-laminated timber were analized by the transformed sections method, gamma method, composite method, shear analogy method and FEM, which was realized by the programs RFEM 5.0 and ANSYS v15.

Investigations of rational structural solution of innovative smart structure were started during the period 2 of the project. Saddle-shaped cable roof with the rigid support contour and dimensions 60X60 in the plan were considered for the purpose. The height of the saddle-shaped cable roof and distance between the cables of the net were equal to 12 and 2.828 m, correspondingly. Steel cables with the modulus of elasticity in 1.5·105 MPa were considered as the cable net's structural material. Ultimate tensile strength of steel wire was equal to 1770 MPa. The cable roof was loaded by the permanent and snow loads which sum was equal to 3.039 kPa. The roof consists from two layers of the boards with the total thickness equal to 66 mm or cross-laminated timber plates. Pine wood with the strength class C24 is considered as a board material. The cable net from the steel cables was analised by the FEM, which was realized by the program ANSYS v14.

2.4. Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

Core task 1:

The following tasks are defined for the Period 3:

1.1.task – Vehicle weight and speed impact on the structural dynamic characteristics.

1.2.task – Development of mathematical model describing influence of building materials physical uncertainty on loadbearing capacity

Core task 2:

The following tasks are defined for the Period 3:

2.1. task - Development of a method for pre-stress loss estimation in pre-stressed steel reinforced concrete structural elements.

2.2. task - Development of a method for identification of damage in plate-type and sandwich structural elements

Core task 3:

The following tasks are defined for the Period 3:

3.1. task - Development of design procedure for load-bearing elements from cross-laminated timber.

3.2. task - Experimental check of developed design procedure for load-bearing elements from cross-laminated timber.

3.3. task - Topology optimization for structure from cross-laminated timber and evaluation of it rational, from the point of view of it materials expenditure, parameters.

3.4. task - Development of load-bearing structure which consists from the main tensioned members and secondary cross-laminated timber members subjected to flexture.

The development and experimental check of design procedure for load-bearing elements from cross-laminated timber must be completed during the period 3. The experimental check must be done for the cross-laminated timber elements, subjected to compression with the bending.

The development of load-bearing structure which consists from the main tensioned members and secondary cross-laminated timber members subjected to flexture must be continued in frames of the period 3. Topology optimization for structure from cross-laminated timber and evaluation of it rational, from the point of view of it materials expenditure, parameters must be started. The optimization algorithm for structure from cross-laminated timber and model of behaviour for structure from cross-laminated timber must be developed for this purpose. Development of numerical model of the structure must be started. The pedestrian bridge with the span equal to 60 m must be considered. The developed design procedure for load-bearing elements from cross-laminated timber must be used for the purposes.

2.5. Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

In the project Period 2 of the Project „Develop new methods of risk assessment for buildings and structures to ensure their safe, efficient and sustainable operation” were prepared:

Participation in international scientific conferences in 2015:

1. Paeglite I. Traffic load on bridge dynamic response, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;
2. Paeglīte I., Smirnovs J. Dynamic effects caused by vehicle – Bridge interaction, 5th International Scientific Conference of Civil Engineering, Architecture, Land management and Environment, Jelgava, Latvia, May 14-15, 2015;
3. Paeglītis A., Freimanis A. Modeling of traffic loads for bridge spans from 200 to 600 meters, 5th International Scientific Conference of Civil Engineering, Architecture, Land management and Environment, Jelgava, Latvia, May 14-15, 2015;
4. Freimanis A. Analysis of yearly traffic fluctuation on Latvian highways, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September -2.October, 2015;
5. Janeliukstis R., Rucevskis S., Wesolowski M., Kovalovs A., Chate A. Damage identification in beam structure using spatial continuous wavelet transform, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;
6. Wesolowski M., Ručevskis S., Janeliukštis R., Polanski M. Damping Properties of Sandwich Truss Core Structures by Strain Energy Method, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September - 2.October, 2015;
7. Janeliukstis R., Rucevskis S., Wesolowski M., Kovalovs A., Chate A. Damage identification in beam structure using mode shape data: from spatial continuous wavelet transform to mode shape curvature methods, ICoEV 2015 - IFTOMM International Conference on Engineering Vibration, Ljubljana, Slovenia, September 7-10, 2015;
8. Janeliukstis R., Rucevskis S., Wesolowski M., Kovalovs A., Chate A. Damage identification in polymer composite beams using spatial continuous wavelet transform, BPS 2015 – Baltic Polymer Symposium, Sigulda, Latvija, September 16-18, 2015;
9. Vilguts A., Serdjuks D., Pakrastins L. Design Methods of Elements from Cross-Laminated Timber Subjected to Flexure, International Scientific Conference "Urban Civil Engineering and Municipal Facilities", St. Petersburg, Russia, March 18-20, 2015;
10. Stuklis A., Serdjuks D., Goremikins V. Materials Consumption Decrease for Long-span Prestressed Cable Roof, 10th International Scientific and Practical Conference "Environment. Technology. Resources", Rezekne, Latvia, June 18-20, 2015;
11. Vilguts A., Serdjuks D., Goremikins V. Design Methods for Load-bearing Elements from Cross-Laminated Timber, 2nd International Conference "Innovative Materials, Structures and Technologies", Riga, Latvia, 30.September -2.October, 2015;

Published peer-reviewed papers in 2015 (abstracted in Scopus or in Web of Science):

1. Freimanis A., Paeglītis A. Analysis of yearly traffic fluctuation on Latvian highways, IOP Conference Series: Materials Science and Engineering,Volume 96, 2015
   a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012064/pdf
2. Janeliukstis R., Rucevskis S., Wesolowski M., Kovalovs A., Chate A. Damage Identification in Beam Structure Using Spatial Continuous Wavelet Transform, IOP Conference Series: Materials Science and Engineering, Volume 96, 2015, 961-12
   a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012058/pdf
3. Wesolowski M., Ručevskis S., Janeliukštis R., Polanski M. Damping Properties of Sandwich Truss Core Structures by Strain Energy Method, IOP Conference Series: Materials Science and Engineering, Volume 96, 2015, 1-8
   a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012022/pdf

4. Mironov A., Doronkin P., Priklonsky A., Chate A. Effectiveness of Application of Modal Analysis for the Monitoring of Stressed or Operated Structures, Aviation, Volume 19, 2015, 112-122
   a. http://www.tandfonline.com/doi/abs/10.3846/16487788.2015.1104860
5. Vilguts A., Serdjuks D., Pakrastins L. Design Methods of Elements from Cross – Laminated Timber Subjected to Flexure, Procedia Engineering, Volume 117, 2015, 10-19
   a. http://www.scopus.com/record/display.uri?eid=2-s2.0-84941059644&origin=resultslist&sort=plf-f&src=s&st1=Serdjuks&st2=&sid=825680C2EBD50EF96A423542C8B86583.Vdktg6RVtMfaQJ4pNTCQ%3a210&sot=b&sdt=b&sl=21&s=AUTHOR-NAME%28Serdjuks%29&relpos=0&citeCnt=0&searchTerm=
6. Vilguts A., Serdjuks D., Goremikins V. Design Methods for Load-bearing Elements from Cross-Laminated Timber, IOP Conference Series: Materials Science and Engineering, Volume 96, 2015
   a. http://www.sciencedirect.com/science/article/pii/S1877705815017713
7. Hirkovskis A., Serdjuks D., Goremikins V., Pakrastins L., Vatin N. Behaviour Analyze of Load-bearing Members from Aluminium Alloys, Inzhenerno-stroitelnyj zhurnal, 86-96
8. Sliseris J., Andrae H., Kabel M., Wirjadi O., Dix B., Plinke B. Estimation of Fiber Orientation and Fiber Bundles of MDF, Materials and Structures, 2015, 1-10

Published full papers in conference proceedings in 2015:

1. Paeglīte I., Smirnovs J. Dynamic effects caused by vehicle – Bridge interaction. In. Proceedings of the 5th International Scientific Conference, Volume 5, 2015, 11-14
2. Paeglītis A., Freimanis A. Modeling of traffic loads for bridge spans from 200 to 600 meters. In. Proceedings of the 5th International Scientific Conference, Volume 5, 2015, 15-23
3. Stuklis A., Serdjuks D., Goremikins V. Materials Consumption Decrease for Long-span Prestressed Cable Roof, In Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources" Volume 1, 2015, 209-215

Defended bachelor theses:

1. M.Cepurnieks "Traffic organisation and safety analysis and possible improvements in Limbazi city", project "Rostokas street reconstruction in Riga", supervisor. J.Smirnovs.
2. Karina BUKA-VAIVADE „Design methods evaluation for load-bearing elements from cross-laminated timber. Health centre." (supervisor Dr.sc.ing. prof. D.Serdjuks).

Defended master theses:

1. K. FREIMANIS, „Load-bearing elements from Z-profiles behaviour analyse"(Supervisor Dr.sc.ing. prof. D.Serdjuks).
2. J. JURIČUKA, „Behaviour analyse of load-bearing elements from cross-laminated timber" (Supervisor Dr.sc.ing. prof. D.Serdjuks).
3. J. MŪRNIEKS, „Analyse of timber roof load-bearing capacity increase",(supervisors Dr.sc.ing. prof. D.Serdjuks, M sc.ing. asist. A. Kukule)
4. T. SAKNITE, „Analyse of fire resistance of arch-type timber roof" (supervisor Dr.sc.ing. prof. D.Serdjuks).

Preparation of a doctoral thesis:

1. Ilze Paeglīte "Moving load effect on the bridge dynamic characteristics", scientific supervisor – prof. Dr.sc.ing. Juris Smirnovs, planned to defend in 2017.

2. Andris Freimanis „ Risk consideration for safe, effective and sustainable bridge structures", scientific supervisor – prof. Dr.sc.ing. Ainārs Paeglītis, planned to defend in 2018.
3. Rims Janeliukštis „Development of damage identification methods for structural health monitoring", scientific supervisor – prof. Dr.sc.ing. Andris Čate, planned to defend in 2018.
4. A.Vilguts „Rational structure of multy-storey buildings from cross-laminated timber", supervisor D.Serdjuks, planned to defend in 2018.

Popular-science publication in journal:

1. Paeglītis,A. (2015) Koka tilti Latvijā – vēsture un perspektīvas (Timber bridges in Latvia – history and perspective). // Būvinženieris, 2015.gada decembris, Nr.47, 156-163.lpp. ISSN 1691-9262.

The performance indicators of the programme and project promotion

Project representatives participated in the NRP IMATEH meetings on the Project progress and implementation on 8.11.2014 and 26.05.2015.

In addition, the Project members was working actively organising two scientific conferences in 2015 - IMST „Innovative Materials, Structures and Technologies" on 30.09.2015-02.10.2015 as well as scientific conference for students on 28.04.2015.

Leader of the project No. 3 ______________ Ainars Paeglitis ______________

(signature and transcript) *(date)*

PART 2: PROGRAMME PROJECT INFORMATION

2.1. Project No. 4

Title	***Layered wooden composite with rational structure and increased specific bending strength***		
Project leader's name, surname	Karlis Rocens		
Degree	Dr.sc.ing.		
Institution	Riga Technical University, Institute of Structural Engineering and Reconstruction		
Position	Professor		
Contacts	*Phone number*		+371 22023321
	E-mail		rocensk@latnet.lv

2.2. Tasks and deliverables *(List all tasks and deliverables that were planned for reporting period, list responsible partner organizations, give status, e.g. delivered/not delivered)*

The aim of the project is creation of rational wooden composite with rational structure.

Development of load bearing layered wood composite with rational structure (standard plywood plates do not have rational distribution of material through the thickness and layered material gives an opportunity to create an optimal topology of material distribution through the thickness) that provides increased specific bending stiffness (stiffness to weight ratio), reduced costs, consumption of materials and energy when compared to traditionally used materials (LV Patent No. 14519).

A new type of composite construction will be proposed with cell type hollow ribs and skins of plywood or other material. This type of ribs allows to vary the stiffness of wood composites in a more meaningful way as it is for standard plywood or existing sandwich constructions. Mainly the serviceability limit state was considered in this project as it is reached at lower load than ultimate limit state.

A particular solution of ribs will be created; absolute and specific strength will be given and compared to standard type of constructions (plywood sheets, sandwich panels). A new method of calculations will be developed for designing and usage of the plates with proposed structure.

This solution offers to adjust with load bearing capacity in bending and to reduce consumption of material in less loaded areas of cross section. This leads to a new design methodology for structural design which harmonizes section stress field with material resistance field of the developed structure.

After realization of the project it will be possible to produce ribbed plates with cell type core and to develop the technology of production for small amounts (experimental parties). This material could be widely used in furniture production and for structural applications. At the same time it will give an opportunity to use the proposed plates in combination with CLT panels in multi-storey wood building industry. Time schedule for project 4 is given in Annex 4-A.

Nr.	Tasks	Deliverable	Responsible partner	Status
1	Development of methodology for determination of bending strength and conceptual experimental investigations of plates with cell type hollow ribs (task ends in the 2nd	Methodology	K. Rocens Institute of Structural Engineering and	In progress

	quarter of year 2016).		Reconstruction	
2	Development of methodology for determination of specific bending strength for plates with cell type hollow ribs and determination of values for the most typical geometrical parameters (task ends in the 3rd quarter of year 2016).	Methodology	K. Rocens Institute of Structural Engineering and Reconstruction	In progress
3	Work-out of plate models with most typical types of hollow cell type ribs and experimental investigations to get specific strength in bending, consumption of materials, energy consumption and costs (task ends in the 2nd quarter of year 2017).	3 types of plates	K. Rocens Institute of Structural Engineering and Reconstruction	In progress

The development of calculation method for plates with cell type core has been proceeded in second phase of the project.

Load bearing capacity in bending has been determined for the plates with cell type core and supports oriented in orthogonal direction of ribs based on MATLAB code which is developed in framework of the project. This MATLAB code automatically generates the input files for ANSYS FEM software in parametric Design language (APDL) providing possibility to calculate the stiffness and to determine the load bearing capacity in bending of a plate depending on characteristics of materials and geometry of structure for the necessary boundary. The results practically do not differ when compared to the results obtained from experimental investigations in case when the rigid connection between ribs and skins is provided.

The methodology has been developed for shear and tensile strength determination for specific specimens with narrow glued line-joint between plywood surface and edges of ribs. Experimentally investigated more than 300 specimens. Obtained results give an opportunity to design the load bearing capacity in bending for plates with the supports oriented in orthogonal direction of ribs by taking into account the characteristics of geometry and deformations.

The laboratory equipment has been made for the manufacturing of cell type hollow ribs and the plates with these ribs. More than 10 plates with cell type hollow ribs have been manufactured and experimentally investigated. Numerical determination of specific load bearing capacity in bending have been done for the case when the plates is bent in the direction of ribs. More detailed information about the results in achieving the object have been reflected in 4 scientific articles and in 2 patents.

The required amount of research in second phase of project for the realization of project aim has been done completely.

In case of non-fulfillment provide justification and describe further steps planned to achieve set targets and results

-

2.3. Description of gained scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

Task	Deliverables
1. Development of methodology for determination of bending strength	***Method of calculations of load bearing capacity in bending when the supports are oriented in orthogonal***

and conceptual experimental investigations of plates with cell type hollow ribs (task ends in the 2nd quarter of year 2016).	***direction of ribs.*** ***Shear and tensile ultimate strength of narrow glued line-joint between the plywood surface and the edge of ribs.*** ***Conceptual analytical and experimental investigations of load bearing capacity in bending (for the supports oriented in orthogonal direction of ribs).***

Continuous the development of methodology for determination of bending load bearing capacity (started in phase 1).

On the basis of the methodology for determination of plate's load bearing capacity in bending specially developed software in MATLAB environment, which automatically generates input file code in ANSYS ADPL and in a parametrical way defines the geometry of plate, properties of materials and applied boundary conditions. ANSYS finite element module calculates the stiffness of a plate and stress-strain field by using this code and generates database of strength and stiffness results depending on geometry of plates. This database is used to train artificial neural network which is used to evaluate the objective function that is used for optimization with genetic algorithm.

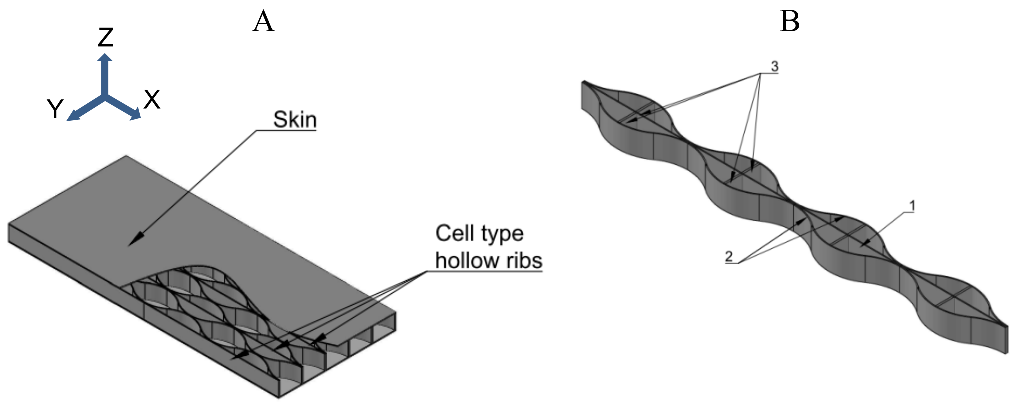


Figure 1. Structure of plate with cell type core: A – structure of a plate; B – structure of one cell type hollow rib with wooden laths. 1 – straight rib part; 2 – waved rib parts; 3 – shear rib laths.

Two different cases have been taken for ANSYS ADPL – plate's behavior when the supports are oriented in orthogonal direction (first case) or in parallel direction (second case). As the experiments show linear bending behavior till fracture for the first case whereas for the second case it is linear only till 30% of ultimate load. Therefore, it is required to take into account nonlinear mechanical properties of glued joint and plywood with crack development in the joint and area near the joint. This nonlinear model of calculations can be used for rational design of energy absorption and vibration damping structures.

The plate is designed in two levels. In the first level the plywood elements (ribs and skins) were designed by using SHELL181 finite elements which are based on Kirchoff-Love (for curved thin ribs) or Mindlin-Reissner theory (for thick plywood elements).

In the second level the ribs (and insulation material if needed) are replaced with one homogenized middle layer (thickness equal to the height of ribs) with anisotropic properties that are obtained from results at first level and numerical homogenization. For the analysis of plate in orthogonal direction to ribs for the homogenized middle layer nonlinear properties (modulus of elasticity and shear modulus) depending on the loads is determined. For the complicated geometry finite elements with homogenized middle layer are used. These elements are based on Reissner-Mindlin shear deformation theory. If the geometry and restrictions are relatively simple, an analytical solution of plates bending problem that is described by partial differential equations is obtained.

Nonlinear behavior of glued joint which is required to take into account for the design of plate's behavior in orthogonal direction of ribs, is simulated by using the cohesive finite element that takes into account the crack development in glue layer. It is realized with INTER20X finite elements in ANSYS environment that simulates separation process in glued joint. In calculations the corresponding interfacial separation δ (displacement jump across the interface) is defined with division in normal δ_n and tangential (shear) δ_t separation. The ultimate normal σ_{max} and ultimate tangential stresses τ_{max}. The cohesive zone model is described with exponential function (TB,CZM,,,,EXPO) with the required input data (TBDATA,1,σ_{max},$\bar{\delta}_n$,$\bar{\delta}_t$,,), if the INTER20X elements are used.

The experimental investigations were made to determinate the required input data for calculation model. In both cases (to determinate the tension and shear properties) special specimens were made that describes the shear and tension behavior of glued joint between plywood surface and plywood edge. Both types of specimens were tested in tension by using loading machine (fig. 2).

For the specimens the tension grips were used to apply force. Displacement (of grips)- load curve was recorded. The double lap specimen was created to determine the shear strength of specimen with 5 mm gap between both rib elements (fig. 2 A). The overlap was created symmetrically on both sides of specimen. For all joints the polyvinyl acetate (Vincents Polyline PVA D3) glue was used that provides water resistant connection of class D3 according to EN 204.

The series of specimens differ to each other with the thicknesses (4.0; 6.5 and 9.0 mm) and the fiber orientation of surface layer (0° and 90°) of ribs and skins. More than 300 specimens were investigated. Mean shear strength was determined 7.18±a MPa (a – difference between mean value and upper and lower value of confidence interval of mean value depending on the value of probability of level of confidence), mean displacement at fracture was 0.63±a mm.

The special series of specimens (fig. 2 B) were made to determine the tensile strength of specimens with various orientations of the outer fiber of plywood and various thicknesses of plywood. The mean tensile strength for plywood edge to surface was determined 3.53 MPa and the mean displacement at fracture was 0.14±a mm.

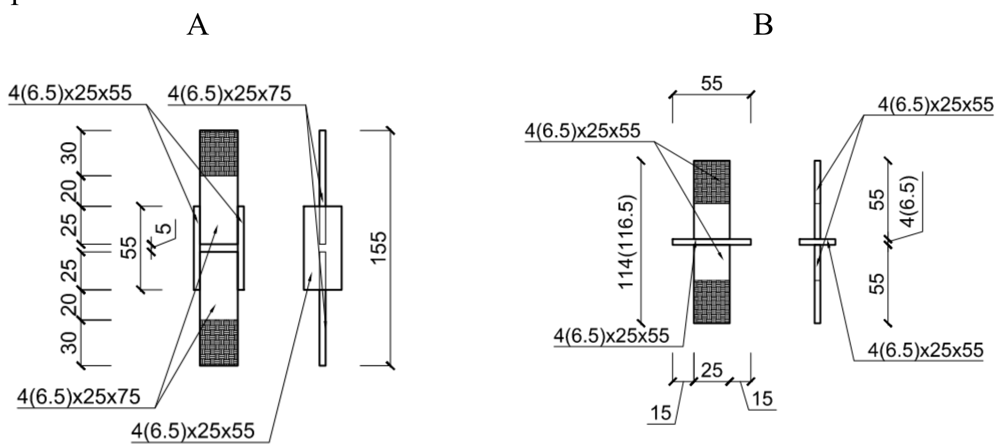


Figure 2. Specially made specimens for determination of ultimate shear and tensile strength of glued joint: A – specimen for shear strength determination of glued joint; B – specimen for tensile strength determination of glued joint.

The distribution that is close to the normal distribution was determined by using statistical analysis of specimen series (fig. 3). For case A: asymmetry – 0.10; excess – 3.00; correlation to the normal distribution – 0.9922. For case B: asymmetry – 0.07; excess – 2.52; correlation to the normal distribution – 0.9945.

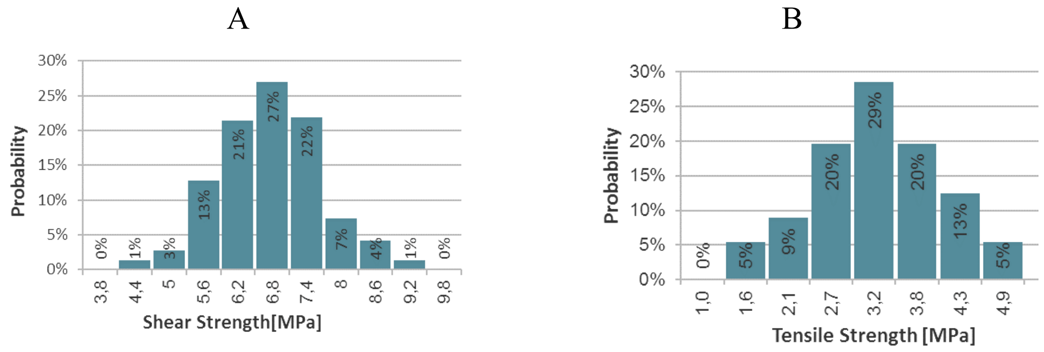


Figure 3. Histograms of plywood edge-to-surface glued joint strength: A – probability distribution of ultimate shear strength; B – probability distribution of ultimate tensile strength.

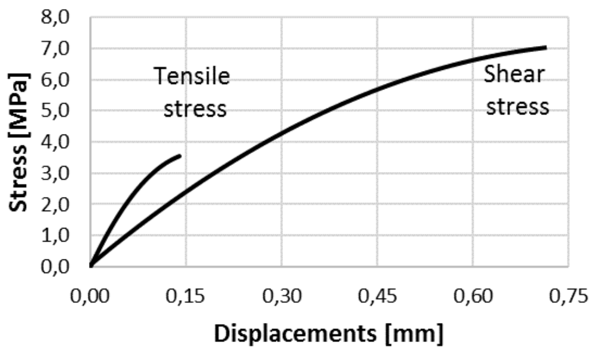


Figure 4. Stress-displacements characteristic curves of glued joints for determination of shear strength (for series with rib plywood with thickness of 6,5 mm and skin plywood with thickness of 4,0 mm with fiber direction same as applied force direction) and tensile strength (for series with rib plywood with thickness of 6,5 mm and skin plywood with thickness of 4,0 mm with fiber direction orthogonal to applied force direction).

Part of experimental results are published in http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012048.

The properties of materials and the glued joint (tension and shear) tests were done in laboratory of Institute of materials and structures by using INSTRON E3000.

More than 10 plates (with thickness 25, 50 and 100 mm with cell type core were investigated in four-point bending (EN 789). For conceptual tests of plates with cell type core in short term loading (supports oriented in orthogonal direction of ribs) the deflections are proportional to the applied load and numerical investigations practically coincidence with experimentally achieved results (difference <5%). The deflection of plates when the longitudinal direction of a plate is in direction of ribs, was determined experimentally according to LVS EN 789:2000 Timber structures – Test methods – Determination of mechanical properties of wood based panels. The methodology should be developed for the case when supports are in parallel direction of ribs.

Second phase of the first task (task ends in the 2nd quarter of year 2016) is successfully done according to time schedule.

2. Development of methodology for determination	*Methodology of calculations for specific*

of specific bending strength for plates with cell type hollow ribs and determination of values for the most typical geometrical parameters (task ends in the 3rd quarter of year 2016).	***load bearing capacity in bending (load bearing capacity to one mass unit) for plates with cell type core (for the supports oriented in orthogonal direction of ribs).***

The specific load bearing capacity in bending has been numerically determined for the plates with cell type core depending on thickness of a plate and the geometrical parameters of cell type hollow rib. The comparison was made for specific load bearing capacity of plates that consist of a) straight rib part and curved rib parts; b) only curved rib parts; c) only straight rib parts to the massive plywood with equivalent thickness. For the ribbed plates with various thicknesses of straight rib part were analyzed.

It has been established that the outer ply of curved rib part has minor influence on the stiffness of a plate in case with the supports oriented in orthogonal direction of ribs. For thickness of ribbed plates less than 1/20 of span (supports in orthogonal direction of ribs), the specific stiffness practically is the same for all investigated ribbed plates. If the thickness increases more than 1/20 of span, highest load bearing capacity in bending for plates with cell type core is obtained.

The developed method of calculations gives an opportunity to compare the efficiency of core for providing required load bearing capacity in bending that characterizes the efficiency of material consumption.

The influence of geometrical parameters on a plate's specific bending stiffness has been determined. The most influence to specific stiffness of plates (stiffness to unit mass for given cross section) in longitudinal direction of a plate (fig. 5) has not only the thickness of hollow rib but also straight rib part and the width of the hollow rib.

Specific load bearing capacity in bending for the plates with cell type hollow ribs is obtained numerically and compared to standard plywood and to the plates with straight ribs. The results show that by increasing the thickness of a plate the benefit of cell type hollow ribs increases. This is described in publication http://journals.ru.lv/index.php/ETR/article/ download/633/609 that shows how the stiffness of a plate changes depending on thickness of a plate, geometry of waves and dimensions of plywood.

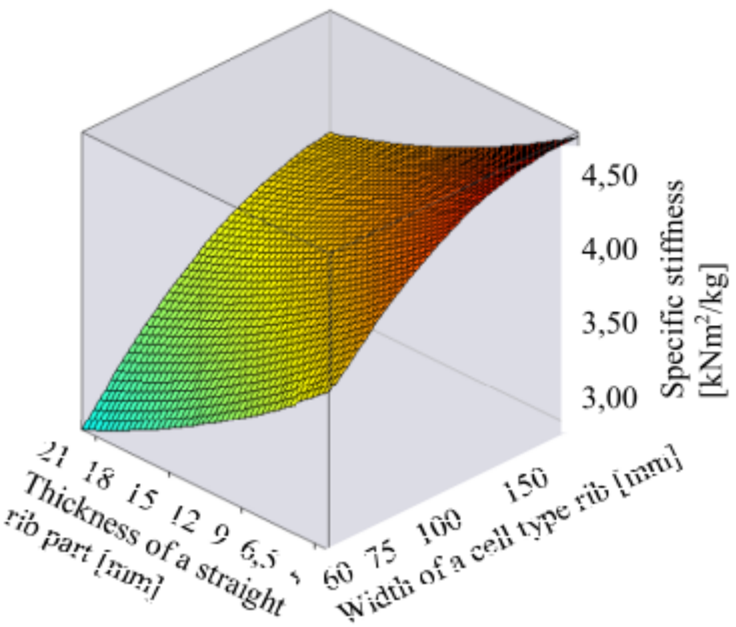


Figure 5. Specific stiffness of a strip with width of 1 m depending on the thickness of straight

rib part and width of a cell type rib (span – 1.5 m; thickness of a plate – 3 cm; number of waves along the length – 3; thickness of skins and waved rib parts – 4.0 mm).

The analysis shows that specific load bearing capacity in bending for the ribbed plates is twice as big as it is for standard plywood. Detailed analysis of specific load bearing capacity in bending for various thicknesses of plate and the curvature of waved rib part is planned in next phase of project.

The part of the second task (task ends in the 3rd quarter of year 2016) planned in second phase is successfully done according to time schedule.

3. Work-out of plate models with most typical types of hollow cell type ribs and experimental investigations to get specific strength in bending, consumption of materials, energy consumption and costs (task ends in the 2nd quarter of year 2017).	***The laboratory equipment for production of plates and pre-product of cell type hollow ribs. More than 10 plates have been made and experimentally investigated.***

The laboratory equipment (fig 6 A) has been made for production of plates and pre-product of cell type hollow ribs. Hydraulic jack (50 kN) was used to apply the load. The dynamometer was used to measure the applied load and to calculate the pressure on plates with accuracy of ±0.01 MPa. The movable plate provides uniformly distribution of pressure along the fixed plane. With this laboratory equipment can be produced plates with dimensions of 1500×850 and thickness up to 250 mm. With special adaptation (fastening the guides) it is possible to use it for the manufacturing of ribs according to the patent LV15083 achieved in a framework of project. The produced forms (fig. 6 B and C) was sawn in strips which width is equal to the height of a ribs and the specimens were made with various thicknesses. The experimental investigations were done for these plates to the first validation of methodology of calculations.

The laboratory equipment made in framework of project allows to produce plates with various thicknesses (up to 250 mm) and to evaluate the influence of technology factors on production quality and form stability to plate's resistance against the behavior when resisting applied loads. Meanwhile it gives an opportunity to produce and test a different structural timber materials and structural elements.

The pre-products and first experiments with plates of three different thicknesses (25, 50 and 100 mm) have been made. After evaluation of produced plates no warping deformations were detected.

A B C

Figure 6. The laboratory equipment and glued pre-product of ribs: A – laboratory equipment for production of plates and rib pre-products; B – pre-products of ribs with glued laths; C – pre-products of ribs without glued laths.

It is shown that experimental investigations coincide to the theoretically calculated and practically does not differ that shows to possibility to produce series of plates with cell type hollow ribs with small variation of mechanical properties. The principles of technology (e. g. bond pressure on glued butt joints) is successfully made and should be specified in detail during next phases.

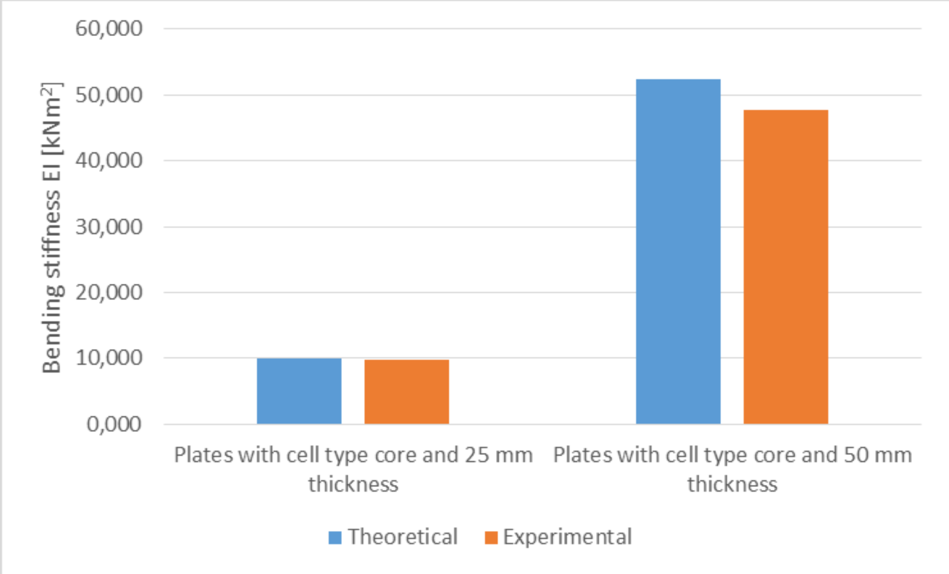


Figure 7. Experimentally and numerically obtained bending stiffness of plates with cell type core. Width of plates is 1m and thickness of 25mm and 50mm. All plywood elements are made of Riga Ply plywood (span 110cm; thickness of skins- 4,0mm; thickness of flat ribs- 6,5mm; thickness of curved ribs- 4,0mm).

To expand the practical use of this material additionally to the planed tasks were done the research about MDF plates which would be possible to use for skins and ribs http://link.springer.com/article/10.1617%2Fs11527-015-0769-1. As well additional research was carried out for the influence of temperature and moisture flow along the plates thickness on the wooden material ribs and their behavior – http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012048.

For the assigned application in first phase of project is recived patent LV14979 „ Method for producing ribbed plates" (K. Rocens, A. Kukule, G. Frolovs, J. Sliseris, G. Berzins) – http://www.lrpv.gov.lv/sites/default/files/20150620.pdf. Additionally, was assigned patent application and received patent LV15083 "Method and equipment of production for ribbed composite plate with goffered wood-based core" (K. Rocens, G. Frolovs, A. Kukule, J. Sliseris) – (http://www.lrpv.gov.lv/sites/default/files/20151220.pdf).

The part of the third task (task ends in the 2nd quarter of year 2017) planned in second phase is successfully done according to time schedule.

The project personal salary makes 24 830 EUR (bruto salaries – 20 376 + social taxes – 4454) in reporting period.

The following research is planned to be made according to time schedule (Annex 4-A).

2.4. Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

It is planned to continue those tasks already started in previous phases. Two additional tasks planed in framework of project will be started:

1. Recommendations work out for design of geometrical parameters of plates with hollow cell type ribs.
2. Recommendations' work out manufacturing and 'work in' technology principles and produce plates' demonstration models.

All tasks related to practical exploitation of the results will be done and shown according to time schedule given in Annex 4-A.

2.5. Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

Published papers in scientific journals:

1. Sliseris J., Andrae H., Kabel M., Wirjadi O., Dix B., Plinke B. Estimation of Fiber Orientation and Fiber Bundles of MDF. – Materials and Structures, 2015, ISSN 1359-5997. – 1 – 10 p.
    a. http://link.springer.com/article/10.1617%2Fs11527-015-0769-1

Published papers in international conference proceedings (with oral presentation in related conference):

1. Frolovs G., Rocens K., Sliseris J. Comparison of a Load Bearing Capacity for Composite Sandwich Plywood Plates. – 10th International scientific and practical conference „Environment. Technology. Resources", Rezekne, 18.06. – 20.06.2015
    a. http://journals.ru.lv/index.php/ETR/article/download/633/609
2. Frolovs G., Rocens K., Sliseris J. Glued Joint Behavior of Composite Plywood Plates with Cell Type Core. – 2nd International Conference „Innovative Materials, Structures and Technologies", Riga, Latvia, 30.09. – 02.10.2015
    a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012048
3. Kukule A., Rocens K. Prediction of Moisture Distribution in Closed Ribbed Panel for Roof. – 2nd International Conference „Innovative Materials, Structures and Technologies", Riga, Latvia, 30.09. – 02.10.2015
    a. http://iopscience.iop.org/article/10.1088/1757-899X/96/1/012034

Patents:

1. Rocens K., Kukule A., Frolovs G., Sliseris J., Berzins G. LV14979 „Method for producing ribbed plates" – The Official Gazette of the Patent Office of the Republic of Latvia 20.06.2015, pp 785 – http://www.lrpv.gov.lv/sites/default/files/20150620.pdf
2. Rocens K., Frolovs G., Kukule A., Sliseris J. LV15083 "Method and equipment of production for ribbed composite plate with goffered wood-based core". – The Official Gazette of the Patent Office of the Republic of Latvia 20.12.2015, pp. 1749. – http://www.lrpv.gov.lv/sites/default/files/20151220.pdf

Submitted and accepted abstracts for international scientific conferences:

1. 12th international conference "Modern Building Materials, Structures and Techniques" in Vilnius, Lithuania, on 26–27 May, 2016
    I. Frolovs G., Rocens K., Sliseris J. Shear and tensile strength of narrow glued joint depending on orientation of plywood plys
    II. Kukule A., Rocens K., Lukasenoks A., Frolovs G. Change of Moisture Distribution in Ribbed Plate with Different Opposite Surface Temperatures
    III. Sliseris J., Gaile L., Pakrastins L. Deformation process numerical analysis of T-stub flanges with pre-loaded bolts.
2. Confirmation of participating with 3 papers in International Conference "Advanced Construction" in Kaunas, Lithuania on 6-7 October, 2016
    I. Frolovs G., Rocens K., Sliseris J. Stress state analysis of plates with cell type ribs under loading.

II. Kukule A., Rocens K. Determination of Moisture Distribution in Ribbed Plates Induced by the Temperature Gradient
III. Sliseris J., Gaile L., Pakrastins L. Non-linear buckling analysis of steel frames

Supervised doctoral thesis:

1. G. Frolovs "Calculations of rational wooden composite structures and their elements";
2. Kukule "Behavior of plywood ribs in various conditions of moisture"

Defended master thesis:

1. Ucelnciece "Impact of snow loads on different types of roof shapes" (Supv. D. Serdjuks, G. Frolovs);
2. Zukovska-Kecedzi, „Wind load action depending on the roof's shape" (Supv. D. Serdjuks, A. Kukule);

Results of the project popularization in phase 2:

1. The representatives of the project have been participated in all meetings of State Research program IMATEH about the process and state of art of projects and program.
2. In framework of program is organized international scientific conference IMST 2015 (30.09. – 02.10.2015).
3. Seminar "Possibilities of cooperation with German company MC Bauchemie" (10.11.2015).
4. Seminar "Research and activity directions in commercialization project's results. Information for representatives of Latvian Academy of Science" (27.11.2015).
5. Seminar "Progress in research of ribbed plywood bending load bearing capacity. Discussion with representatives of industry" (11.12.2015).

Detailed information about activities and actualities of 4th Project has been published in the IMATEH home page http://imateh.rtu.lv/.

Leader of the project No. 4 ______________________Karlis Rocens____________________

(signature and transcript) *(date)*

PART 2: PROGRAMME PROJECT INFORMATION

2.1. Project No. 5

Title	***Material mechanical micro- nano- scaled features and their impact on human safety***		
Project leader's name, surname	Jurijs Dehtjars		
Degree	Dr. hab. phys		
Institution	Riga Technical University, Institute of Biomedical Engineering and Nanotechnologies		
Position	Head of the Institute, Professor		
Contacts	*Phone number*		+371 29469104
	E-mail		jurijs.dehtjars@rtu.lv

2.2. Tasks and deliverables

(Describe the project goals and objectives so that the achievements reported below could be placed in context and evaluated)

Project goal: To research early destruction of surface of polymer composite materials, to develop methods of early diagnostics and analyze application of the methods in enterprises.

Task 1 of the 2nd Period: *Development of research methods for diagnostics of early destruction of surface of polymer composite materials: the method to research influence of aquatic microorganisms on early destruction of materials.*

The following was planned in order to accomplish the Task: (1) to perform TOC (*total organic carbon*) leaching and microorganisms counting experiments using aging acceleration of polymeric pipes (at 60 °C temperature); (2) to develop the research method for development of diagnostics of early destruction of surface of polymer composite materials using *in situ* electron emission spectroscopy (the Deliverable).

Task 2 of the 2nd Period: *Development of research methods for diagnostics of early destruction of surface of polymer composite materials: the method to research visual recognition of early destruction using destruction-induced staining.*

The following was planned in order to accomplish the Task: (1) to perform experimental measurements and simulations in order to determine mechanical properties of microcapsules embedded in an elastic matrix; (2) to develop the research method for development of diagnostics of early destruction of surface of polymer composite materials using destruction-induced staining (the Deliverable).

Time frame for the tasks is given in Annex 5-A.

The goal and tasks of the 2nd Period of the Project were fully achieved:

- Ability of the inner walls of polyethylene pipes to leach organic compounds into drinking water was tested at 60 °C temperature (under leaching promoting conditions). Using microbial consortium of Evian water and indicator of faecal contamination *E.coli* bacteria as an example, it was shown that the organic compounds leached into the water serve as nutrients for bacteria and promote bacterial growth.
- Using the method of photoelectron emission spectroscopy, it was determined that structural changes in surface of polymer composite materials occur already in the region of elastic deformation.

- Two types of polymer composite materials containing dye and developer-filled microcapsules were prepared and tested for the main mechanical properties. Using Voigt and Reuss models of the general rule of mixtures, effective modulus of elasticity of the microcapsules was indirectly estimated.
- Electropassive unidirectionally reinforced composite based on nanomodified epoxy resin was prepared. Conductivity anisotropy of the composite was determined experimentally: longitudinal and lateral conductivity differed about 10 times.
- It was found that increase in the concentration of nanotubes in epoxy binder to 1.5% changes electric conductivity of the composite from insulator to electrical conductor and the resistivity drops about 100 times.
- Literature review about mechanical testing methods of microcapsules has been launched.

The following Deliverables were delivered upon the completion of the 2nd Period:

Nr.	Task	Deliverable	Responsible partner	Status
1.	Development of research methods for diagnostics of early destruction of surface of polymer composite materials: the method to research influence of aquatic microorganisms on early destruction of materials	Research method for development of diagnostics of early destruction of surface of polymer composite materials using *in situ* electron emission spectroscopy	J. Dehtjars, Institute of Biomedical Engineering and Nanotechnologies, RTU	Delivered Annex- NN
2.	Development of research methods for diagnostics of early destruction of surface of polymer composite materials: the method to research visual recognition of early destruction using destruction-induced staining	Research method for development of diagnostics of early destruction of surface of polymer composite materials using destruction-induced staining	A. Aņiskevičs, Institute of Material Mechanics of the University of Latvia	Delivered Annex- NN

2.3. Description of gained scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

Tasks of the Project	The main results
1. Development of research methods for diagnostics of early destruction of surface of polymer composite materials: the method to research influence of aquatic microorganisms on early destruction of materials.	***The method developed***
The following results were achieved during the report period: Ability of polyethylene pipes to leach organic hydrocarbons into drinking water was tested. Evian water filtered through 0.1 μm filter was used. Water was replaced daily in the pipes. After 72 hours increase in the number of bacteria found in the water with the leached organic compounds was measured. The results showed that the polymeric pipes leached organic substances into water and this promoted multiplication of bacteria. Moreover, not only number of Evian water consortium bacteria increased (which is a normal phenomenon because this is a common environment for the bacteria) but number of *E.coli* bacteria increased as well. Multiplication of *E.coli* indicates that polymeric pipes can promote growth of faecal bacteria in case of unintentional or intentional contamination.	

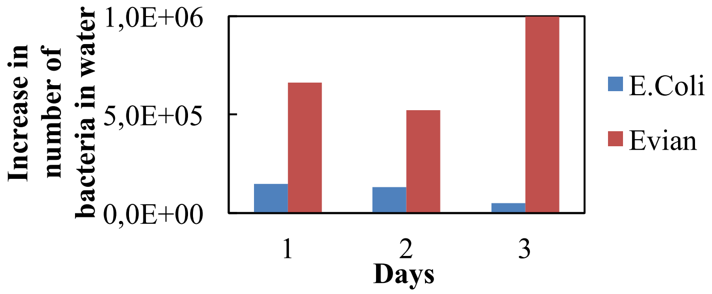


Fig.1. Increase in the number of bacteria in water that was held 24 hours in polyethylene pipes

The research method for development of diagnostics of early destruction of surface of polymer composite materials using *in situ* electron emission spectroscopy was developed (the Deliverable): in order to detect early mechanical changes in the surface of materials, it is necessary to measure photoelectron emission during mechanical deformation of the samples and monitor photoelectron emission current changes that occur in the elastic deformation region. Fig. 2 (a) shows behaviour of PE-80 polymeric pipe during deformation. Stress is linearly dependent on strain until the strain reaches 1.6 %. One may conclude that PE-80 pipe behaves like an elastic material in the strain region from 0 to 1.6%, however, there is a sharp decrease in the electron emission current at a strain of 0.8% (shown with the black dashed vertical line in Fig. 2 (a)). This decrease can happen due to structural changes in the polymeric pipe. Changes in electron emission during elastic mechanical loading of fiberglass and epoxy resin composite are shown in Fig. 2 (b). There is an increase in photoelectron emission intensity at a stain of 1.8% which means that structural changes occurred in the material.

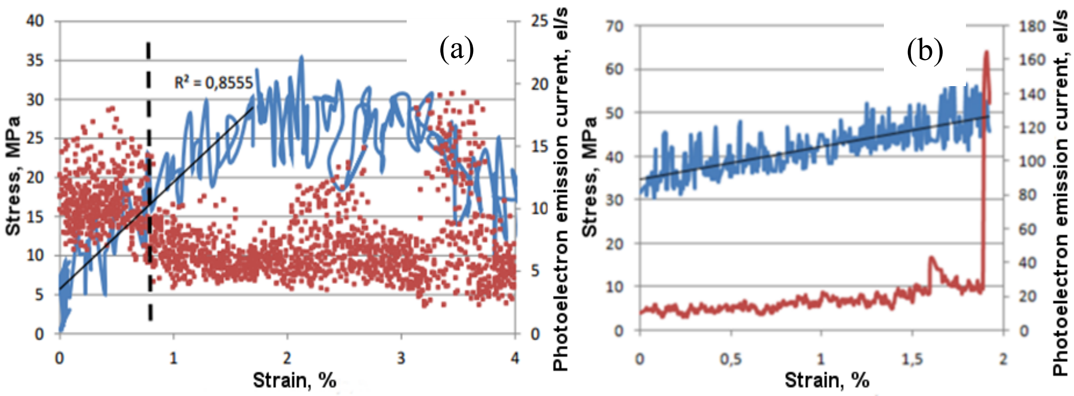


Fig.2. Stress-strain relationship (in blue) and dependence of photoelectron emission intensity on stain (in red): (a) PE-80 polymeric pipe; (b) fiberglass and epoxy resin composite

2. Development of research methods for diagnostics of early destruction of surface of polymer composite materials: the method to research visual recognition of early destruction using destruction-induced staining.	***The method developed***

The following results were achieved during the report period:

Two types of polymer composite materials containing different concentrations of dye and developer-filled microcapsules were prepared: 1) microcapsules in PVA (polyvinyl acetate) glue matrix, 2) microcapsules in epoxy resin matrix. All samples were tested in tension. In addition, effective modulus of elasticity of the microcapsules was indirectly estimated using Voigt and Reuss models of the general rule of mixtures.

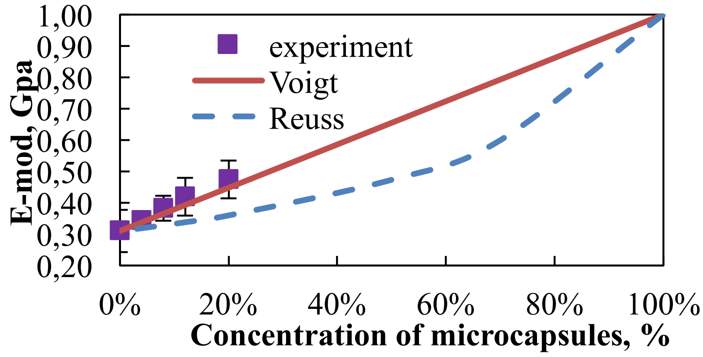


Fig.3. Effective modulus of elasticity of the microcapsules that was measured experimentally and estimated indirectly using Voigt and Reuss models

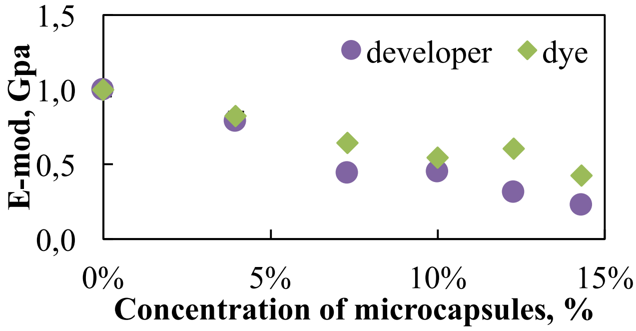


Fig.4. Effective modulus of elasticity of epoxy resin containing microcapsules

Electropassive unidirectionally reinforced composite based on nanomodified epoxy resin was prepared. Conductivity anisotropy of the composite was determined experimentally: longitudinal and lateral conductivity differed about 10 times.

Increase in concentration of nanotubes in Araldite LY 1564 + Aradur 3486 epoxy binder up to 1.5% changes electric conductivity of the composite from insulator to electrical conductor and the resistivity drops about 100 times (to 20 Ω·m).

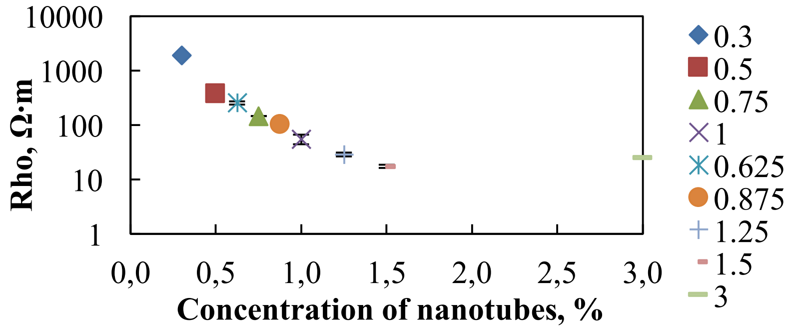


Fig. 5. Conductivity of Araldite LY 1564 + Aradur 3486 epoxy binder depending on concentration of nanotubes

Literature review about mechanical testing methods of microcapsules has been launched. Analysis of scientific publications about micro-manipulation techniques and AFM (atomic force microscopy) for testing of microcapsules was performed.

The research method for development of diagnostics of early destruction of surface of polymer composite materials using destruction-induced staining was developed (the Deliverable).

The achieved results have the following scientific and practical importance:

- It has been proved that in order to predict destruction of polymer composite materials, it is important to take into account structural changes in the material that occur at micro and nano scale already in elastic deformation region.
- Nowadays polymeric pipes are widely used in water supply systems, however not much information is available on the influence of organic compounds leached into water from

the walls of the pipes on human health. The results obtained in the project draw this problem to attention.

2.4. Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

Technological readiness has been achieved for the implementation of the 3rd Period of the Project. The achieved results demonstrate ability to continue implementation of the Project in accordance with the original application and develop methods for diagnostics of early destruction of polymer composite materials. **Therefore, two following tasks are planned for the 3rd Period:**

1. Development of methods for diagnostics of early destruction of surface of polymer composite materials: the method for diagnostics of early destruction using *in situ* electron emission spectroscopy; the method for diagnostics of early destruction, based on influence of aquatic microorganisms.
   - The method for diagnostics of early destruction of surface of polymer composite materials using *in situ* electron emission spectroscopy will be developed (the Deliverable).

2. Development of methods for diagnostics of early destruction of surface of polymer composite materials: the method of visual recognition of early destruction using destruction-induced staining.
   - The method for development of diagnostics of early destruction of surface of polymer composite materials using destruction-induced staining will be developed (the Deliverable).

The following research will be done:

- Influence of aquatic microorganisms on mechanical strength of polymeric pipes will be studied. First, polymeric pipes will be treated with water to which typical aquatic bacteria and *E.coli* bacteria will be added. After that, photoelectron emission of the pipes will be measured during mechanical loading and the results will be compared with those obtained for the new pipes.
- Influence of micro and nanoparticles on mechanical properties of polymer composite materials will be studied by measurements of photoelectron emission during mechanical loading. SiO_2 micro and nanoparticles will be used.
- Data on mechanical properties of microcapsules obtained during the 2nd Period of the Project will be used to create theoretical model and simulate mechanical behaviour of polymeric matrix with embedded microcapsules.

Practical exploitation of the achieved results:

Possibility to develop a method for diagnostics of early destruction of polymer composite materials has been confirmed. As a result:

a) The knowledge about destruction processes taking place in polymer composite materials and water-supply polymeric pipes at nano and micro scale will be developed.
b) Quality and safety of polymer composite materials and corresponding constructions, as well as sustainability and safety of water supply systems will be improved.

2.5. Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

Participation at scientific conferences in 2015:

1. Aniskevich, A., Bulderberga, O., Dekhtyar, Yu., Denisova, V., Gruskevica, K., Juhna, T., Kozak, I., Romanova, M. Coloured Reactions and Emission of Electrons towards Early

Diagnostics of Polymer Materials Overloading. *2nd International Conference Innovative Materials, Structures and Technologies (IMST 2015)*, September 30 – October 2, 2015, Riga, Latvia, Book of abstracts, p.19. (abstract and poster presentation)
2. Dombrovskis E., Kozaks I., Gruskevica K., Dekhtyar Yu. Diagnostic method for early collapse of polymer pipes under mechanical load. *Riga Technical University 56th International Scientific Conference*, October 14-16, 2015, Riga, Latvia (oral presentation)
3. Aniskevich, A., Kulakov, V. Express procedure for evaluation of durability of complex shape pultruded composite profiles. *Baltic Polymer Symposium 2015*, September 16-18, 2015, Sigulda, Latvia, Book of abstracts, p. 67. (abstract and poster presentation)
4. Zeleniakiene, D., Leisis, V., Griskevicius, P., Bulderberga, O., Aniskevich, A. A numerical study to analyse mechanical properties of polymer composites with smart microcapsules for high performing sensing applications. *Baltic Polymer Symposium 2015*, September 16-18, 2015, Sigulda, Latvia, Book of abstracts, p. 71. (abstract and poster presentation)

Conference abstract and journal paper were submitted and accepted:
1. Aniskevich A., Bulderberga O., Dekhtyar Yu., Korvena-Kosakovska A., Kozak I., Romanova M. Electron emission of the carbon nanotube-reinforced epoxy surface nano layer towards detection of its destruction induced by elastic deformation. *International Nanotechnology Conference & Expo (Nanotech-2016)*, April 4-6, 2016, Baltimore, USA
2. Ivanov, D. S., Le Cahain, Y. M., Surush Arafati, Dattin, A., Ivanov, S. G., Aniskevich, A. Novel method for functionalising and patterning textile composites: liquid resin print. *Composites Part A: Applied Science and Manufacturing* (SNIP 2.518)

Two master theses were defended:
1. Inguna Krista Anspoka. Influence of destruction of composite material on electron emission from composite material surface, supervisor Prof. A.Balodis
2. Irina Golovko. Influence of plastic water supply material on quality of drinking water, supervisor Asoc. Prof. K. Tihomirova

Three bachelor theses were defended:
1. Anna Korvena-Kosakovska. Early failure of composite material under mechanical load, supervisor Prof. A. Balodis
2. Ēriks Dombrovskis. Diagnostic method for early collapse of polymer pipes under mechanical load, supervisor Prof. J.Dehtjars
3. Toms Vāvere. Indirect determination of mechanical properties of polymer matrix spherical fillers, supervisors Dr. Sc. Ing. Andrejs Aņiskevičs, Msc. Olga Bulderberga

The doctoral thesis is being developed:

O. Bulderberga. Polymer composite with damage indication ability: development and determination of properties. Supervisor A. Aņiskevičs, the defence is planned in 2017.

Dissimination of the results:

Project participants held **four meetings** to discuss the results of the Project (13.04.2015, 13.05.2015, 10.09.2015, 21.12.2015). The stuff of the departments involved in the implementation of the Project as well as bachelor and master students who participated in the research were invited to participate in the meetings.

Results and performance indicators of the Project were presented on May 26, 2015, at the **seminar on the research progress of IMATEH Programme.**

On October 2, 2015, the results and performance indicators of the Project were presented during special session of IMST 2015 conference dedicated to IMATEH Programme: J.Dehtjars "Material mechanical micro- nano- scaled features and their impact on human safety".

On March 3, 2016, the **seminar was organized** at “Aviatest” Ltd. company, Rezeknes Str.1, Riga. The aim of the seminar was to present the results of the Project to entrepreneurs and discuss future cooperation possibilities.

Information about implementation of the Project is regularly updated on the website of IMATEH Programme: http://imateh.rtu.lv/.

Leader of the project No. 5 ________________________Jurijs Dehtjars_____________________

(signature and transcript) *(date)*

PART 2: PROGRAMME PROJECT INFORMATION

2.1. Project No. 6

Title	***Processing of metal surfaces to lower friction and wear***	
Project leader's name, surname	Karlis Agris Gross	
Degree	PhD	
Institution	Riga Technical University	
Position	Assoc. Prof./ lead researcher	
Contacts	*Phone number*	+371 2020 8554
	E-mail	kgross@rtu.lv

2.2. Tasks and deliverables

(List all tasks and deliverables that were planned for reporting period, list responsible partner organizations, give status, e.g. delivered/not delivered)

Target: ***Develop a method and criteria for the optimization of metallic material properties to improve the surface treatment and coating for reduced friction and wear of friction pairs including interaction with metal surfaces and ice.***

Time frame for the core tasks is given in Annexes 6-A.

Task 1 of the 2nd period: To characterize the metal surface and determine the best testing methods.

Planned tasks: (1) to develop a polishing method for smaller samples, (2) to analyse the surface of the samples with scanning electron microscope (SEM), two types of optical microscopy, atomic force microscopy (AFM), and profilometer, (3) to compare analysis results of each method used, (4) to prepare scientific publication

Task 2 of the 2nd period: To modify the slip-measuring equipment for laboratory conditions, and to prepare a climate simulator for experiments at low temperatures.

Planned tasks: (1) to prepare a climate simulator for operation at temperatures ranging from 0°C to -10°C, (2) to adjust laboratory equipment in accordance with the climate simulator dimensions (3) to determine the measurement sensor location for obtaining data with greater relevance, (4) to find information on where improvements can be made to the installation and/or climate simulators, (5) to develop a method for measuring the slip under laboratory conditions (deliverables).

Task 3 of the 2nd period: To modify the metal surface, and to determine the slip dependence on the modifications made.

Planned tasks: (1) to prepare metal samples with different degrees of surface roughness, (2) to prepare metal samples with different degrees of surface hardness, (3) to determine the reliability of slip measurement results, (4) to determine how the sliding ability changes with temperature (5) to submit an abstract and participate in the European Materials Research Society conference.

The second phase of the project objectives have been fully completed:

1. Detailed analysis of metal surface samples, using various analytical methods, has been performed. Results concluded that AFM provided the best quantitative and qualitative information and allowed for the detection of scratches from 4nm in size. In contrast, optical microscopy was shown to be the fastest method to detect surface scratches (approx. 72% of scratches were detectable by AFM). The ranking order of methods used for scratch detection is improved in the following order: profilometer, SEM, optical microscopy, AFM.

2. The custom-built, energy efficient, microclimate chamber was fitted with a cooling module, and is now capable of providing an internal air temperature ranging between +0°C to -20°C, with an accuracy of ±2°C (the desired average operating temperature -10°C). A slip stand was built for testing the slip of metallic materials on ice (adapted for use in the climate simulator). The optimisation of the ice-track freezing, and the manufacturing process, provided the necessary information to determine the inclination of the plane.

In order to optimise the automatic polishing of samples, sample holders were made. Experiments were conducted to obtain a variety of surface roughness by using different coarseness of sandpaper. A method for a smooth and repeatable surface was developed. The first experiments were to determine the effect of scratches on the sliding surface. Certain samples and air temperatures have an effect on the sliding ability. The first experiments were conducted on hardened samples.

Nr.	Tasks	Deliverable	Responsible partner	Status
1	Develop a method for measuring slip under laboratory conditions	Report (method) 31.12.2015.	K.A. Gross, Biomaterials research laboratory, RTU	Delivered Annex- NN
2	Develop a method for determining the slip under real track conditions, in comparison with laboratory equipment	Report (method) 30.06.2017.	K.A. Gross, Biomaterials research laboratory, RTU	In beginning
3	Optimise metal surface for increased gliding on ice	Report 30.06.2017.	K.A. Gross, Biomaterials research laboratory, RTU	In progress
4	Determine the relationship of gliding between the metal surfaces and ice (report)	Report 30.09.2017.	K.A. Gross, Biomaterials research laboratory, RTU	In progress
5	A recommendation for a modification of metal surface to improve gliding in track conditions, application of the material	Report 30.12.2017.	K.A. Gross, Biomaterials research laboratory, RTU	In beginning

In case of non-fulfillment provide justification and describe further steps planned to achieve set targets and results

In case of non-fulfilment provide justification and describe further steps planned to achieve set targets and results

The planned targets of the NRP IMATEH Project 6 „ *Processing of metal surfaces to lower friction and wear”* were fully achieved in the reporting period from 01.01.2015 till 31.12.2016. The planned tasks are completed and the main results obtained.

2.3. Description of gained scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

Tasks for Period 2	Main results
1. To characterize the metal surface and determine the best testing methods	***A scientific paper published in the journal***

In order to determine the most appropriate test method for precise metal surface characterisation, different methods of analysis were tested and compared. The methods tested were: optical microscopy, scanning electron microscopy, atomic force microscopy and profilometer. The different methods were all tested on a polished steel sample, seen in Figure 1.a). Digital images were taken of the exact same area of the surface under study with the exact same proportions, which were marked by nano-sized indents (see red points in Figure 1.b). From the resulting scanned images, two small areas were examined. The two examined areas, with a size of 50x50 µm, helped to determine the best method of qualitative and quantitative surface characterisation.

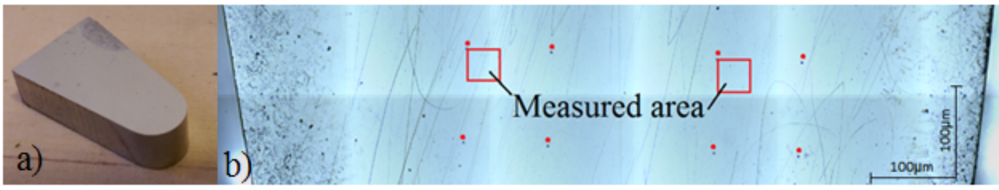


Figure 1: a) polished steel sample for analysis, b) analysed areas

Visual qualitative analysis of the data gave the resulting images (see. Fig. 2). The sharpness and level of detail in the images were evaluated and compared. In order to objectively compare each method, the resulting images were studied, visible scratches were counted and the percentage comparison between each method was calculated. Results showed that the image with the best resolution was given by the atomic force microscopy. With special software, quantitative analysis was done between the resulting images from the atomic force microscope and profilometer; this improved the ability to identify scratches on the profile cross-section.

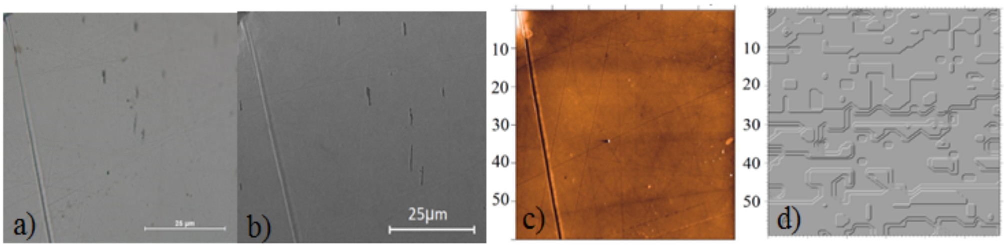


Figure 2: Different topography method results: a) optical microscope; b) scanning electron microscope; c) atomic microscope; d) profilometer

From results it was concluded:

1) Atomic force microscopy provides the best qualitative and quantitative indicators of the viewed surface, but it is expensive and has limitations for the size of the samples studied;
2) The success of scratch detection between different topography methods have been placed in the following order: profilometer, scanning electron microscopy, optical microscopy, atomic force microscopy;
3) Optical microscopy proved to be the fastest way to obtain a good quality image of the sample surface. Although much faster, the images provided about 70% of the information obtained by atomic force microscopy;
4) Atomic force microscopy allows up to 4 nm saddle scratches;
5) Profilometer method is not effective on such a small surface areas.

Scientific paper was prepared and published: Z.Butans, K.A.Gross, A.Gridnevs, E.Karzubova. "Road safety barriers, the need and influence on road traffic accidents." Materials Science and Engineering (MSE), in 2nd International Conference on Innovative Materials, Structures and Technologies, S. Rucevskis and D. Bajare, Editors; 2015, pp. 1.-8.

2. To modify the slide measuring equipment for laboratory testing, and to prepare a climate simulator for low temperatures	***Equipment for measuring the sliding ability, which is suitable for a customised cooling chamber. Report (deliverable): "The method for measuring the slip in laboratory conditions"***

A device (slip stand), built to measure modified metal samples gliding on ice at a variation of experimental settings, has been developed. To complete the phase, tasks were carried out in the following order:

1. Design the stand concept and make stand prototype;
2. Modify climate simulator
3. Adjust the sliding bench for experiments in the climate simulation chamber;
4. Conduct pilot experiments.

Experiments using the slip stand evaluated the effects different surface treatments had on metal gliding on ice, and where appropriate, on other materials such as metal or plastic. The structure of the stand was based on the use of the inclined planes with optical sensors that measured the time the samples took to slip from the top to the bottom of the inclination. The time, in which the sample took to slip, was the chosen parameter to characterise the slip properties numerically.

During experiments the stand was located in the climate simulation chamber. Its design was easily customised for various geometry models, this flexibility in design opened up a wide range of experimental variations, to provide more detailed information.

The successful development of the ice track for laboratory experiments, was based on the duration of each test, refrigeration modes, ice treatment, and plane angle. With the developed methodology the required experimental conditions were achieved.

An extensive series of pilot experiments, helped to determine the various factors that influenced the results, i.e. sample weight, the temperature of the ice, the angle of the plane, and the absolute value of the dispersion. This helped confirm which variable most influenced the sliding of the metal on ice conditions under which the experiment is best observed in the surface modification effect. In consideration of the obtained experimental data, a methodology for future experiments was established.

The completion of the 2nd task of the 2nd phase saw the development of the slip measurement equipment, alterations to the climate simulator for laboratory experiments at low temperatures and the completed deliverable (report) “The method for measuring the slip in laboratory conditions”. The deliverable has been written in Latvian, 16 A4 pages long, it includes the following sections: (1) Sliding stand prototype, (2) Climate simulation chamber modifications, (3) Adjustments to the sliding stand for experiments in the climate simulation chamber (4) Pilot experiments in the climate simulation chamber (4.1) Preparation of the ice track for experiments, (4.2) To find the optimal inclination angle for the trace (4.3) The effect of temperature, in the climate chamber and of the studied sample, on the metal sample and ice quality.

3. Modify the metal surface to determine the slip dependence of the modifications	***Prepared report, submitted abstract, and participation in the European Materials Research Society Conference***

In consideration of the possibilities and limitations of the manufactured slip stand, 42 identical metal samples were made. These samples were polished to a mirrored surface using an automated polishing machine, for laboratory testing.

In order to obtain metal samples with different degrees of surface roughness, they were scratched with sandpaper. Since the manufacturer range of sandpaper is so large, sandpaper samples of different brands were compared, each test ensuring the same compression weight, number of scratches and scratch length. The developed samples were examined and compared under a microscope, and with 3D micro-topography measurements. The results found the best sandpaper brand suited for the samples. The deciding factor of the sandpaper was to ensure that all samples had a surface texture as similar as possible.

To improve reliability of the data collected from experiments, each experiment was repeated multiple times. Samples with different degrees of surface roughness were compared by timing the slip speed. These experiments were repeated over several days. Data was obtained on the number of required samples, how many times the experiments must be repeated, and the number of experimental days, to be sure that the experimental results were credible.

To determine the temperature and conditions needed for the experiments and the influence temperature had on the slip, the experiments were carried out at different temperatures. The results helped determine the optimal temperature to minimise systematic error, under the assumption good ice quality would not materially affect the sample roughness. A chart representing the sliding times, of differently processed samples, with a dependence on temperature, can be found in Figure 3.

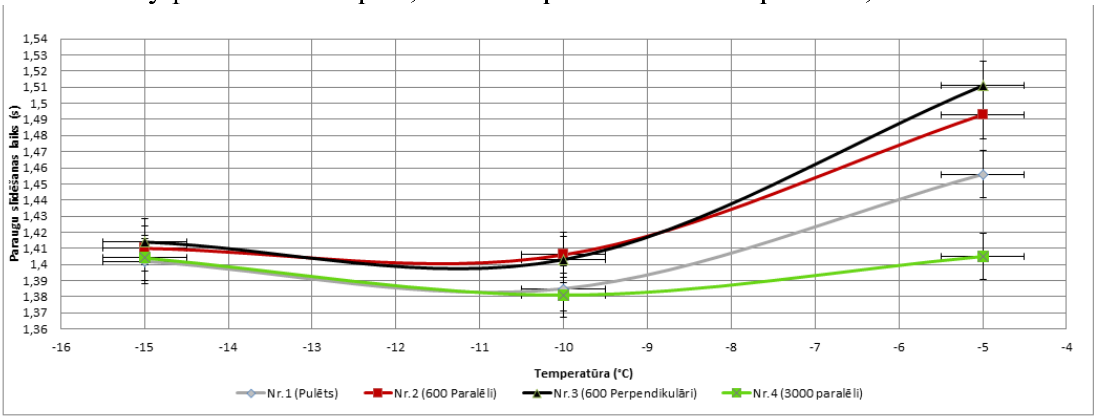


Figure 3. Sample sliding time with a dependence on the temperature

Experiments were conducted to obtain information about the effect of applied weight on the sample sliding time, with the aim to determine the best weight for the samples. The optimum conditions for the surface roughness, to be the only influencing factor in the experiments, were then chosen.

A method to measure the hardness of stainless steel was developed. After detailed research on the materials used, the experimental samples were heat-treated using an annealing furnace. The heat treatment process involves three stages: annealing, hardening and tempering. During the heat treatment process the prototype had formed an oxide layer, which was partially rubbed away to prepare the sample surface with a roughness of Ra≤2 μm. This was important to collect the correct hardness measurements. Initial results showed that the material hardness increased by ~30%.

An abstract was written for the participation at the European Material Research Society (EMRS) Conference "EMSR Fall meeting 2015", Warsaw, Poland, 15.09.2015-18.09.2015 with the poster: "Finding the best qualitative and quantitative assessment method for highly polished low-friction surfaces" (J.Lungevics. J.Zavickis, L.Pluduma, K.A.Gross). The best and most effective method to polish metallic surfaces for qualitative and quantitative evaluation was presented at the conference. The greatest benefit of this study is the idea of how effective and useful it is to have a variety of surface evaluation methods that, with further progress of the project, will allow rational decisions on optimal selection of equipment. Multiple ideas, from other research reports, on a variety of surface modification methods to improve thermal resilience, and slip and abrasion resistance properties have influenced the methods chosen for this project. This information allowed for future research in the direction of the project and a way to achieve the objective pursued.

2.4. Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

With the use of the slip measuring equipment (the laboratory track) and the development and customisation of the climate chamber, the first two phases of the project were fully completed. Great care was taken to ensure precise methodology for the assessment of various parameters and their influence on the measurement results. As a result, measurement repeatability and reliability of results was achieved. A study of various metal surface analysis methods helped to discover the advantages and disadvantages of each method, this allowed for the selection of the most appropriate test method.

The results achieved and developed methods are the basis for all subsequent experiments, to evaluate the influence of a variety of metal surfaces on gliding.

During the project phase 3 a research on different methods for metal surface modification will be continued:

- Roughness - the first experiments were conducted in phase 2, with plans to evaluate the effects of surface roughness on sliding, to determine the best degree of surface roughness and texture.
- Hardness – research in the second phase showed that the modified samples have shown a slightly better sliding time than untempered sample. In order to judge the full impact thermal treatment has on the gliding of the samples, there will be more in-depth studies using statistically reliable measurements, such as a larger number of samples. The comparison of scratching resistance between tempered and untempered samples, and the examination of how different temperatures effect the slip properties of these samples will also help to judge the impact thermal treatment has on sliding speed.
- Chemical modification - The metal sample's surface hydrophobia will be measured and modified to improve its relation to gliding.

Work on the development of surface modification methods for the large metal samples has also begun.

Tasks for the 3rd period:

3. Modify the metal surface, to determine the slip dependence of the modifications
   - Expected results: Discover the best direction for surface modification, which will increase metal on ice sliding properties.
   - Participation in the conference and publication.
4. Develop methods for improving the gliding surface of a larger surface under real conditions
   - Expected results: Data collection, compilation, and analysis. The beginning of new methods for larger metal surface modification.

One of the major issues during the execution of the second phase of the project was due to personal changes in the project staff, this occurred mainly due to limited finances. Lead researcher, J.Zavickis, stopped work on the project due to changes in employment, as a result, the project manager had to take over his duties and become more actively involved in the planning of experiments.

Limited project funding in phase 3 could also cause changes in staff, but all project employees are actively involved in all the planning of experiments and discussions, as well as ensuring all experimental results were uploaded to the Dropbox folder, to minimize the impact of staff turnover during the project.

2.5. Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

Submitted conference thesis:

1. J.Lungevics. J.Zavickis, L.Pluduma, K.A.Gross. "Finding the best qualitative and quantitative assessment method for highly polished low-friction surfaces". EMSR Fall meeting 2015", Warsaw, Poland, 15.-18.09.2015.

Conference participation (poster presentations can be viewed in the project website):

1. '*European Material Research Society (EMRS)*' conference "EMRS Fall meeting 2015", Warsaw, Poland, 15.-18.09.2015, with the poster: "Finding the best qualitative and quantitative assessment method for highly polished low-friction surfaces" (J.Lungevics. J.Zavickis, L.Pluduma, K.A.Gross).

2. International conference "Innovative Materials, Structures and Technologies" (IMST 2015), Riga, Latvia, 30.09. - 02.10, with the poster: "Road safety barriers, the need and influence on road traffic accidents" (Z.Butāns, K.A.Gross, A.Gridnevs, E.Karzubova).

Participation in scientific seminars:

1. "Meeting of s-SNOM practioners", Garmisch, Germany, 09.06.15 - 11.06.15 Key findings: The seminar brought together users of optical microscopy to characterize materials. There is great interest to combine results from the chemical and structural analysis, to provide a much greater insight into the material surface. Workshop participants examined the capability of infrared for the analysis of various depths, and by using atomic force microscope tip, were able to explore the topography at nano-size. It was presented in studies, that such methods are already being used to describe the material areas at the nano level, proving success of the method. After the meeting, the company Neaspec, presented the capabilities and possibilities of SNOM instruments, related to surface characterisation. The information gathered from the seminar showed the possibilities that would bring great benefit to the surface of material characterization.

Full-text scientific papers (can be viewed in the project website):

1. Butans Z., Gross K.A., Gridnevs A., Karzubova E. Road safety barriers, the need and influence on road traffic accidents, IOP Conference Series: Materials Science and Engineering Volume 96, 2015
    a. http://iopscience.iop.org.resursi.rtu.lv/article/10.1088/1757-899X/96/1/012063/pdf

Bachelor thesis in progress (scheduled to be defended in June 2017):

1. Klavs Stiprais, "Metal treatment to reduce friction", overseen by Asoc. Prof. K.A.Gross.

Master's thesis in progress (scheduled to be defended in June 2016):

1. Jānis Lungevičs, "Friction and wear-reducing surface treatment methods for the assessment of tribology properties", overseen by Prof. J.Rudzitis.
2. Ernests Jansons, "The effects of surface roughness on the sliding of metal on ice couples", overseen by Prof. J.Rudzītis.

Doctoral thesis in progress (scheduled to be defended in 2017):

1. Žans Butāns, "The mechanical properties of road safety barriers surface and its impact on traffic, accidents, and safety of passengers", overseen by A/Prof K.A.Gross

Completed project deliverables (written report):

1. The method for measuring the slip under laboratory conditions

Dissemination of results:

Within the second phase of the project two project meetings (17.04.2015. and 14.10.2015.) were organised. Researchers, staff and industry representatives attended and discussed the project tasks and deliverables. Internal meetings are regularly (at least once a month) held to discuss work progress, with the attendance of the project manager and project staff who are directly involved.

The IMATEH website (http://imateh.rtu.lv/) provides information on the activities of the project, publications, conferences and current events.

Leader of the project No. 6 ____________ Karlis Agris Gross ____________

(signature and transcript) *(date)*

Annex 1-A

Time frame the Core task 1 activities of the Project 1
Innovative and Multifunctional Composite Materials from Local Resources for Sustainable Structures

	2014		**2015**				**2016**				**2017**			
	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1. To create production method of high performance concrete composites (compression strength >100MPa) for use in infrastructure and public buildings, partly replacing concrete with microfillers having local origin.	x	x	x	x	x									
1.1.1. To design high strength concrete mixes	x	x	x	x	x									
1.2. To determine mechanical and physical properties.	x	x	x	x	x									
1.3. Preparation method for innovative and advanced cement composite with microfillers materials for infrastructure projects and public buildings (deliverable)					x									
2. To develop recommendation on increase of the corrosion and freeze resistance properties for the concrete produced from the Latvian cement.			x	x	x	x	x	x	x	x				
2.1. To assess sulphate resistance of the developed concrete mixes			x	x	x	x	x	x						
2.2. To determine alkali silica reaction resistance of the developed concrete mixes							x	x	x	x				
2.3. To assess carbonisation resistance of the developed concrete mixes			x	x	x	x	x	x	x	x				
2.4. To assess resistance to the impact of chloride of the developed concrete mixes					x	x	x	x						
2.5. To assess freeze resistance of the developed concrete mixes			x	x	x	x	x	x	x					
2.6. Recommendation on increase of the corrosion and freeze resistance properties for the concrete produced from the Latvian cement (deliverable)										x				

3. To develop methods for innovative reinforced cement composite material production for infrastructure and public buildings										x	x	x	x
3.1. To design mixes for glass fibre reinforced concrete composites										x			
3.2. To determine mechanical and physical properties of the designed mixes										x	x	x	
3.3. To assess alkali silica reactions by using pozzolanic additives in glass fibre reinforced concrete composites											x	x	
3.4. Method for innovative reinforced cement composite material production (deliverable)													x
4. Parameter optimisation of cement composite mixing process										x	x		
2.1. Recommendation for parameter optimisation of cement composite mixing process (deliverable)											x		
4. Publications, Scopus													
5. Conferences													
6. Supervision of doctoral thesis and master's thesis	x	x	x			x	x		x	x	x		x	x

Annex 1-B

Time frame the Core task 2 activities of the Project 1
Innovative and Multifunctional Composite Materials from Local Resources for Sustainable Structures

	2014		2015				2016				2017			
	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1. To create production method for high performance asphalt concrete mixes from local low quality components.	x	x	x	x	x	x								
1.1.To select raw materials, to deliver them, to assess their properties	x	x	x	x	x	x								
1.2. To design high performance asphalt concrete mixes by using local dolomite shiver and bitumen B20/30			x	x	x	x								
1.3. Production method for high performance asphalt concrete mixes from low quality components (deliverable)						x								
2. To develop recommendations for parameter optimisation of mixing process for asphalt concrete mixes					x	x	x	x	x	x				
2.1. To design high performance asphalt concrete mixes by using local gravel shiver and bitumen B20/30					x	x	x	x						
2.2. To design high performance asphalt concrete mixes by using local gravel and dolomite shiver and polymer-modified bitumen PMB							x	x	x	x				
2.3. Recommendation for parameter optimisation of mixing process for asphalt concrete mixes (deliverable)										x				
3. To develop recommendations for transportation and incorporation of asphalt concrete mix											x	x		
3.1. Recommendation for transportation and incorporation of asphalt concrete mix (deliverable)												x		
4. To develop methodology for use of									x	x	x	x	x	x

recycled asphalt concrete														
4.1. To select raw materials, to deliver them, to assess their properties									x	x				
4.2. To determine design and exploitation properties of the designed mixes									x	x	x			
4.2.1 To restore properties of asphalt concrete mix recovered from recycled material with traditional bitumen having lower viscosity									x	x				
4.2.2 To restore properties of asphalt concrete mix recovered from recycled material with warm asphalt concrete production additives											x	x		
4.3. Methodology for use of recycled asphalt concrete (deliverable)														x
4.4. Recommendation for use of high-viscosity bitumen using warm asphalt concrete production additives														x
5. To prepare economic assessment of high performance asphalt concrete exploitation											x	x	x	x
5.1.To assess external factors – transport load and temperature											x	x		
5.2.To select forecasting model (based on results of laboratory experiments) and to determine parameters for functions of the model												x	x	
5.3. Economic assessment of high performance asphalt concrete exploitation (deliverable)														1
6. Recommendations for improvement of road technical rules													x	x
4. Publications, Scopus														
5. Conferences														
6. Supervision of doctoral thesis and master's thesis						x	x		x	x	x		x	x

Annex 1-C

Time frame the Core task 3 activities of the Project 1
Innovative and Multifunctional Composite Materials from Local Resources for Sustainable Structures

	2014		2015				2016				2017			
	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1. To develop method for production of ecological composite materials from textile plants and local mineral binders.		x	x	x	x	x	x							
1.1. To design fibre composite materials mix		x	x	x										
1.2. To determine mechanical and physical properties		x	x	x	x	x								
1.3. Method for production of ecological composite materials from textile plants and local mineral binders (deliverable)							x							
2. To develop and write guidelines for data collection system, which is suitable for heat and humidity migration control in energy-efficient buildings.	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.1.To develop plan for sensor installation in real stand (in cooperation with producer)	x	x												
2.2. To install sensors		x	x											
2.3.To collect data (humidity, temperature, etc.)			x	x	x	x	x	x	x	x	x	x	x	x
2.4. To develop model based on the collected data								x	x	x	x	x	x	x
2.5. Guidelines for data collection system (deliverable)														x
3. Life-cycle calculations of natural fibre composite materials						x	x	x	x	x				
3.1. To collect and process data						x	x	x	x	x				
3.2. Method for life-cycle calculations of natural fibre composite materials (deliverable)										x				
4. Recommendation for information about thermal properties of natural fibre composite materials to be added to LBN 002-01											x	x	x	x
4.1. To prepare recommendations for information about thermal properties of natural fibre composite materials to be added to LBN 002-01 (deliverable)														x

4. Publications, Scopus													1	
5. Conferences														
6. Supervision of doctoral thesis and master's thesis	x	x	x			x	x		x	x	x		x	x

Annex 2-A

Time frame activities of the Project 2
Innovative and multifunctional composite materials for sustainable buildings

	2014	2015				2016				2017			
	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1. Experimental research on component scale specimens. Additional investigation damping and impact properties on finalised panels with vertical stiffeners	**X**	**X**	**X**	**X**	**X**	**X**	**X**						
1.1 Identification of material mechanical properties	X	X	X										
1.2. Identification of material thermal properties	X	X	X	X	X	X							
1.3. Identification of vibration damping properties		X	X	X	X								
1.4. Identification of impact properties					X	X	X						
2. Virtual modelling and optimisation by numerical methods	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
2.1 Updating of the Finite Element numerical model	X	X	X	X	X	X	X						
2.2 Optimisation of the product/process				X	X	X	X	X	X				
2.3 Validation of numerical model with experimental results					X	X	X	X	X	X			
2.4 Development of design methodology									X	X	X	X	
3. Prototyping at laboratory scale. Development of design guidelines	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
3.1. Upgrading of the chemical coposition of foam material	X	X	X	X	X								
3.2. Laboratory scale prototyping				X	X	X	X	X	X	X			
3.3 Scale-up of industrial manufacturing								X	X	X	X	X	X
4. Dissemination	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**

Annex 3-A

Time frame the Core task 1 activities of the Project 3
Risk consideration for safe, effective and sustainable structures

	2014		**2015**				**2016**				**2017**			
	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1. Develop method for assesment of bridge dynamic characteristics.	X	X	X	X	X	X	X	X	X	X				
1.1.Studie about vehicle weight and speed impact on the bridge structure dynamic characteristics.			X	X	X	X	X	X	X	X				
1.2.Develop a method to asess heavy and very heavy vehicle dynamic effects on the bridge structure.							X	X	X	X				
1.3.Determine and justify limit values of the bridge dynamic characteristics based on the developed methods for assesment of bridge dynamic characteristics.											X	X	X	X
2. Analyse traffic load influence on bridge structure using theoretical probability distribution models.	X	X	X	X	X	X	X	X	X	X				
2.1. Develop a method for external action correlation forecasting.	X	X	X	X	X	X	X							
2.2.Study about properties range of materials used in bridge construction.	X	X	X	X	X	X	X							
2.3.Develop theoretical probabilistic distribution models for in construction used materials property variation.				X	X	X	X	X	X					
2.4.Analysis about ageing process influence on the construction material properties and its variation for existing structures.			X	X	X	X	X	X	X	X				
2.5.Develop a probabilistic model for building accuracy and description of other "human factor" induced structural properties variation and their impact on load–carrying capacity.							X	X	X	X				
2.6.Comparison of resulting action and material resistance probabilistic modes using limit state method defined in Eurocode, it will allow to determine existing bridge									X	X	X	X	X	X

safety and robustness (with appropriate safety factors).														
3. Publications, Scopus		1				3								2
4. Conferences		1				3				2				2
5.PhD and Master theses	X	X	X			X	X		X	X	X		X	X

Annex 3-B

Time frame the Core task 2 activities of the Project 3

Risk consideration for safe, effective and sustainable structures

	2014		**2015**				**2016**				**2017**			
	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1. Develop of method for localization of damage site and evaluation of damage size in various structural elements by using appropriate signal processing techniques experimentally measured dynamic parameter changes.	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1.1. identification of damage in beam-type structural elements	X	X	X	X	X									
1.2. identification of damage in plate-type structural elements				X	X	X	X	X	X					
1.3. identification damage in sandwich-type structural elements							X	X	X	X	X	X		
1.4. methodology for exploitation damage identification in various structural elements											X	X	X	X
2. Development of new technologies for monitoring and diagnostics of aviation engines and various elements of rotary machines.			X	X	X	X	X	X	X	X	X	X		
2.1. investigation of aviation structural element health monitoring and diagnostics			X	X	X									
2.2. experimental investigation of dynamics parameters of aviation structural elements				X	X	X	X	X						
2.3. exploitation damage identification in aviation structural elements						X	X	X	X	X				
2.4. recommendation for health monitoring and diagnostics of aviation structural elements										X	X	X		
3. Development of method for pre-stress loss estimation in pre-stressed steel reinforced concrete structural elements.							X	X	X	X	X	X	X	X

3.1. investigation of methods, based on analysis of loss of pre-stress in pre-stressed steel-reinforced concrete structural elements							X	X	X	X				
3.2. numerical modelling and simulations of pre-stressed steel-reinforced concrete structural elements									X	X	X	X	X	
3.3. experimental estimation of dynamic parameters of pre-stressed steel-reinforced concrete											X	X	X	
3.4. method for evaluation of pre-stress loss in prestressed steel-reinforced concrete structural elements												X	X	X
4. Publications, Scopus						2	1	1				1	1	
5. Conferences									1				1	
6. Supervision of doctoral thesis and master's thesis	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**

Annex 3-C

Time frame the Core task 3 activities of the Project 3
Risk consideration for safe, effective and sustainable structures

	2014		2015				2016				2017			
	1	2	1	2	3	4	1	2	3	4	1	2	3	4
1. Development of design procedure for load-bearing elements from cross-laminated timber	x	x	x	x	x	x	x	x	x	x				
1.1. Data generalization for development of design procedure for load-bearing elements from cross-laminated timber	x	x	x											
1.2. Development of design procedure for load-bearing elements from cross-laminated timber			x	x	x	x	x	x						
1.3. Experimental testing of design procedure for load-bearing elements from cross-laminated timber				x	x	x	x	x	x	x				
2. Topology optimization for structure from cross-laminated timber and evaluation of it rational, from the point of view of it materials expenditure, parameters							x	x	x	x	x	x	x	x
2.1. Model of behaviour for structure from cross-laminated timber							x	x	x	x				
2.2. Development of optimization algoritme for structure from cross-laminated timber							x	x	x	x	x	x	x	x
2.3. Evaluation of it rational parameters for structure from cross-laminated timber							x	x	x	x	x	x	x	x
3. Development of load-bearing structure which consists from the main tensioned members and secondary cross-laminated timber members subjected to flecture							x	x	x	x	x	x	x	x
3.1. Development of Numerical model of the structure							x	x	x	x	x	x	x	x
3.2. Development of physical model of the											x	x	x	x

structure														
4. Conferences, papers		1	2											
5. Supervision of doctoral and masters thesis	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6. Publications, Scopus														

Appendix 4-A

Time schedule for project 4.
Layered wooden composite with rational structure and increased specific bending strength

	2014		**2015**				**2016**				**2017**			
	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1. Methodology work-out for determination of bending strength and conceptual design of plates with cell type hollow ribs	x	x	x	x	x	x	x	X						
1.1. work-out of calculation methodology	x	x	x	x	x	x	x	X						
1.2. determination of specimens' mechanical properties				x	x	x	X							
1.2.1 Developement of shear Resistance determination methodology for glued joint joint between plywood surface and edge.				x	x	X								
1.2.2 Determination of deformability and strength of plates in bending					x	x	X							
2. Methodology work-out for determination of specific bending strength for plates with cell type hollow ribs and determination of values for the most typical geometrical parameters.					x	x	x	x	X					
2.1. work-out of calculation methodology					x	x	x	X						
2.2. determination of specific bearing capacity							x	x	X					
3. Work-out plate models with most typical types of hollow cell type ribs and experimental investigations to get specific strength in bending, consumption of materials, energy consumption and costs.				x	x	x	x	x	x	x	x	X		
4. Recommendations work out for design of geometrical parameters of plates with hollow cell type ribs.									x	x	x	x	X	
5. Recommendations' work out manufacturing and 'work in' technology principles and produce plates' demonstration models.							x	x	x	x	x	x	x	X
6. Publications, Scopus													1	
7. Conferences						1			1				1	
8. Supervision of doctoral thesis and master's thesis	x	x	x			x	x		x	x	x		x	x

Annex 5-A

Time frame of the Project 5
Material mechanical micro - nano- scaled features and their impact on human safety

	2014		2015				2016				2017			
	III	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**II**	**IV**	**I**	**II**	**III**	**IV**
1. Development of research methods for early diagnostics of destruction of surface of polymer composite materials	**X**	**X**	**X**	**X**	**X**	**X**								
1.1. a method to study the influence of aquatic microorganisms on early destruction of materials	X	X	X	X	X	X								
1.2. a method to study visual recognition of early destruction using destruction-induced staining	X	X	X	X	X	X								
2. Development of methods for early diagnostics of destruction of polymer composite materials							**X**	**X**	**X**	**X**				
2.1. the method for early diagnostics of destruction using *in situ* electron emission spectroscopy							X	X	X	X				
2.2. the method for early diagnostics of destruction, based on the influence of aquatic microorganisms							X	X	X	X				
2.3. the method of visual recognition of early destruction using destruction-induced staining							X	X	X	X				
3. Application of methods for early diagnostics of destruction of surface of polymer composite materials in enterprises											**X**	**X**	**X**	**X**
3.1. Application of diagnostic methods in machinery manufacturing and constructions (development of recommendations)											X	X	X	X
3.2. Application of diagnostic methods in manufacturing of polymeric pipes for drinking water (development of recommendations)											X	X	X	X
4. Number of scientific publications						**1**				**2**				**2**
4.1. Scopus										1				1
4.2. Proceedings of conferences						1				1				1
5. Conferences						**1**				**1**				**1**
6. Development of doctoral and master theses	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
7. Registered Latvian patent														**1**

Annex 6-A

Time frame of the Project 6
Processing of metal surfaces to lower friction and wear

	2014		2015				2016				2017			
	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1. To characterize the metal surface and determine the best test methods	X	X	X	X	X	X								
1.1. Develop a method for the preparation of the metal surface of the samples - cutting, rough polishing, fine polishing	X	X		X	X									
1.2. Develop a method for full sample surface analysis (optical microscopy, atomic force microscopy, scanning electron microscopy, profilometry)			X	X	X	X								
2. To develop a test apparatus to simulates an ice track and a climate simulator to test metal surface friction and wear reduction	X	X	X	X	X	X								
2.1. Develop testing apparatus (simulation of bobsled track) and software to detect movement of the sample at a certain angle	X	X												
2.2. Develop a climate simulator which can be adjusted to work at low temperatures		X	X	X	X									
2.3. Develop a method for measuring slip under laboratory conditions	X	X	X	X	X	1								
3. To modify the metal surface, and calculate the new slip determined by any modifications made					X	X	X	X	X		X	X		
3.1. Develop a method for metal surface modification to increase slip (surface roughness, hardness, chemical modification)					X	X	X	X	X		X			
3.2. Optimise metal surface for increased gliding on ice (report)											X	1		
4. Determine the relationship of gliding between the metal surfaces and ice (report)											X	X	1	
5. To develop methods for the optimisation for the gliding surface with real track conditions						X	X		X		X	X	X	X
5.1. Develop a method for determining the slip under real track conditions, in comparison with laboratory equipment (report)						X	X				X	1		
5.2. Develop a method for surface modification of a larger metal sample									X		X	X		
5.3. Make a modification recommendation for the metal													X	1

surface to improve gliding in track conditions (report)														
6. Publications						1								1
7. Conference					1				1				1	
8. Science publications									1					
9. Seminars														1
10.Master’s thesis	X	X	X	X	X	X	X	X	X		X	X	X	X
11. Patent results in Latvia														1
12. New methods for exploitation														1