SIGNIFICANCY OF MOVEMENT JOINTS OF MASONRY WALLS FOR BUILDINGS BEING IN OPERATION

Sandra Gusta, Janis Gruntmanis, Silvija Strausa, Andris Steinerts
Latvia University of Life Sciences and Technologies, Latvia
sandra.gusta@llu.lv, janisgruntmanis@inbox.lv, silvija.strausa@llu.lv, andris.steinerts@llu.lv

Abstract. In recent years, the construction industry is experiencing a number of changes in the regulatory enactments to improve the quality and safety of construction work. As Latvia is one of the few countries, where you can experience all four seasons (spring, summer, autumn and winter), you can observe significant temperature fluctuations. This has an effect on both the construction and the various finishing materials. If calculations are made in the first case, taking into account the effect of the weather, then in the second case the weather impact is rarely observed. However, the weather effect on the finishing materials is enormous, so it is necessary to take measurements over longer periods of movement joints in walls and facades to observe and analyse the changes depending on the weather. It can be successfully implemented by installing crack-measuring plates and measuring weekly or more frequently at temperature fluctuations. The aim of the study is to perform deformation monitoring on the walls, to observe the state of the cracks and to make measurements, to determine the causes of the cracks, to make proposals to stabilize the situations. This will give an idea of the processes that are taking place under the influence of the weather and will lead to the assessment of new projects including structural design projects, renovation projects and European funded projects. In many projects this is not properly assessed, but the presence of deformation in the form of cracks can be observed in real life at homes with multiple sections or long wall spans. In time, this can lead to further damage to the facade. In order to save money and make the facades long lasting, these issues should be given more attention, so the authors focus on researching these issues.

Keywords: movement joints, cracks, masonry wall, monitoring.

Introduction

There are many EU-funded projects currently under way in Latvia to reconstruct and insulate various buildings. When insulating buildings, sometimes cracks appear in the facades, it significantly deteriorates the appearance of the building because of the wall's flawed constructive solution. Commissioning party blames the contractors at the occurrence of defects for providing a poor quality job, although often the reason lies far more deeply – in the wrong constructive solution of the wall – excluding the designing of movement joints.

Need for movement joints in masonry walls

While building is being operated, temperature fluctuations and deformation of the wall structure can cause cracks or shifts of the masonry. This usually happens in places where the wall is weakened by openings or columns, as well as in places where longitudinal integration ends or steel columns are laid. The main causes of cracks are:

- Deep excavation and poorly sealed shutter primer will over time compress and settle, causing the wall to crack. This process can take months or even years. Such natural landing causes narrow vertical cracks rather than large robot cracks. However, significant downward movement under the wall can cause structural defects. If the soil is rinsed (for example, a gradual leak or sudden flood), significant sowing may occur. Sink holes are a dramatic example of this;
- Reactive soil, such as clay, that changes its volume due to moisture and drought may cause cracks in masonry walls;
- If the building is near a construction site or a quarry, it may be exposed to wall cracking. The use of heavy machinery, vibration, excessive mechanical compression of the soil or blasting (use of explosives for excavation) can cause wall cracking. If cracks in the walls appear after construction in your area, then it is necessary to make a gap assessment and legal advice. Similarly, earthquakes, although rare in Latvia, can cause cracks in the walls;
- Wall cracking can also occur when a building or part of it (such as an extension) is poorly designed or constructed. Excessive load on the load-bearing wall can cause cracks to appear.

Inadequate, erroneous or damaged building materials or incorrect foundation footprint can contribute to wall cracks;

- Blocked gutters, flood damage, garden sprinklers, dams or leaking pipes can cause the soil to be impregnated with water or even soil denudation, which can cause wall cracking;
- Trees often have influential root structures that can contribute to wall cracking, so make sure there are only small shrubs near the walls. Regardless of destructive roots, trees can also contribute to wall cracking by absorbing water from the soil and affecting the soil moisture content. Removing large wood from an area close to your building can cause cracking, as it can destabilize the soil in the space previously occupied by the root system. It can also cause changes in soil moisture levels or landing over time;
- Deterioration of building materials can cause cracks in the walls. If the causes are not too serious, cracks can be prevented by installing movement joints in the wall. The distances between the temperature and movement joints should be determined by calculation. Movement joints in walls associated with reinforced concrete or steel structures must coincide with the joints in these structures.

These issues should be transparent and incorporated into the regulatory framework. These issues are very serious. There may also be very low-risk and dangerous consequences for human life, if they are not respected [9]. The causes of cracks should be evaluated in a timely manner and eliminated.

Regulatory framework

Masonry structure buildings have been built since ancient times and, overtime, conditions for erection of safe masonry wall structures have been developed which have gained regulatory status in recent decades. Taking into account the fact that the tensile and shear strength of the masonry structures is very low, practically it is zero for non-reinforced masonry structures, when designed and erected, provisions should be made for and measures must be taken to avoid the negative impact of tensile and shear stresses in such structures. Shear and tensile stresses in the masonry walls most commonly derive from alteration of the surrounding temperature, setting of base ground and deformations of other structures. In order to avoid the harmful effects of stresses caused by these deformations, movement joints shall be fitted in the masonry wall structures. Distinction shall be made between the temperature joint compensating the temperature deformations of large-scale structures and the movement joint, which compensate the irregular deformation of the base of the structure.

During the Soviet occupation period the design and construction process of structures was governed by the construction regulations of SNiP – Construction norms and regulations. The placement of movement joints in masonry wall structures was defined in SNiP II-22-81 “Masonry and reinforced masonry structures”, erection of masonry structures was regulated by SNiP III-17-78 “Rules for the performance and recruitment of building works. Masonry structures”, but from the 01.06.88 accordingly with SNiP 3.01.87 “Load bearing and boundary structures”. According to the requirements of the paragraph 6.79 of SNiP II-22-81, the distance between the vertical temperature joints depending on the type of the structure and average temperature of the coldest five days, shall be not less than 35 to 120 meters. The paragraph 6.81, on the other hand, stipulated that movement joints should be installed in the walls in all places where an uneven setting of the base is possible. Such requirements were also applicable in Latvia after April the 30, 1998, when the Latvian Building Code LBN 205-97 “Design norms of masonry and reinforced masonry structures” [1] entered into force, which almost entirely took over the requirements of SNiP II-22-81 regarding the movement joints.

The situation changed on June the 1, 2015, when the new version of LBN 205-15 “Design of masonry structures” [2] came in force. According to the requirements of LBN 205-15, the masonry structures shall be designed in accordance with the methodology specified in the Eurocode standards, particularly according to the LVS EN 1996 “Eurocode 6: Design of masonry structures”. Provisions for deformation joins are included in the paragraphs NA 2.3.1 and NA 2.3.2 of the National annex to the standard “Eurocode 6: Design of masonry structures – Part 2: Design considerations, selection of materials and execution of masonry”. The horizontal distances between the temperature joints, depending on the type of brick and the average air temperature of the coldest five days, must be not more than 50 to 120 meters. The horizontal distances between the vertical movement joints of the non-load bearing walls, depending on the material of the masonry, must not exceed 6 to 12 meters. The movement joints of the walls must be arranged in all cases where uneven setting of the base of the building is possible.

The outer wall or facade is a very important part of the building, since it not only forms the aesthetic face of the building, but serves as an external climate protector. The outer wall must be able to provide protection against precipitation, temperature variation, winds, cold, noise and other adverse effects of the external environment. A high-quality exterior wall structure is one of the main preconditions for a healthy and homegrown indoor microclimate. One way of ensuring the longevity of the facade and avoiding the deformations leading to cracks is to design and build buildings, anticipating the construction of movement joints to ensure depreciation of the building's movements. The various materials available include a variety of distances for the placement of joints of 20, 6, 7.5 m, but it is often observed in nature that movement joints have not been constructed at all. However, it is clear that there are many buildings where movement joints should be, but there are none. In assessing and identifying the causes of cracks, it is possible to plan and take the necessary remedial measures or a set of them. Proper design and building helps avoid creating unwanted cracks. Similar topics are addressed in scientific research by other authors [8;9]. Today, many different materials and methods enable successful choices of solutions.

Materials and methods

Research methods such as comparative analysis, observations, experiment, methods of measurement and others are used in the research part.

The aim of the study is to perform deformation monitoring on the walls, to observe the state of the cracks and to make measurements, to determine the causes of the cracks, to make proposals to stabilize the situation.

The research task is setting up, evaluating and compiling the resulting measures, identifying consistency between the occurrences of cracks. Measurements were performed by crack monitoring rulers. These high-quality plastic (polycarbonate) ones are appropriate for use at temperatures ranging from -40 till + 80 ºC, because they have an extremely low thermal expansion factor: $6.8 \cdot 10^{-5}$ $cm \cdot cm^{-1}$ to °C.

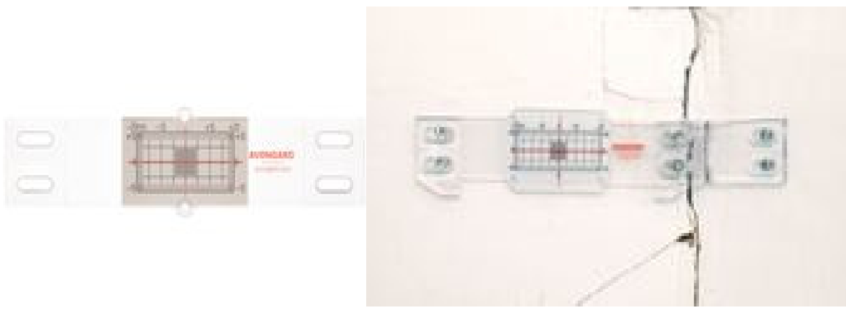

Fig. 1. **Standard plane rulers and corner rulers (photo by J.Gruntmanis)**

Fig. 2. **Ruler sliding planes, crack width rulers and digital gauge (photo by J.Gruntmanis)**

The rulers may be fixed on the wall by means of dentils (screws), glues, or both. By nature, the rulers have two planes moving one in relation to the other. The table to be displayed on the line is calibrated to 1 mm, the smallest section value is 0.5 mm. Plane rulers and corner rulers have special pins against which to push the slider. This allows to read the results at a resolution of 0.01 mm.

Other high-precision techniques available today

Digital tools for automatic crack monitoring are electronic data loggers for automatic and very accurate recording of crack distance and ambient temperature. Gap monitoring logger CMR U1 provides continuous reading of the crack widths and ambient temperature with a programmable interval of 1-91 hours. The data are later transferred to the PC via a USB cable.

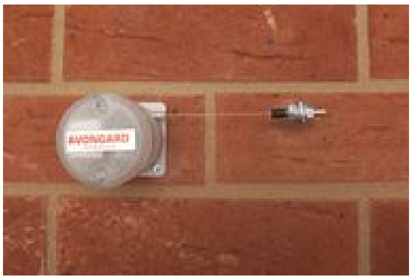

Fig.3. **Digital tools for automatic crack monitoring – electronic data loggers (hoto by J. Gruntmanis):** Resolution: 0.003 mm; Range: 80 mm; Linearity: 0.07 % throughout the range; Temperature sensor: -20 till + 80 ºC; Resolution: 1 ºC; Data capacity: 31926 readings; Power: CR2023 battery; Working temperature: -10 till + 60 ºC

The latest technologies in construction monitoring are related to the creation of automated control systems controlled by a computer, thus minimizing the possibility of human error. It is possible to control mechanical displacements, vibrations, operating conditions and chemical processes.

Depending on the parameter to be measured, appropriate measuring systems shall be used:

1. crack displacements shall be measured by optical fiber, piezoelectric or resistance tensometers [3];
2. compaction deformations shall be measured by radar or automated multi-purpose operation
3. laser rangefinders [4];
4. surface vibration shall be read from the reflected laser beam scanner, accelerometers or geophone [5].

Automated systems can control these processes in continuous mode and cyclically. One of the most promising types of global building monitoring and development trends is satellite radar systems that record the displacement of structures or parts of buildings. When processing satellite radar measurements, not only displacements are obtained, but also the rate of deformation in the vertical and horizontal directions.

The research is conducted by a relatively simple method of measuring the installed crack monitoring rulers.

The course of the experiment

The experiment will monitor the outer walls of two types of houses. The first is a building with 375 mm Aeroc wall blocks without additional silences with consciously incorporated movement joints, which are observed in the various parts of the building, Fig. 4. As seen in Fig. 5, the other type is a production building walled from the clay bricks of Kalnciems, where uncontrolled cracks have emerged in the wall in various parts of the building, which are then observed.

Readings are carried out at intervals of 7-9 days, with an indication of the outdoor air temperature, relative humidity and the results on all eight installed crack-monitoring rulers. When looking at the results obtained, it can be seen that in both cases deformation occurs. In the second case, the wall creates uncontrolled cracks in the weakest areas of the wall (at openings, covers, etc.). In the first case, the deformation is compensated by the embedded deformation profile. Compared to one reading from each type of the walls, we see that the Aeroc Wall, with a pointed point of deformation, is larger than the brick wall, which suggests that it retains more internal pressure that adversely affects the longevity of the brick material. Other schedules show that the negative winter temperatures had an effect on deformation, while the effects of humidity are less apparent. On the other hand, looking at the graphics, by type of the walls in all points, four of them show that variations take place differently and in different directions.

Fig. 4. **Aeoroc wall block building with movement joints (photo by J.Gruntmanis)**

Fig. 5. **Ceramic brick wall building without movement joints (photo by J.Gruntmanis)**

If comparing the measurements by one point from each wall, we see, that for the Aeroc with a deformation stitch the observed deformation is 30 % higher and consequently the impact of the stress on the wall is smaller, Fig.6. The graph in Fig. 7 shows that deformation at the various points of the building takes place differently.

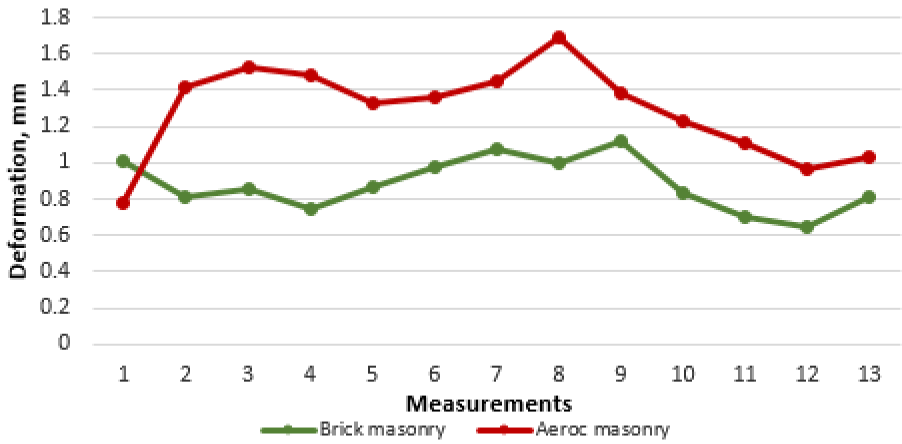

Fig.6. **Deformation measurements over time**

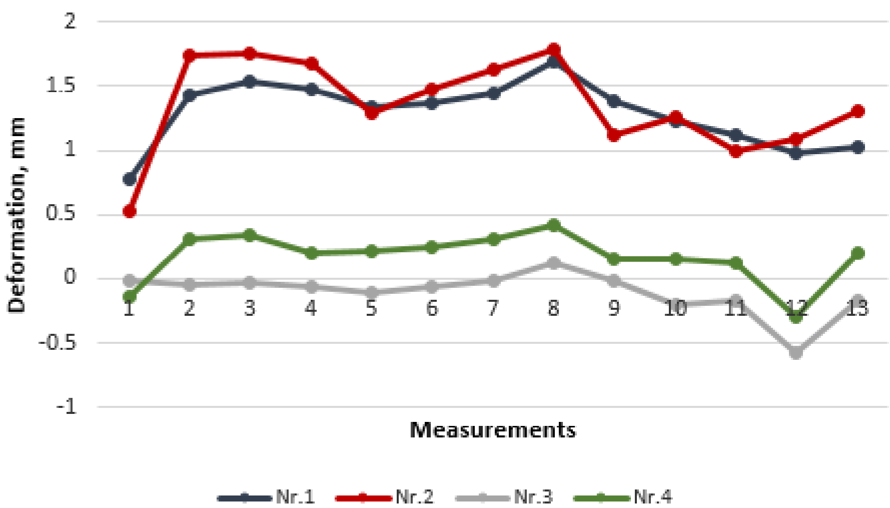

Fig. 7. **Aeroc (aerated concrete block) masonry deformation measurements**

The graph in Fig. 8 shows that deformation at different points occurs differently, and when the strains are summed up, the deformation is explicit at certain stages.

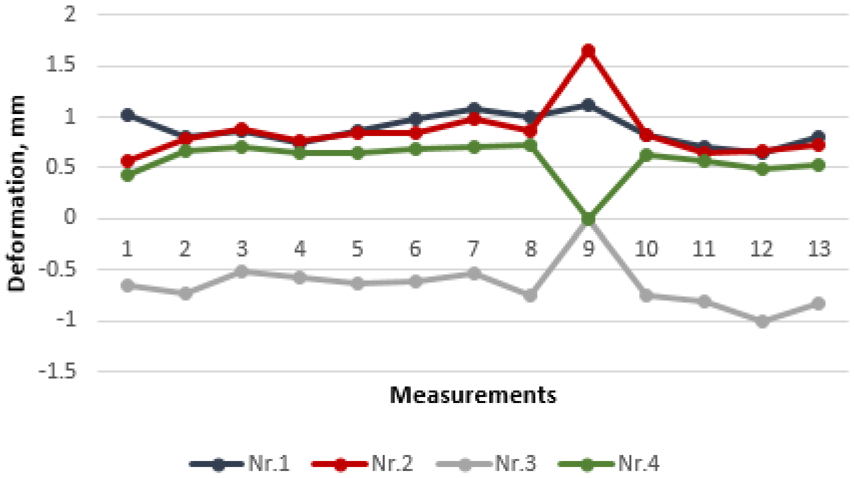

Fig. 8. **Brick masonry deformation measurements**

From the graph in Fig. 9 it can be inferred that humidity does not have as significant effect on deformation as the temperature does. The graph in Fig. 10 shows that the deformation of Aeroc is slightly different from the wall deformation due to the stress in the wall.

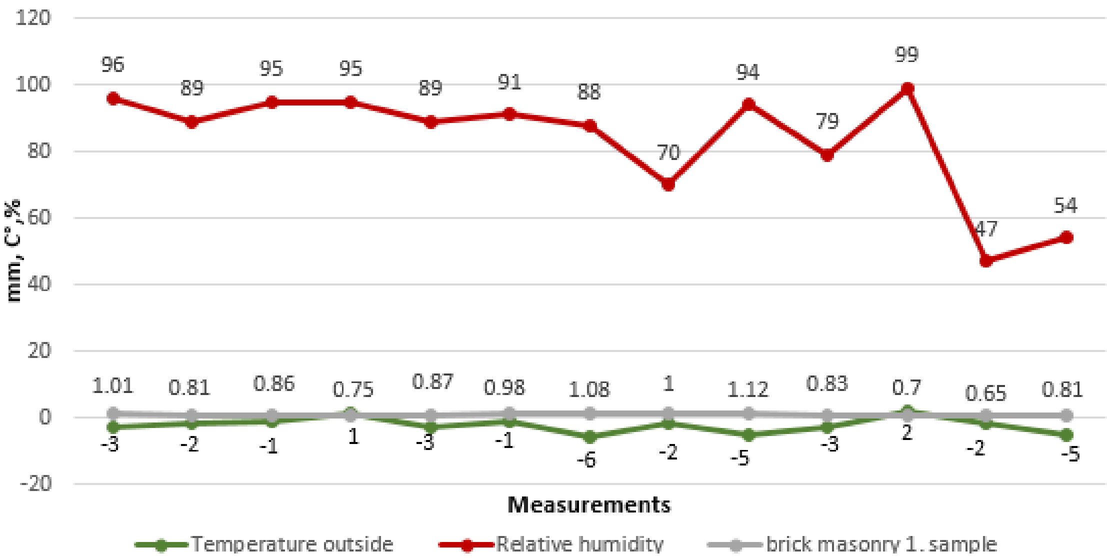

Fig. 9. **Measurements of outdoor temperature, relative humidity and brick wall deformation fluctuations**

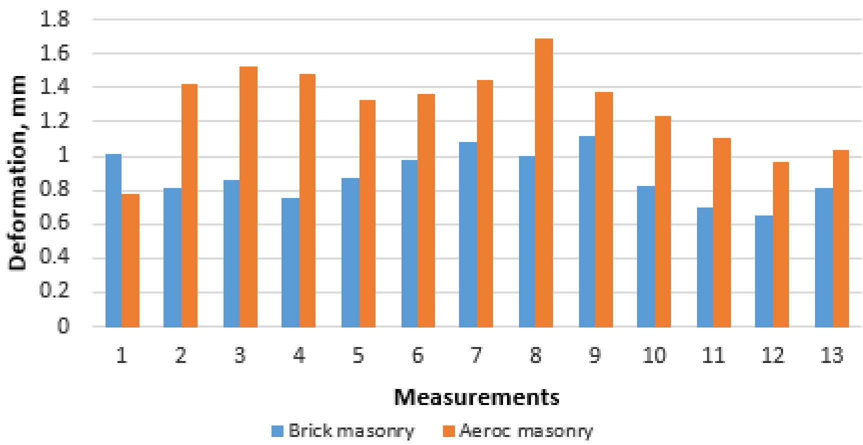

Fig. 10. **Measurements of brick and Aeroc masonry samples**

Conclusions

1. Buildings containing movement joints do not form cracks, as all internal pressures are captured by these joints.
2. In buildings, where movement joints are not applied, uncontrolled cracking on the facade is observed, where deformation sutures should be located.
3. The results of the study confirm that cracks are formed in the facade in places where there should be movement joints and in variations due to the temperature changes.
4. The Building Design Rules (Eurocodes) require movement joints in masonry structures and, when designing a building design, the responsible designer (architect) must specify the location of the movement joints. In addition, a careful geological exploration must be carried out before designing the building design.
5. Construction worker (work supervisor) work must be implemented according to the developed construction project.
6. During the renovation or insulation of the building, the technical inspection of the building must be carried out before the project is completed. If necessary, cracking measures should be taken. Otherwise, covering the structures with thermal insulation, if necessary, will make it difficult to inspect and detect the growth of the cracks.
7. During the operation of the building, care must be taken to ensure that the hydrological conditions (rainwater drainage, groundwater leaching) remain unchanged.
8. Failure to comply with the above paragraphs may result in substantial material damage as well as financial loss to the responsible persons.
9. More extensive gap monitoring should be intensified; the latest technology deployment monitoring should be promoted to provide more objective and operational information to technical surveyors.
10. Continuous, systematic and effective investment in renovation of large-scale buildings is necessary to maintain the building safety at an appropriate level. Proper design and proper construction help avoid unwanted cracks, thus saving the building resources. The results of the study confirm that cracks are formed in the facade where there must be movement joints and in variations due to the temperature changes.

References

[1] Regulation of the Cabinet of Ministers No. 139 of April the 21, 1998, Regulations Regarding the Building code of Latvia LBN 205-97 "Design Norms for Masonry and Reinforced Masonry Structures": "Latvijas Vēstnesis", No. 111; 24.04.1998.

[2] Regulation of the Cabinet of Ministers No. 248 of May the 26, 2015, Regulations Regarding the Building code of Latvia LBN 205-15 "Design of masonry structures": "Latvijas Vēstnesis", No 103; 28.05.2015.

[3] Deng L., Cai C.S. Applications of fiber optic sensors in civil engineering// Structural Engineering and Mechanics. Vol. 25, Nr. 5, 2007, pp. 577-596.

[4] Xue Z., Karpjoo J., Lim Sang Boem L.S., MTRMS: A TMO-based Multi-Target Real Time Monitoring System // ICCIT '07 Proceedings of the 2007 International Conference on Convergence Information Technology. 21-23 Nov. Gyeongju 2007. pp. 1687-1693.

[5] Bonaca A. Bosi Buratta R. Serafini R.Structural health monitoring experiences and innovations// MuRiCo3, Mechanics of masonry structures strengthened with composite materials. Università IUAV di Venezia. 2009. 22.-24. April. Italia, Venetia: - Proceedings of the Conference, 2009, pp. 91-98.

[6] Li Y., Wang T., Nie H. The Simple Simulation Study of Temperature Cracks in Masonry Structure Wall; Published in: 2015 Sixth International Conference on Intelligent Systems Design and Engineering Applications (ISDEA) ISBN Information: INSPEC Accession Number: 15956562; DOI: 10.1109/ISDEA.2015.225

[7] Avci O, Al-Smadi Y.M. Unreinforced Masonry Facade Assessment of a Historic Building for Excessive Displacements Due to a Nearby Subway Construction PRACTICE PERIODICAL ON

STRUCTURAL DESIGN AND CONSTRUCTION Volume: 24 Issues: 1 Article Number: UNSP 05018005 Published: FEB 2019.

[8] Hansaprojects, survey of buildings and monitoring, (In Latvian). [online] [03.03.2019]. Available at: http://www.hansaprojects.lv/eku-monitorings

[9] Derox, laboratory and testing equipment, (In Latvian). [online] [03.03.2019]. Available at: http://www.derox.eu/lv/materi %C4 %81lu-test %C4 %93 %C5 %A1anas-iek %C4 %81rtas/crack-width-monitoring/plaisu-monitoringa-logeri

[10] Gusta S. Tragedy in Zolitude – a lesson for contemporary society / Sandra Gusta // Proceedings of the 7th International scientific conference "Rural Development 2015: Towards the transfer of knowledge, innovations and social progress", Kaunas, Lithuania, 19-20 November, 2015 / Aleksandras Stulginskis University Kaunas, 2015. 1pdf. DOI: 10.15544/RD.2015.017, URL: http://conf.rd.asu.lt/index.php/rd/article/view/179