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.	Method of traffic data analysis	A.Paeglitis, Department of Roads and bridges, Institute of Transport	In progress

	Analysis of traffic load data		infrastructure engineering, RTU	
2.1	To develop 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.	Methodology of damage identification in different type of structural elements (beam, plate, sandwich)	S. Rucevskis, Department of Composite Materials, Institute of Materials and Structures, RTU	In progress
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.

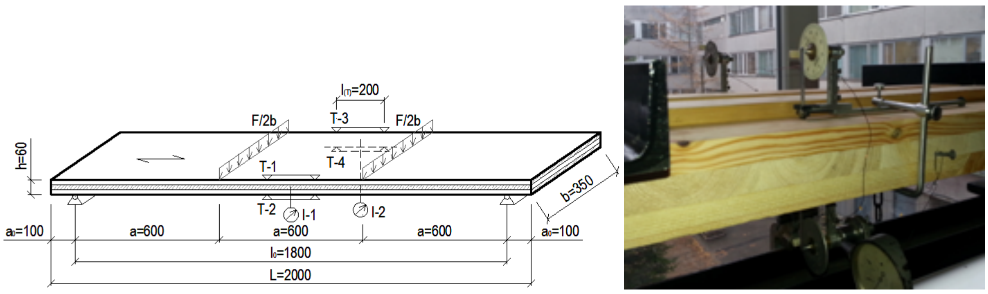
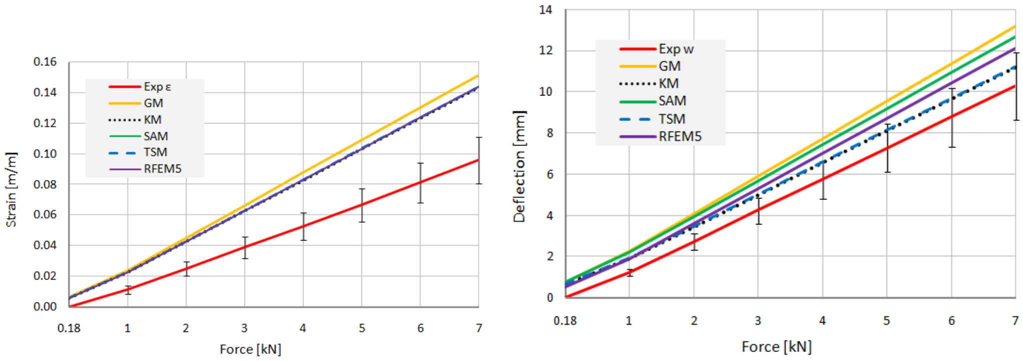


Figure 1. Loading scheme and placement of aparatus for CLT plate.

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.

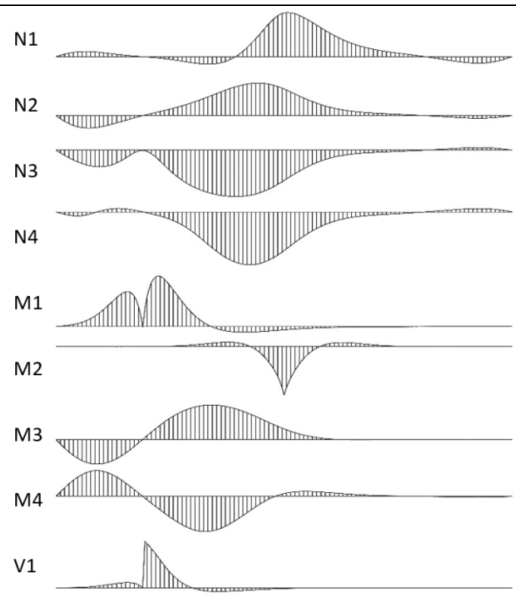
Task 3.2. Period from years 2014 and 2015. Traffic load impact on bridge superstructure

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	***The rational parameters of the saddle-shaped cable roof prestressing, which enables to***

rational, from the point of view of it materials expenditure, parameters	***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;

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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)