ICOSADOS 2018

8th INTERNATIONAL CONFERENCE ON SAFETY AND DURABILITY OF STRUCTURES

23rd-25th of May 2018

Proceedings

Latvia University
of Life Sciences and Technologies

Latvia University of
Life Sciences and Technologies

Faculty of Environment and Civil Engineering

8th International Conference on Safety and Durability of Structures

ICOSADOS 2018

May 23-25, 2018, LLU, Latvia

Proceedings

Editors:
Lilita Ozola, Ulvis Skadiņš

2018 | Jelgava

ISBN 978-9984-48-299-6

PREFACE

This proceedings contains papers presented in the 8th lnternational Conference on Safety and Durability of Structures (ICOSADOS 2018), held in the Latvia University of Life Sciences and Technologies (LLU), city of Jelgava, Latvia, from 23th to 25th of May 2018.

A contribution in the internationalisation goal of ICOSADOS was achieved with this event taking into account that authors or members of the Scientific Committee of nine countries collaborated. These countries are Poland, Latvia, Portugal, Italy, Mexico, Czech, Brazil, Slovakia, and Lithuania.

In this conference there were four lectures presented by keynote speakers who are international references in the topics of safety and durability of structures.

The conference scope includes a wide range of safety and durability of structures topics. In this event all the contributions can be grouped in five sections:

S1 - Degradation: diagnostics and evaluation methods

S2 - Structural, physical and material characterisation

S3 - Assessment, conservation, repair and strengthening

S4 - Numerical modelling

S5 - Case studies

The Editors are grateful to all authors, members of the scientific committee and other colleagues that make possible the publication of this book.

COMMITTEES

ORGANISING COMMITTEE

Ulvis Skadiņš,
chair, Latvia University of Life Sciences and Technologies (LLU), Jelgava, Latvia
Andrzej Pawłowski,
co-chair, Wroclaw University of Environmental and Life Sciences (WUELS), Poland
Anabela Paiva,
co-chair, University of Trás-os-Montes e Alto Douro (UTAD), Portugal
Silvija Štrausa,
co-chair, Latvia University of Life Sciences and Technologies (LLU), Jelgava, Latvia

Maciej Orzechowski, WUELS, Poland
Isabel Bentes, UTAD, Portugal
Sandra Gusta, LLU, Latvia
Raitis Brencis, LLU, Latvia
Jorge Tiago Pinto, UTAD, Portugal
Zofia Zięba, WUELS, Poland

SCIENTIFIC COMMITTEE

Lilita Ozola,
chair, Latvia University of Life Sciences and Technologies (LLU), Jelgava, Latvia
Jerzy Sobota,
co-chair, Wroclaw University of Environmental and Life Sciences (WUELS), Poland
Jorge Tiago Pinto,
co-chair, University of Trás-os-Montes e Alto Douro (UTAD), Portugal

Juris Skujāns, LLU, Latvia
Jānis Kreilis, LLU, Latvia
Raitis Brencis, LLU, Latvia
Guntis Andersons, LLU, Latvia
Leonīds Pakrastiņš, Riga Technical University, Latvia
Jānis Šliseris, RTU, Latvia
Hoła Jerzy, Poland
Kempiński Jan, Poland
Skowroński Wojciech, Poland
Śniady Paweł, Poland
Wysokowski Adam, Poland
Débora Ferreira, IPB, Portugal
Fernanda Rodrigues, UA, Portugal
Hugo Rodrigues, IPL, Portugal
Humberto Varum, FEUP, Portugal
João Lanzinha, UBI, Portugal

Sofia Ribeiro, LNEC, Portugal
Ivan Vaníček, Czech Technical University in Prague
Enrico Spacone, University of Chieti-Pescara, Italy
Fulvio Parisi, University of Naples Federico II, Italy
Giorgio Monti, Sapienza Università di Roma, Italy
José Jara, University Michoacana San Nicolás de Hidalgo, Mexico
Peter Koteš, University of Žilina, Slovakia
Raphaela Gomes, UEG, Brazil
Rytis Skominas, Aleksandras Stulginskis University, Lithuania
Raimundas Sadzevicius, ASU, Lithuania

CONTENTS

Proceedings of the 8th International Conference on Safety and Durability of Structures
ICOSADOS 2018
May 23 - 25, 2018, LLU, Latvia

INVESTIGATION OF FRICTION BETWEENN GRAVELY SAND OR NON-VOWEN GEOTEXTILE AND TEXTURED HDPE GEOMEMBRANE WITH USAGE OF INCLINED PLANE TEST

Andrzej Pawłowski[1, a]

[1] INSTITUTE OF BUILDING (Instytut Budownictwa) pl. Grunwaldzki 24 50-363 Wrocław, Poland

[a]andrzej.pawlowski@upwr.edu.pl

Keywords: textured geomembrane, soil-textured geomembrane friction, geotextile-textured geomembrane friction.

Introduction

Friction is the most important stability factor in every soil-geotextile-geomembrane system placed on a slope. HDPE geomembrane, which is widely used in watertight sealing systems, has relatively low friction coefficient limiting inclination of earth structures planes to ensure enough safety against sliding of covering soil layers. To increase friction forces on the contact planes and thus range of application, different texture patterns increasing geomembrane surface roughness are used. A newly developed pattern of geomembrane surface texture was tested.

Inclined plane test - which is a good model of real condition on a slope - was used to determine friction characteristics between textured geomembrane and soil. The speed of plane platform lifting (rotation) was regulated by multitest-tensile strength testing machine controlled by an individually created computer program. Geomembrane was fixed to the platform plane (Fig. 1, 2). Plane inclination was growing with constant speed 3°/min, as recommended by the standard PN-EN ISO 12957 – 2:2007 [1]. Influence of compaction and of moisture content of the soil on friction coefficient was investigated. Because very often nonvowen geotextiles are used in sealing systems as protection layer, friction coefficient between geotextile and geomembrane was tested, too.

Tests' program and description

Tests were performed on small 60x60x19 mm samples. Usage of programmable strength test machine assured constant angular velocity (3°/min). In tests described in the standard [1] calibrated sand 0,08-2 mm with rounded grains and water content smaller then 0,2 % is to be used. This method is good to compare different products between themselves. For particular projects necessary values should be obtained by testing soils, which are to be applied during realization [2]. According to Bhatia and Kasturi [3] "interface friction is very specific to the soil as well as the membrane". That is why in the reported investigation gravely sand was tested, as a material to be applied in designed realization. Soil sample was placed in square metal frame, which was moved slightly up to ensure, that only soil is in contact with textured geoemebrane. Water content and density index was determined for every soil sample. If friction between non-woven geotextile and textured geomembrane was tested, geotextile was wrapped around box with soil.

In spite of soil material some other changes were introduced adapting the tests to the possibilities of the laboratory. Angle of slipping "δ" is defined in the ISO standard [1], as an angle at which the box's displacement attains 50 mm. Test arrangement (Fig.2) presented in the paper, was prepared not to control sample displacement, but to measure force "V" lifting the plane and to determine displacement of inclined plane free end. When box with soil starts to move changing the position on the plane, sudden drop of lifting force, because of load movement, can be observed. This moment is precisely determined by measuring system of the strength testing machine. Slipping angle δ can be easily determined from the diagram presenting values of lifting force versus vertical displacement of the plane end (Fig. 3).

Fig. 1. Strength testing machine adopted to the inclined plane friction test

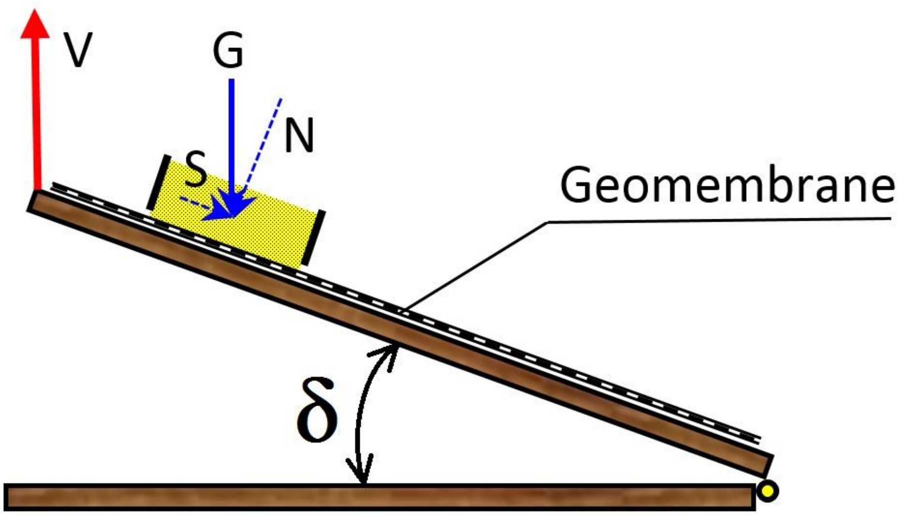


Fig.2. Inclined plane test arrangement

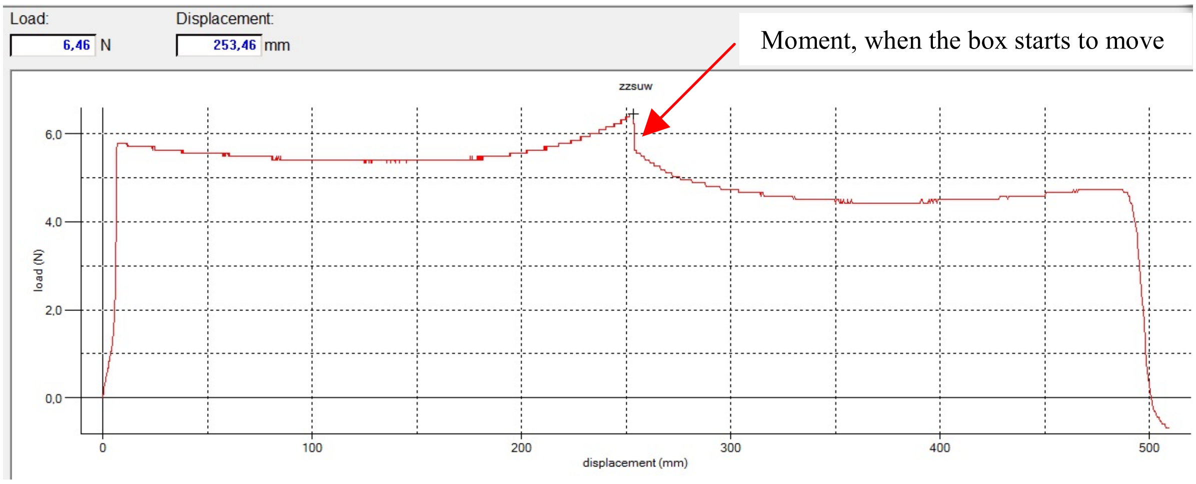


Fig. 3. Example diagram to determinate the moment, when box with soil starts to move

Despite of main tests, some investigation were made to determine soil parameters. The main tested parameters were:

- grain size distribution
- maximal and minimal porosity
- specific weight density
- optimal water content (Proctors test)
- angle of internal friction (in direct shear apparatus)

Average soil's parameters are presented in the table 1.

Table 1. Parameters of soil – gravely sand (grSa) - used in the tests

d_{60}	d_{10}	d_{60}/d_{10}	$\gamma_{max}/\gamma_{min}$	e_{max}	e_{min}	γ_{dmax}	w_{opt}	φ	c
mm	mm	-	kNm^3	-	-	kNm^3	%	deg	kPa
0,9	0,255	3.53	16,39/18,61	0,617	0,424	17,52	6,19	42	0

Textured geomembrane was made of HDPE and was 2 mm thick. Both geomembrane sides were textured. Texture pattern is presented on Fig.3
Non woven (needle punched) geotextile was 2,5. mm thick and its surface density was 175 g/m^2.

Fig. 4. Geomembrane texture pattern

Gravely sand -geomembrane friction on contact plane

The inclination, by which box filled with soil starts to move down, here called angle of slipping, can be taken as equivalent of friction angle between soil and geomembrane. In the highest position plane inclination was ca. 50°. Further movement of the computer controlled lifting arm was impossible, because the machine was reaching its extreme upper position. In some test configuration (moisture content, density) this inclination was too small to reach final slipping position, so further plane movement was continued manually, with much smaller accuracy. Only tests made with air-dry soil have given expected results – angle of slipping δ, based on other, then in the ISO standard criteria – was on the level 45° or less. In other tests, when water content was equal optimal value from Proctor's test or when gravely sand was fully saturated, slipping angels were much bigger than 45° and in extreme cases plane has to reach vertical position to start the box movement. One can suppose, that by so high angels, because of increasing sliding force and the moment it caused on soil – geomembrane contact surface, there was generated some additional suction pressure increasing resisting forces. Probably in real condition such phenomenon would not occurred and is only possible in certain condition of laboratory tests. No reports have been found about similar observation by inclined plane tests made with standard, big dimensions equipment, probably because the ISO standard presume usage of practically dry soil material. So using method described in this article it is recommended to use air dry material too, to eliminate other factors influencing stability of box with soil sample place on inclined plane. Results of the test, which were repeated 3 times for each soil parameters configuration, are brought together in the table 2. Test series 1÷3 were made on loose soil, in tests series 4÷6 soil was compacted.

Table 2. Test parameters and sliding angle δ from inclined plane tests (average values) of friction between geomembrane and gravely sand

Nr. of test series	γ	γ_d	w	I_D	δ	tan δ/tan φ
	kN/m³	kN/m³	%			
1	16,84	16,84	~0 (air-dry)	0,23	37,76°	0,86
2	14,10	13,27	6,19 (w_{opt})	<0	73,50°	3,75
3	20,04	16,70	20,05	0,15	45,00°	1,11
4	18,14	18,14	~0 (air-dry)	0,81	45,85°	1,14
5	18,40	17,32	6,19 (w_{opt})	0,45	55,4°	1,61
6	22,21	18,52	20,05	0,96	>90°	

Geotextile-geomembrane friction on contact plane

Geotextile-geomebrane friction was controlled on the same way as for soil samples. Geotextile was wrapped over metal box filled with loose gravely sand. Soil was used only to fill the box and to press geotextile to the surface of geoemebrane. Non vowen geotextile used in this investigation, was or air-dry, or saturated with distilled water. Before the tests, to saturate geotextiles samples, they were submerged in distilled water for at least 24 hours.

Test run was similar to tests made with gravely sand. Geomembrane was fixed to the plane. On it, box filled with soil and wrapped with geotextile, was put carefully and then the plane was pulled up until slipping of the box has occurred. Test results are presented in the table 3.

In the series 7 and 8 average values were calculated on the base of 2 tests only. The results of tests, when the box with geotextile could reach vertical position of the plane (δ = 90°, Fig. 4) and still was connected to the geomembrane, have been rejected.

By testing non-vowen geotextiles - material made of synthetic fibers - and geoemembrane with rough, textured surface formed during production process, it was obvious, that in spite of friction resisting sliding force, there is another resistance component because of mechanical connection between fibers and rough elements of geomembrane texture. The sum of this 2 resistance forces leads to much higher angle of slipping δ, than in standard test with geomebrane and soils, sometimes reaching even 90°. In this case influence of fibers entangled around rough elements of geomembrane surface could be determined with inclined plane tests only if we could use different material filling the box e.g. soil and metal balls, to carry the tests with 2 different loads. The same quantitative determination of other, then friction, factors influencing resistance against sliding forces can be made with direct shear apparatus [4].

Table 2. Test parameters and sliding angle from inclined plane investigation (average values) of textured geomebrane and nonvowen gotextile

Nr. of test series	**G**	**Moisture of geotextile**	**δ**
	G		deg
7	105,91	~0 (air-dry)	81,5°
8	122,12	Water saturated	73,50°

G - weight of the box, filling from gravely sand, and geotextile

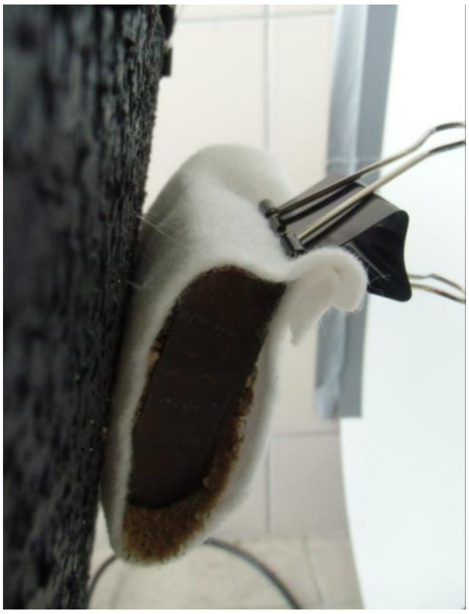


Fig. 5. Box with geotextile wrapped around just before the moment of break off from textured surface of geomembrane.

Conclusions

1. Tests on inclined plane with textured geomembrane and gravely sand have proved, that the geomebrane texture pattern assure very good friction. The smallest values of slipping/friction angle was observed for air-dry soil samples. In extreme cases (when soil is compacted and saturated) plane was lifted almost to vertical position, before sample start to move. It can be supposed that suction forces influenced test results by high water content of the sample.
2. Nonvowen geotextile during the tests exhibited very good connection with textured geomebrane surface. Inspite of friction, fibers from nonvewen geotextiles are tangled with protruding, rough

components of texture pattern increasing this way resistance against sliding. In some extreme cases the sample was detached from the geomembrane only by plane inclination near 90°.

3. To obtain reliable values for design purposes it is recommended to use dry soil, because in air-dry state slipping angle was the smallest. In the case of nonvowen geotextile and textured geoemembrane, there were not so big differences between air-dry and saturated material. Higher values were obtained by bigger moisture content.
4. Laboratory equipment can sometimes be adjusted (like in the example presented in this paper) to realize other tests, then it was primary designed for, using its precise measuring systems and individual programing possibilities to adapt to certain test condition.

References

[1] PN-EN ISO 12957 – 2:2007 Geosyntetyki. Wyznaczanie właściwości ciernych. Część 2: Równia pochyła. (Geosynthetics -- Determination of friction characteristics -- Part 2: Inclined plane test)

[2] Borys M.: Opory tarcia na styku geosyntetycznych ekranów przeciwfiltracyjnych w wałach przeciwpowodziowych. (in polish). (Frictional resistance at the junction of geosynthetics anti-filtration screens in flood embankments). Woda-Środowisko-Obszary Wiejskie/Water-Environment-Rural areas, 2007.t 7z 2b(21), pp. 21-31

[3] Bhatia S. K., Kasturi G.: A report on comparison of PVC and HDPE geomebranes (interface friction performance), November 1996; Syracuse University, pp. 46

[4] PN-EN ISO 12957 – 1:2007 Geosyntetyki. Wyznaczanie właściwości ciernych. Część 1:Ścinanie bezpośrednie (Geosynthetics -- Determination of friction characteristics -- Part 1: Direct shear test)

Proceedings of the 8th International Conference on Safety and Durability of Structures
ICOSADOS 2018
May 23 - 25, 2018, LLU, Latvia

RESEARCH ON CREEP OF HIGH PERFORMANCE FOAMED CONCRETE CYLINDERS IN COMPRESSION

Eva Namsone[1, a], Rihards Gailitis[2,b], Leonids Pakrastins[2,c], Genadijs Sahmenko[1,d], and Elvija Namsone[1,e]

[1]Riga Technical University, Department of Building Materials and Products, Institute of Materials and Structures, Kipsalas street 6a, Riga, Latvia, LV-1048

[2] Riga Technical University, Department of Structural Engineering, Institute of Structural Engineering and Reconstruction, Kipsalas street 6a, Riga, Latvia, LV-1048

[a]eva.namsone@rtu.lv, [b]rihards.gailitis@gmail.com, [c]leonids.pakrastins@rtu.lv, [d]genadijs.sahmenko@rtu.lv, [e]elvija.namsone@inbox.lv

Keywords: creep, foamed concrete, deformation.

Introduction

The development of specialized foaming and mixing equipment and synthetic foam agents has improved the stability of foam of foamed concrete (FC), which in turn has expanded the scope of FC in recent years from insulation material until road construction [1]. Polyvinyl alcohol (PVA) fibres usually are used to obtain the composite materials, but polypropylene fibres are used just as stabilizer of the mix [2]. One of relevant factor of using FC is an early-age creep.

The creep (also known as cold flow) is the ability of the solid material to slowly or continuously deform its plastic deformation under steady load conditions (mechanical stresses). The development of plastic deformation depends on the type of the load and temperature. The creep is found in almost all constructive materials with visco-elastic nature.

The creep is influenced by the environmental conditions like temperature, moisture, etc [3]. But creep of concrete is influenced by type of aggregate, water/cement ratio, compressive strength, age of loading, type of sample, isotropy and moisture. Literature research shows that use of “softer” aggregates reacts in higher values of creep (see Fig. 1 [4]). This picture shows that higher values of 28-day creep of aggregates indicate sandstone and gravium, but lower values of 28-day creep of aggregates indicate quartz and limestone. During the time of 25 years, values of creep are changing, especially basalt.

Results of Fig. 1 show that the effect of filler types on the creep is explained by the elastic modulus. If the value of elastic modulus is higher, there is a greater limitation of the potential creep of the cement paste. The creep is also affected by the porosity of composition. If the value of porosity is lower, there is a higher value of elastic modulus. In general, the main factors affecting the creep are the amount of fillers and the elastic modulus that restrict the creep of composition.

The changes in the properties of concrete are based on long-term chemical processes in the cement paste. The creep of the aging material depends not only on the length of the load, but also on the load time or the age of the material at the time of loading [5].

The characterization of creep involves the creation of creep curves, which show the deformation during a steady load change.

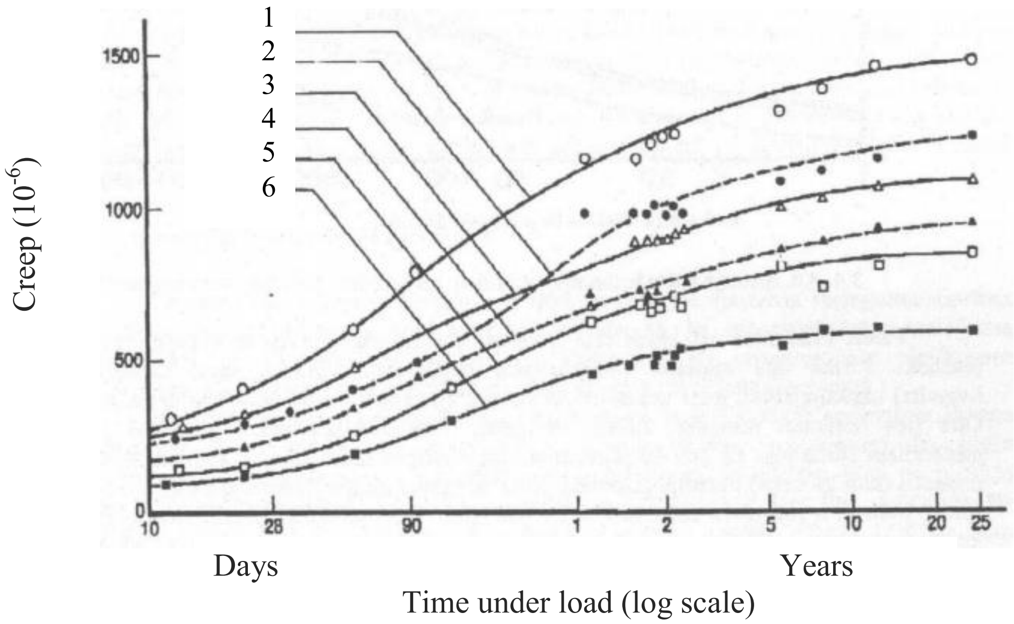


Fig. 1 Creep lines of aggregates: 1 – sandstone; 2 – basalt; 3 – gravium; 4 – granite; 5 – quartz; 6 – limestone

There is a basic creep that appears in conditions where there is no moisture exchange with the environment, and the common cracks, that is, the creep appears in conditions of drying, in which an additional component appears - the so-called dry creep, which occurs even after free-rushing, measured for the unloaded element. As a result of creep there occurs process that is called "relaxation of cracks".

There are advantages and disadvantages of deformation of creep. On the one hand, the main positive aspect is that creep helps to relieve unwanted (unnecessary) efforts in concrete, resulting from accidental and unexpected effects such as shrinkage, extreme initial temperature, placement of constructions and displacement of supports, which are resulted in stresses. Internal compressive stress obstructed cracks opening. On the other hand, the negative effect of creep can affect the exploitation time of construction by increased initial deformations, by increased level of efforts in the parts of construction where it was not foreseen. Creep may also result in a change in the structure of the system under load or in a significant deformation or the formation of internal efforts in the rigid support structures, etc.

The aim of the study is to investigate the role of lightweight aggregate and PVA fibers to decrease creep deformations of foamed concrete.

Materials and methods

Prepared compositions

FC samples were prepared using mixing foaming technology. Synthetic foaming agent (PB-Lux) was added during the mixing (beforehand it had been mixed with water). In this study four mixtures of FC were prepared. Control of reference mixture REF (I) was prepared without adding porous aggregate and fibers of polyvinyl alcohol (PVA). The second one P (II) – mixture with porous aggregate, it was prepared using expanded glass granules. PVA fibers were used for the third mixture F (III), but for the preparation of PF (IV) mixture a combination of porous aggregate and PVA fibers was used. Compositions of the prepared mixtures are summarized in Table 1.

Table 1

Mixes of compositions (weight proportions of the cement)

Aggregates	REF (I)	P (II)	F (III)	PF (IV)
Cement CEM I 42,5N	1.000	1.000	1.000	1.000
Sand 0/0,5mm	0.357	0.357	0.357	0.357
Sand 0/0,3mm	0.214	0.214	0.214	0.214
Foam agent „PB Lux"	0.005	0.005	0.005	0.005
PVA fibers	0	0	0.006	0.006
PP fibers	0.004	0.004	0.004	0.004
Metacaolin LMK	0.071	0.071	0.071	0.071
Micro silica Elkem 971 U	0.043	0.043	0.043	0.043
Foamed glass 4/8mm	0	0.207	0	0.207
Water	0.643	0.643	0.643	0.643
Plastificator „Stachema"	0.011	0.011	0.011	0.011
water/cement ratio	0.643	0.643	0.643	0.643

FC samples were formed in cylindrical shapes with a height of 180 mm and diameter of 70 mm using cylindrical moulds (see Fig. 2). In addition to the experiment, cubes with standart dimensions 100x100x100 mm were also used. All specimens prepared were stored at the temperature 20±2^{o}C and relative humidity >95±5%.

Compressive strength

Compressive test was performed after 7 and 28 days of hardening. Both type of obtained FC specimens (cylinders and cubes) were used to determine values of compressive strength. The load was applied at a constant rate 0.8 MPa/s (according to [6]).

The experimental cylindrical and cubic compressive strength is determined acoording to the starting day of the long-term load tests, because, based on the value of failure load, the value of load to be applied to the samples exposed to creep test is calculated.

Detection of creep single axis deformations by pressure

Creep deformations of high performance FC cylinders in compression were determined according to [7] and [8]. It is recommended to determine the creep deformation in the pressure cylinder with cylindrical specimens by inserting them into spring or hydropneumatic loading stands, and applying a constant compression load (maximum 0.4 from the disruptive load to view the linear creep section) and defining deformations over a prolonged period of time.

For all samples, aluminum plates (dimensioned 10x15 mm, thickness 0.5 mm) were attached to the side surfaces centrally and symmetrically to ensure the stable position of the distoriton measuring instruments (knives). Six plates are fixed to one cylindrical specimen. The distance between the centers of two aluminum plates is 50 mm. To determine the value of basic creep, the specimens of FC were wrapped in two layers of aluminum foil in order to ensure that no drying process occurs [9].

Before placing the samples in a creep lever on the stand, deformation gauges (round shaped mechanical clock tensometers) were fixed on the side surfaces of the samples. There were 3 tensometers (base 50 mm, section value 10 μm and maximum stroke 10 mm) used for the cylindrical specimens, placed at equal distances apart from each other on the aluminum plates. Tensometers were attached to the samples with elastic, ring shaped rubbers (see Fig. 2). Tensometers measure the change of length of specimen in tensometer base range, which is 5 cm.

Fig. 2 Cylindrical moulds (at the left) and specimens with tensometers attached (at the right)

For experimental study of creep phenomena, FC samples were inserted into the creep stands, maximally centered between compression planes. In each stand there were placed two samples. The creep lever stand (see Fig. 3) with shoulder strain ratio 1:40 and precission in pressure 1/100kg or 0.01% was used to determine creep of FC samples.

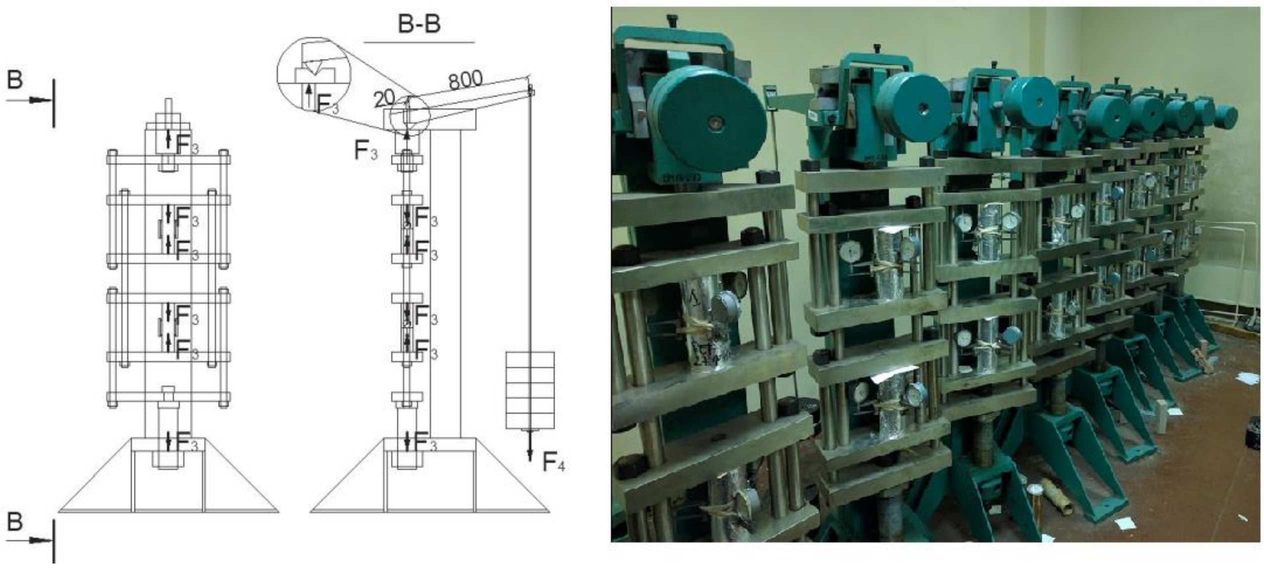


Fig. 3 Single axis creep lever stand

All samples were loaded by a constant, uniform, static load (20% of the value of the failure load). The samples were repeatedly loaded and relieved twice. Before loading, it was decided not to load the samples of FC cylinders with the standard load (40% of the value of the failure load), but only

20% of the failure load value, because compared to high strength concrete, FC is much more porous and it was expected that the deformation of the samples would be much faster. Also, due to the too small stroke, there was a possibility that there would arise a moment where the lever opens against its support and the loading of samples would be stopped.

On the first day after loading the FC specimens, the data was recorded every two hours, then once a week during the first week. After the first week of loading, the data was recorded at intervals of 2-3 days, approximately 30 days after the start of the loading, after the first month the data was recorded once a week.

Reaching the duration of the loading of interest for the experiment, the load was gradually removed. At each load level, the strain values were obtained, resulting it in instantaneous or immediate, reversible deformations. The load removal rates are equal to the load application rates. When the FC sample was relieved, it was left permanently on the creep lever stand to determine the revisable deformation by time.

During the test of creep, the humidity level and temperature of the surrounding environment were recorded also.

Results and discussion

Compressive strength and density

Results of compressive strength and density are presented in Fig. 4.

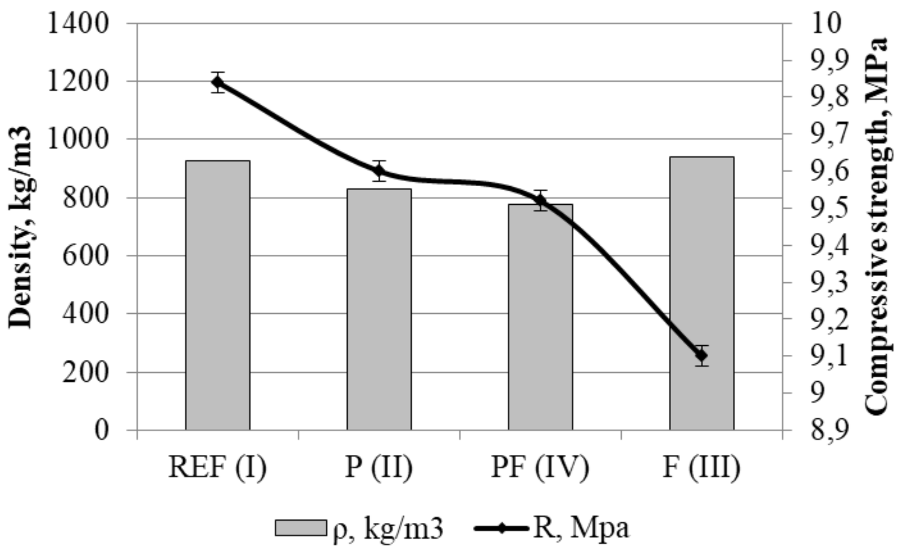
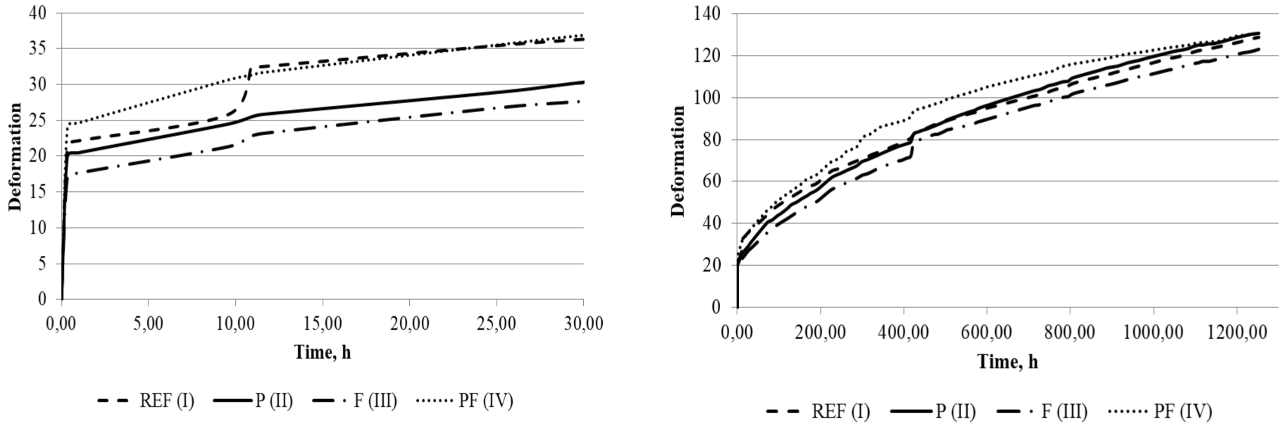


Fig. 4 Compressive strength, MPa (28 days) and density, kg/m^3 (28 days)

The graph shows that higher value of compressive strength has REF (I) mix, but the lowest value of compressive strength has F (III) mix, where PVA fibres were used. It can be seen that mixes (REF (I) and F (III)) without granules of expanded foamed glass have D900 density class (in average 900 kg/m^3), but mixes (P (II) and PF (IV)) with granules of expanded foamed glass have D800 density class (in average 800 kg/m^3). Results show that higher value of density provides higher value of compressive strength except the F (III) mix with PVA fibres. It can be concluded that adding granules of expanded foamed glass improves physical and mechanical properties of foamed concrete by reducing value of density in range of 10% and reducing value of compressive strength in range of 3% instead of adding PVA fibres that affect on microstructure of composition by damaging cells of porous structure and reducing value of compressive strength in range of 8%. These deductions were obtained in previous researches of the author ([10] and [11]).

Creep deformation

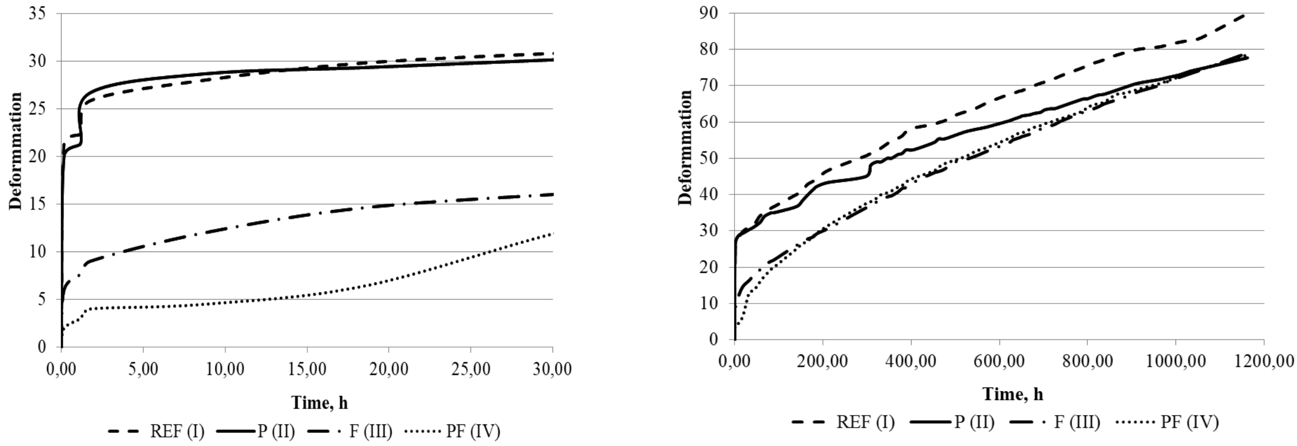
After the tests of compressive strength, measurements from tensometers and calculated creep deformations from specimens after 7-day and 28-day binding were determinate. Obtained results are shown in Fig. 5 and Fig. 6.



A B

Fig. 5 Deformation strains (after 7-day binding) in A and B

During the first 30 hours of early creep (7-day) deformation values show that adding separately granules of expanded foamed glass and PVA fibres reduces deformation in range of 19% and 24%, comparing to REF (I) mix. It can be explained by hardening process of FC. At early age of specimens adhesion between FC and the disperse reinforcement (PVA fibres) and porous aggregate were not so high like later (28-day), which resulted in the involvement of the fibres in the compressive force.



A B

Fig. 6 Deformation strains (after 28-day binding) in A and B

Experimental data of creep deformation during 1200 hours show that specimens after 28-day binding have lower values of creep deformation in a range of 35%, compared to specimens after 7-day binding. It can also be explained by bonds during the forming process of concrete.

The highest value of creep deformation after 28-day binding during 1200 hours showed REF (I) mix by 90 mm · 10^{-2} without granules of expanded foamed glass and without PVA fibres. Comparing these results to other mixes, it can be concluded that values of creep deformation are about 12% lower. It can be explained by elasticity modulus. The use of disperse reinforcement decreases values of creep deformation. The less materials, that during the time change its elasticity modulus, are added in FC composition, the less is the deformation of creep.

Conclusions

1. In this experimental study disperse reinforced FC composition was produced, which showed a value of compressive strength of 9.8 MPa (after 28 days).
2. The use of granules of expanded foamed glass decreases density and insignificantly decreases value of compressive strength, because granules are lightweight porous aggregate and their microstructure is similar to microstructure of composition matrix (FC).
3. The use of PVA fibers decreases value of compressive strength. Although the fibers of PVA structure the composition of FC and have a function of reinforcement, the microstructure of FC was influenced and damaged by fibers.
4. About 13% lower value of deformation of creep (after 28 days) showed mixes (with PVA fibers and expanded foamed glass granules – PF (IV), and mixes with PVA fibers – F (III)), which contained more materials with lower deformation than FC.

Acknowledgements

The financial support of European Regional Development Fund project Nr.1.1.1.1/16/A/007 "A New Concept for Sustainable and Nearly Zero-Energy Buildings" is acknowledged.

References

[1] Martin Decký, Marian Drusa, Katarina Zgútová, Matej Blaško, Matej Hájek (2016) - Foam Concrete as New Material in Road Constructions. Procedia Engineering 161 (2016) pp. 428–433. (doi: 10.1016/j.proeng.2016.08.585).

[2] Eva Namsone, Genadijs Sahmenko, Aleksandrs Korjakins (2017) - Durability Properties of High Performance Foamed Concrete. Procedia Engineering 172 (2017), pp. 760-767. (doi: 10.1016/j.proeng.2017.02.120).

[3] Dejian Shen, Jinliang Jiang, Yang Jiao, Jiaxin Shen, Gouqing Jiang (2017) - Early-age tensile creep and cracking potential of concrete internally cured with pre-wetted lightweight aggregate. Construction and Building Materials 135 (2017), pp. 420–429. (doi: 10.1016/j.conbuildmat.2016.12.187).

[4] Leonids Pakrastins,Andine Sprince. Betona slude. Specialais kurss. 2011. Editors: Rigas Tehniska universitate p. 42. ISBN: 9789934815140.

[5] Girts Bumanis, Andina Sprince (2012) - Experimental Testing of Early Age Concrete Creep. 53th Riga Technical university Student scientific and technical conference materials (2012) pp. 178. ISBN 978-9934-10-380-3.

[6] LVS EN 12390-3:2009 /AC:2011 Testing hardened concrete - Part 3: Compressive strength of test specimens.

[7] ISO 1920-9:2009 Testing of concrete.

[8] ASTM C512 / C512M-10 Standard Test Method for Creep of Concrete in Compressio.

[9] Andina Sprince (2015) - Methodology For Determination of Long- Term Properties and Crack Development Research in Extra Fine Aggregate Cement Composites. 2015. Editors: Riga Technical university p.172.

[10] Eva Namsone, Genadijs Sahmenko, Elvija Namsone, Aleksands Korjakins (2017) - Thermal conductivity and frost resistance of foamed concrete with porous aggregate. Vide. Tehnologija. Resursi. - Environment. Technologies. Resources. 3 (2017), pp. 222–228. (doi: 10.17770/etr2017vol3.2625).

[11] Aleksandrs Korjakins, Genadijs Sahmenko, Eva Namsone (2017) - Foamed concrete with reduced shrinkage. P-16-100, 2017.

Proceedings of the 8th International Conference on Safety and Durability of Structures
ICOSADOS 2018
May 23 - 25, 2018, LLU, Latvia

PATHOLOGIES IN OLD BUILDINGS OF THE HISTORIC CITY CENTER OF VILA REAL

Andreia Queirós[1,a], Anabela Paiva[2,b] and Jorge Pinto[3,c]

[1] Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, 5000-801 Vila Real, Portugal

[2] Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, 5000-801 Vila Real, Portugal. C MADE – Centre of Materials and Building Technologies

[3] Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, 5000-801 Vila Real, Portugal. C MADE – Centre of Materials and Building Technologies

[a]andreiaqueiros30@hotmail.com, [b]apaiva@utad.pt, [c]tiago@utad.pt

Keywords: pathologies, old buildings, historic city center, Vila Real.

Abstract
In the 80's people tended to move out from the city centers to live in peripheral areas, in more modern buildings, with larger spaces and higher levels of comfort. Due to the abandonment, the city centers became unsafe, degraded and devalued.
The historic city centers are strongly linked to the cultural heritage of cities, so they should be preserved. However, they should evolve accompanying the needs of the users, in order to be attractive, while preserving their cultural, architectural and construction characteristics.
In Vila Real, a city located in the northeast of Portugal, this happens too. Some years ago, with the help of European, National and Municipal incentives, the historic city center began to be rehabilitated. Even so, there are still a lot of buildings in need of attention.
In this context, a set of eighteen buildings, representative of the historic city center of Vila Real, was selected for the purpose of this work. A survey of the construction characteristics and associated pathologies of these buildings has been carried out. We analyzed the most frequent pathologies in the various construction elements of the external and internal envelope, namely cracking, humidity, degradation of the painting in walls and timber frames, and parasite vegetation on the roofs.

Introduction
The increase of construction of new buildings led to the desertification of city centers, so their historic buildings have been abandoned and degraded, resulting in the need to rehabilitate them. As they represent the history, the culture and the identity of the city and of the people, they should be rehabilitated in a way that preserves their characteristics [1].
Nowadays, in Portugal, the population tends to go back to the historic city centers and consequently, there is an interesting dynamic of rehabilitation of these areas and the historic center of Vila Real, in the region of Trás-os-Montes e Alto Douro (TMAD), has also been following this dynamic.

In this context, this research work is within the scope of the Construction Observatory of TMAD [2] that intends to disseminate the characteristics and the dynamics of new construction and rehabilitation in this region.
In order to contribute to the regeneration and rehabilitation of the historic centre of Vila Real, a survey of the characteristics and pathologies of 18 buildings was carried out.
In this article the adopted methodology to develop this work is presented, as well as the characteristics and the more frequent pathologies of the studied buildings.

Methodology
The characterization and survey of the pathologies of the buildings of the historic city center of Vila Real was done through a case study. So, a representative number of buildings were selected. and a datasheet was adapted from the datasheet prepared by Mouraz [3] and used in the Freeze Viseu project [4]. This datasheet is divided into different topics related to the external characteristics, design and organization of the buildings, roofs, walls, spans and window frames and characteristics of the internal elements, such as partition walls, walls in contact with other buildings, floors, ceilings, equipment, as well as their pathologies.
Using the datasheet a field work was carried out in which several visits and meetings with the owners or users were held. A vast set of photographs was also taken to document the existing features and pathologies of the buildings.
After, the collected data was analyzed and conclusions were drawn.

Case Study
The city of Vila Real, in the northern interior of Portugal has a population of around 52,000 inhabitants, an area of 370 km2 and an altitude of 450 m [5].
The case study consists of 18 buildings located in the historical center of Vila Real. In Figure 1 a partial view of the historic city center of Vila Real and the location of the 18 buildings (from A to R) are shown.

Figure 1 - Location of the studied buildings of the historic center of Vila Real [Source: https://www.360cities.net/image/vila-real-historic-center]

Construction Characteristics
In this section the construction characteristics of the buildings studied will be presented.
These buildings were built before 1900and are a two or three storey buildings, Figure 2. Usually the ground floor is used for commercial or catering activities and the other floors for housing. They are terraced houses with only a facade to the street. The facade is made of granite and have a natural smooth finishing or is plastered and painted. The plaster was made with sand and lime in the buildings that have never been rehabilitated. All these buildings have pitched roofs with two or more slopes and timber structure. 14 of them are coated with Marseille ceramic tiles Figure 3 and some of them have eaves and skylights. The buildings shown in Figure 2 can be considered

representative of the buildings of the historic centre of Vila Real.

a) Two storey house b) Three storey terraced house

Figure 2 - Building I and E of the historic center of Vila Real.

Figure 3 - Pitched roof with Marseille ceramic tiles and skylight

The partition walls are *Tabique* walls (Fig. 4a)) in 11 cases, which are made of vertical timber boards with horizontal slats and filled and plastered with an earth and lime based mortar. In 9 cases these walls are made of hollow brick and in 3 cases of concrete block. The existence of these construction solutions leads to the conclusion that these buildings have already been rehabilitated. The interior doors are made of timber, Figure 4b).

a) Tabique wall b) Timber ceiling and door

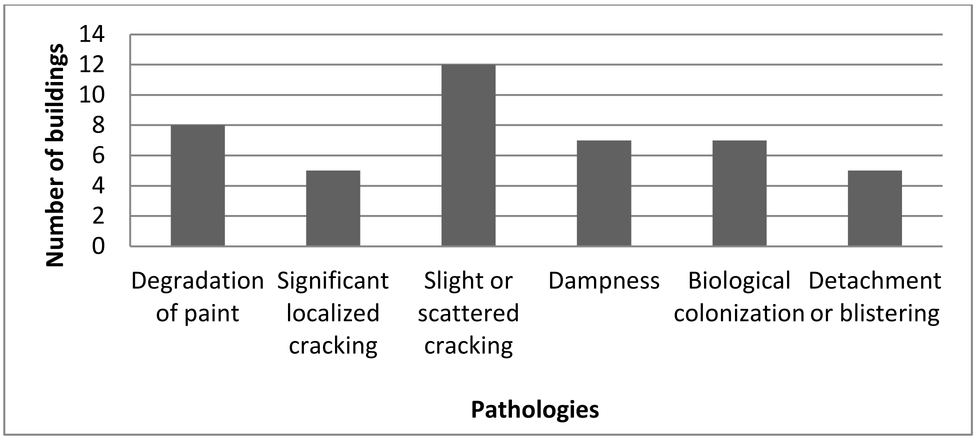
Figure 4 - Construction solutions for partition walls and ceilings.

The floors and ceilings in 9 cases are made of timber and the common finishing is paint or varnish. In 11 buildings the floors are made of concrete slabs and in 9 buildings the ceilings are also made of concrete slabs. These slabs are used in buildings that were already rehabilitated.

The windows frames in 12 buildings are also made of timber and in the remaining buildings they are made of aluminum (8 cases) or PVC (7 cases). The types of windows presented in these buildings are casement and hung windows. The window sills are mainly made of granite (12 cases) and timber (10 cases).

Buildings Pathologies

Most of the buildings of the historic center of Vila Real need to be rehabilitated, as already referred to, so a survey of major pathologies was carried out. The results of this survey, in what concerns the facades, showed that there is slight or scattered cracking in 12 of the studied buildings, degradation of the paint in 8 of them and dampness and biological colonization in 7 others, Figure 5.



.Figure 5 - Pathologies in facades

In Figure 6 the facades of two buildings are presented. On the left photo the facade of the building presents dampness, mould and peeling paint. On the right photo the granite is cracked, and there is dampness under the window sill.

Figure 6 - Facades with dampness, mould, peeled paint and cracks.

The access of the exterior of the pitched roofs, in most of the buildings was difficult, even so it was found the presence of parasitic vegetation in the ceramic tiles in 6 cases and deterioration of the drainage system in 5 cases. A damaged roof is shown in Figure 7.

Figure 7 - Parasitic vegetation in Marseille tiles

The most frequent pathologies found in window frames are the degradation of the paint, in 12 buildings and the degradation of the wood in 9 of them. 4 buildings have broken glasses, Figure 8.

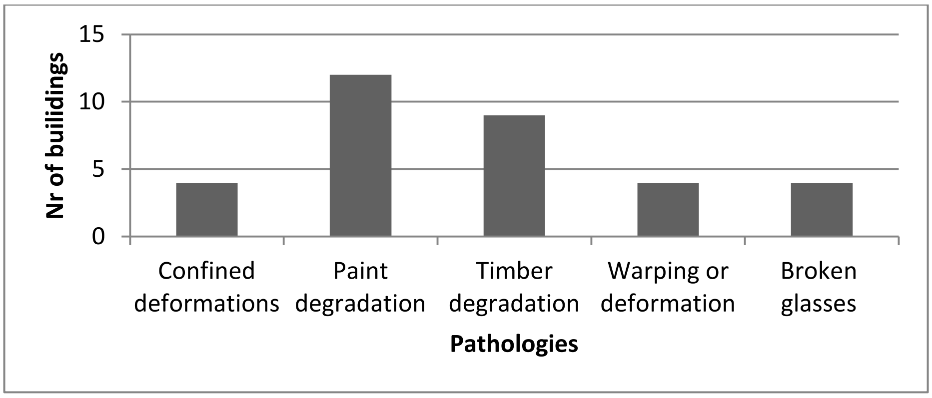


Figure 8 - Pathologies in windows

Several pathologies in a window can be observed in Figure 9, such as degradation of the paint and of the timber frame, broken glass and window sill.

Figure 9 - Pathologies in window.

The more frequent pathologies in interior walls are crack, in 15 of the studied buildings and dampness in 10 of them. In the example presented in Figure 10, the main cause of these pathologies can be water infiltration, due to roof or drainage problems. The dampness leads to the appearance of mould and possibly to the cracking and blistering of the mortar.

Figure 10 - Dampness, cracks and mould in an interior wall

The floors, as well as the doors and their frames are made of wood. In Figure 11 the pathologies in floors are presented. The main problems are the floor wear in 10 of the buildings (Figure 12) and cracking in 9 of them. Deformations and degradation of the baseboard is also present. These pathologies are due to the use and the lack of maintenance.

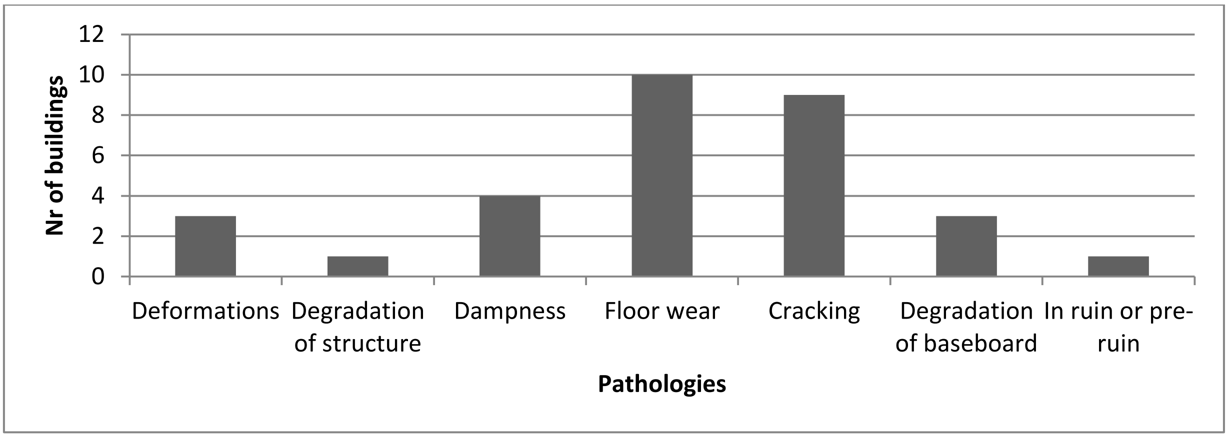


Figure 11 - Pathologies in floors

The stairs have as main pathology the wood wear in 14 of the buildings. Cracking and degradation of the wood are others pathologies shown. Also the use and the lack of maintenance are responsible for their degradation.

Figure 12 - Wood wear on stairs

The more frequent pathologies that affect the ceilings are the cracking and dampness that appear in 9 of the studied buildings, as can be seen in Figure 13. The ceilings in 3 buildings are in ruin or pre-ruin and 2 of them are deformed or have the structure degraded or have mould.

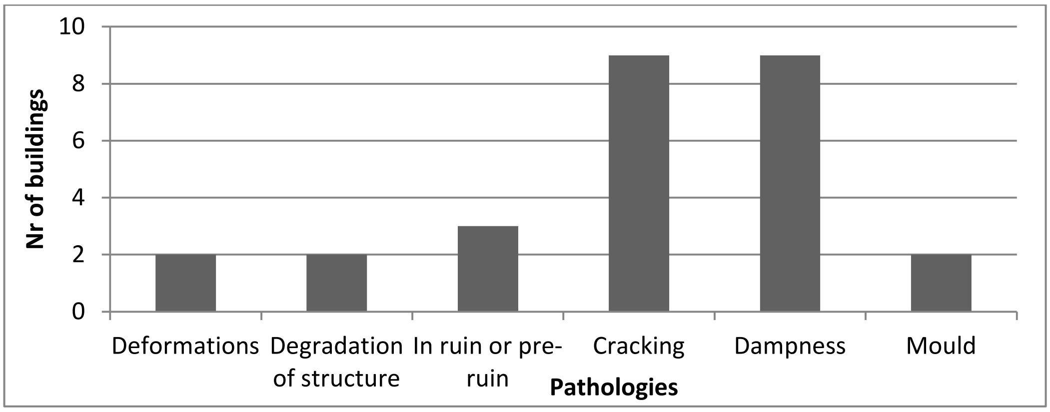


Figure - 13: Pathologies in ceilings

The pathologies in ceilings are mainly due to problems in the roof or condensations, Figure 14.

Figure 14 - Consequences of dampness in ceiling

Although, the buildings pathologies identified, none of the buildings are in ruin or pre-ruin. This leads to the conclusion that the construction solutions used have great potential for rehabilitation. So, instead of replacing wood floors and ceilings with reinforced concrete lightened slabs with pre-stressed beams or the earth and lime based plaster of *tabique* walls with cement and lime based plaster or plasterboard or the windows wooden frames with aluminum or PVC frames, the ancient construction solutions could be preserved. Some of the buildings already rehabilitated are shown in Figure 15 and 16. The old wooden floors, ceilings, stairs, handrail, baseboard and door were restored. The facade was maintained, as well as windows frames and the balconies guardrails.

Figure 15 - Rehabilitated building

Figure 15 - Rehabilitated building - facade and interior

Conclusions

The historic city center of Vila Real is in a revitalization process, but there is still a lot rehabilitation work to be done. The eighteen buildings that were studied are representative of this situation.

The pathologies that have been identified are related to the aging of the materials and the presence of water, due to cracking, drainage systems damage and cracking or absence of ceramic tiles on the roofs, that could have been drastically reduced with a regular maintenance.

As no situation of ruin or irreversible damage was found in the studied buildings, it can be concluded that the rehabilitation of this patrimony seems to be a promising option and that the rehabilitation process must be considered in order to preserve the original construction solutions.

Acknowledgements

This research was partially funded by the Foundation for Science and Technology (FCT), PEst-OE / ECI / UI4082 / 2013 (C-MADE).

To the students of the Course Conservation and Rehabilitation of Buildings, of the Master in Civil Engineering of UTAD, of the 2016/2017 school year.

References

[1] AIRES, B. A., Estratégias de reabilitação urbana caso de estudo: Bairro dos Ferreiros, Dissertação de mestrado em Engenharia Civil da UTAD, Vila Real, Portugal, 2009

[2] Paiva, A., Paiva-Rodrigues, E., Faustino, J., Barbosa-Vieira, J., Ramos, L. (2000), Observatório da Construção em Trás-os-Montes e Alto Douro: um Instrumento de Apoio à Intervenção dos Agentes Regionais do Setor Imobiliário Habitacional, 3rd International Congress of Real Estate, Construction and Company Evaluation, Lisbon, Portugal.

[3] MOURAZ, C. P., A (2016) Importância da Caracterização Construtiva e do Estado de Conservação na Sustentabilidade ds Acções de Reabilitação: Um caso de estudo no Centro Histórico de Viseu, Master's Dissertation in Civil Engineering, FCTUC, Coimbra, Portugal,.

[4] County of Viseu, Projeto Freeze Viseu, http://viseupatrimonio.pt/projeto-enquadramento-objectivos.php. Accessed in March of 2018.

[5] County of Vila Real, http://www.cm-vilareal.pt/index.php/municipio/caraterizacao. Accessed in March of 2018.

Proceedings of the 8th International Conference on Safety and Durability of Structures
ICOSADOS 2018
May 23 - 25, 2018, LLU, Latvia

TECHNICAL SOLUTION PROBLEMS OF CONCRETE INDUSTRIAL GROUND FLOORS IN LATVIA

Sandra Gusta[1, a], Silvija Strausa[2, b], Mareks Pavars[3, c]
[1,2,3] Latvia University of Life Sciences and Technologies, Latvia, Akademijas street 19, Jelgava, Latvia
[a]sandra.gusta@llu.lv,[b]silvija.strausa@llu.lv,[c]pavars.mareks@gmail.com

Keywords: concrete floor slabs, surface levelness and flatness.

Abstract. The construction industry in Latvia has been developing very rapidly in recent years, and especially construction of public and industrial buildings. All these new buildings are characterized by a large volume of floors with specific characteristics and quality requirements, which are based either on the reception of heavy loads or on certain requirements for surface level and flatness of the surface. The research focuses on the requirements of the floor surface in different countries. The standards and standards of surface tension and flatness as well as the technology and measurement equipment used to determine surface tension and flatness are summarized in countries such as United States, United Kingdom and Germany. Having assessed the foreign experience in determining and controlling the quality of industrial floors, we noted the importance of this process in terms of building exploitation. Upon acquainted with the specification of the technical design of floors of public and industrial buildings, we found a lack of standard requirements. When describing and measuring the precision and flatness of concrete floors in Latvia, we also found insufficient quality assurance. Using analytical, statistical and empirical research methods and using appropriate measuring devices, we obtain the results, which are summarized, analyzed and conclusions drawn, which indicates the need to develop standards for determining the surface quality of floors.

Introduction

Construction output was by 21.7% higher than in 2016 (see in table 1). This is largely due to the launch and implementation of European Union Structural Fund projects, which have a positive impact on the sector.

Table 1

Construction Output by Type of Construction; 2015, 2016, 2017 in Latvia

At current prices (thsd.euro)

	2015		2016		2017	
	thsd.euro	%	thsd.euro	%	thsd.euro	%
Total	1 743 726	100	1 425 952	100	1 735 952	100
Residential buildings	223 394	12.8	234 576	16.5	216 044	12.5
Non-residential buildings	634 154	36.4	610 941	42.8	754 416	43.5
Industrial buildings and warehouses	99 941	5.7	101 395	7.1	139 917	8.1

Created by the authors according CSB data [7]

As it is seen in table 1, in 2017 the volume of industrial production buildings and warehouses has reached 13,991 thousand euros, or 8.1% of the total construction output (1 735 952 thousand euros).

Table 2 gives a breakdown of the volume of construction output by type of work in 2016-2017.
In 2017, the volume of construction products increased both in buildings and in engineering structure basic categories.The fastest increase was observed in the construction of engineering structures. Compared to the previous year, construction output was 31.9% higher. In terms of volume, the largest increase was observed in the construction of highways, streets, roads, aerodrome runways and railways. It is expected that construction of civil engineering structures will continue to grow in the coming years, taking into account the implementation of European Union structural funds projects and large-scale infrastructure projects.
The purpose of the research work is to evaluate the quality of concrete floors located on the ground in commercial buildings built in Latvia, mentioning applied construction technology and making a comparison in accordance with the standard used in England. An analytical, statistical, and empirical research method has been used in the work, using measuring devices to measure physical quantities and calculus for mathematical and logical operations with measurable values.
Building construction in general increased by 14.8%. This was achieved by an increase of 23.5% in the construction of non-residential buildings, while in the group of residential buildings there was a decrease of 7.9%. In non-residential buildings, the largest contribution to growth was in industrial buildings and warehouses (by 33.3%) and office buildings (by 28.7%).

Table 2

Construction Output by Type of Work; 2016, 2017

At current prices (thsd.euro)

	2016			2017		
	Total	New construction	Repairs	Total	New construction	Repairs
Total	1 425 952	696 333	729 620	1 735 952	1 996 428	739 524
Residential buildings	234 576	142 133	92 443	216 044	165 474	50 569
Non-residential buildings	610 941	295 841	315 100	754 416	425 017	329 399
Industrial buildings and warehouses	101 395	71 412	29 982	139 917	85 136	54 781

Created by the authors according to CSB data [7]

In the 4th quarter of 2017, construction output increased by 24.4% compared to the 4th quarter of 2016. The growth was observed in construction of buildings and civil engineering structures, the growth was 19.6% and 31.1%, respectively, in the construction of buildings in the 4th quarter construction of non-residential buildings increased rapidly (by 30.7%), while the volume of construction of residential buildings decreased by 9.8% [6].
According to the data of the Central Statistical Bureau, in 2017 2540 building permits for the construction, reconstruction, reconstruction and restoration of one-apartment houses for the total area of 531.1 thousand m^2 were issued, including 1948 construction permits for a new building with a total area of 395.8 thousand m^2. 202 construction permits were issued for the construction of industrial production buildings and warehouses for the total area of 336 thousand m^2. Of these, 113 construction permits were issued for new buildings with a total area of 134.7 thousand m^2. Due to the increase in the volume of construction of industrial buildings and warehouses, the issue of the quality of floors becomes more and more relevant.

Technological solutions to the problems of concrete industrial floors on the industrial ground floors in Latvia.
This research explores what makes industrial concrete floors different from ordinary concrete floors and what are the main requirements and their indicators for the quality of floors in individual countries.

Flooring depends on the design, specifications and construction technology. The flooring quality is based on a complete understanding of the requirements of use and necessity.
The essential requirements for concrete flooring are as follows:

- They must maintain their applicability according to the planned conditions;
- The floor should receive the designed static concentrated and dispersed loads without causing unacceptable deformation, cracks, joint damage;
- Position of the joints must take into account the position of the shelves and columns;
- Seam arrangement must be in line with the design layout;
- Seam and reinforcement layout should be fully protect floors against cracking;
- The floor surface must be in regular compliance with the regulatory requirements;
- Floor should be appropriately rough and chemically resistant;
- Floor finishing must be in accordance with the requirements.

In this research key attention is paid to the regularity of the surface of industrial concrete floors in accordance with requirements and quality control.
In the past, for quality control for concrete floors used only tape measures and 3 meters long lats, as well as ruler for slit size determination. Such measurements were not very precise and depended on the lighting, shading, room size, and many other factors.
Today, floors are divided into classes and each class has strict requirements for quality. A number of precise instruments for determining the quality parameters have also been developed.
Each country has its own standards for determining the floor quality [1].

Table 3

Comparison of Standards by Country

Country	For free traffic	For defined transport movement
UK and areas of UK influence	Concrete Society's Technical Report 34 (TR34) Free Movement Specification Table	Concrete Society's Technical Report 34 (TR34) Defined Movement Specification Table
USA and areas of American Influence	ASTM F-number system	The ACI F min number system
European countries	DIN 18202	DIN 15185, EN15620
Germany	DIN 18202	VDMA Guideline

Created by the authors

In the England area, the floor surface is evaluated for flatness and levelness. Typically, the surface flatness is determined at 600mm section, while the levelness is 3m margin. If materials are moved with specialized lifting equipment, the leveling is determined according to the size of the machine. The vertical deviation is allowed within ± 15 mm of an accepted or fixed zero mark.
In industrial buildings, two traffic areas are divided into floor areas: with free movement and a certain movement direction. In buildings with free transport there are no specially designated transport routes and they are production buildings with low stacks (up to 4 meters high). Buildings with a certain movement have high stacks and narrow fixed roads that are adapted to a specific size transport.
For free movement in buildings, the quality of the floor surface is determined by two parameters: levelness E and flatness F. For determining E the floor is conditionally divided into 3m long cuttings. Measurements are made with precision optical level meters at each intersection. The values of F are measured with a special digital measuring instrument in parallel with the previously marked lines.
Data analysis and tolerances: 95% value method is used, which determines that 5% of the largest deviations are rejected and 95% is evaluated.
The quality of the floor is inadequate if:

- Max of the permissible 95% values exceeds the normative;

- One of points from the E measurement is out of range ± 15mm.

Table 4

Flooring tolerances depending on their application

Floor type	Floor application	E value	F value
FM1	Very high demands on surface flatness and level. 13m without transport change	4,5	1,8
FM2	8-13m without transport change	6,5	2,0
FM3	Lower floors with 8-13 m without transport change	8,0	2,2
FM4	Lower floors where the height of the cargo is limited to 4m	10,0	2,4
	Transport shifts are designed to branch out		

Using the **Lats Method (Straightedge Method)**, the supervisor places the lats in a freely chosen direction and measures the gap between the floor and the lats with the special metal calibrators (Lenght of lats in Europe 2m, ASV-3m). The slit size is compared to the standard tolerance. Local roughness is measured with shorter ruler (in Europe - 0,2 m; US-0,3 m). In England, using the latte method, the tolerances are determined by BS EN 13670. Standard BS 8204 defines tolerances for the floor level depending on the finish of the floor support plate.

Table 5

Standarts requests to the floors levelness and flatness

Normative	Floor classification	tolerance to the level, mm	tolerance for flatness, mm
BS EN 13670	Unformed surface Flat surface	15 9	6 4
BS 8204	SR3 SR2 SR1	10 5 3	No norme
ACI 117	Usual100% 90% moderate level 100% 90% Flat100% 90%	19 13 16 10 10 6	No norme

This method is widely used because it is inexpensive, easy to understand, but has several drawbacks: difficult to measure larger floor space, difficult to obtain random results, and multiply test results.Therefore, less labor-intensive and more sophisticated measurement technologies, such as the F-Number method, Terrestrial Laser Scanning (TLS), BIM quality control, have been developed.

The US and its impact countries use the ASTM F-Number System. (F Number systems) The ASTM E-1155 test method results in measurements of a plurality of floor surfaces, from which the floor surface flatness F_F and levelness F_L are statically calculated [2].

Table 6

Floor surface classification	General flatness SOF_F	General plain SOF_L
Normal	20	15
Moderately smooth	25	20
Smooth	35	25
Very smooth	45	35
Excellent smooth	60	40

F numeric meter F Speed Reader moves through the floor between start and stop points and collects data digitally [15]. Such measurements carrie out on the entire intended floor. Data is entered on a computer and processed by the F Speed Reader program. The computer performs a survey analysis and generates general and local F numbers, as well as summarizes the table.

Terrestrial Laser Scanning (TLS) is a new measurement technology the Laser Camera moves through the surface of the measuring floor and, with laser light, obtains accurate data in 3D dimensions at high speeds. The scanner inputs data into the data cloud, from which you can obtain specific sizes, visualizations, and save valuable information. Also, the results obtained are not consistent with current standards. According to scientists, this method is not yet fully suitable for floor quality control [3].

BIM quality control. BIM is a smart digital model-based process for designing and managing building and infrastructure construction. Control takes place at two levels: firstly at the level of specifications. In England, the BIM model is closely linked to the NBS (National British Standard). Consequently, the user of the program specifies the type of floor, for example, the concrete floor and indicates a specific NBS. The specification automatically displays all the requirements for execution and tolerances for this floor type. All BIM users, both contractors and control bodies, receive precise specifications for a particular site on a specific construction site.

Secondly, the BIM model with integrated specifications ensures effective and good quality control. English authors present the experience that using the 4D BIM model with integrated specifications, the program automatically creates a list of construction components that should be controlled at each stage of construction. A control plan and controller equipment are prepared. Real measurements on a construction site are automatically compared with specifications and certain deviations.

Technology for obtaining excellent industrial building floor quality

By working with hands, the coarse bending of concrete can be done with a rake, but smooth alignment with the aluminum surface lining. In Latvia, the specialized equipment for aligning concrete "Laserscreed technology" is being used more and more.

The production of the product was based on the demand growth for high quality requirements for the level and flatness of the concrete floor surface. The machine alignment mechanism is equipped with a laser using 3-dimensional profiling system. Concrete insertion takes place with special wings. The vibrating and leveling of the concrete surface is carried out with the aluminum vibro lats installed in the unit. This technology is fast, high precision and high productivity, reaching up to 20m^2 flattened surface per minute. Consequently, one day a large-size warehouse floor can be built and construction deadlines can be significantly shortened. One of these devices is shown in Figure 1.

Fig.1 „Laserscreed" Insertion technology [16]

Surface quality measurements

At the end of 2017, concrete floor surface quality measurements were carried out in a public building in the Vidzeme region, Latvia. The total building area is 3048.2m^2. Concrete floor surface quality measurements were made in a trading hall with a total area of 2458.0m^2. The data obtained and calculated are summarized in 4 graphs. Concrete additions to this site were carried out using comparatively traditional methods, that is, using a concrete pump. Concreting was done with self-made scaling using human hand work, such as garden rakes and aluminum lats. Concrete in the construction site is delivered with a concrete mixer from a concrete production unit. The concrete grade used is C25/30 with blended steel fibers. The amount of steel fiber per 1m^3 of concrete is 20kg. The total thickness of the concrete floor is 100mm. The built-in floor structure is based on 300mm thick thickened sand layers, 150mm thick densified dolomite chips, 100mm thick extruded polystyrene and 200μ thick PVC waterproofing.

Figure 2 shows the levelness measurement device. It is a laser leveler and lata laser detector. According to the standard floor surface flatness mesurment technology, according to the British technical report, a floor surface survey plan has been drawn up and a relative mark has been determined from which measurements have been made. A measurement grid is designed to measure the floor surface in steps of 3.0m * 3.0m and measurements at intersection points of the network axis [12].

For measurement of surface flatness, according to the British technical report, the measurement value is 1/10 of the total area of the floor. In our case, the required level of flatness of the floor surface is 2458.0 / 10 = 245.8 t / m. Using a surface levelness measurement network, the number of measurements is sufficient if we use each second measurement network in each direction, it is every ~ 6.0m, which collects 360.0 t / m or 16.6% of the total surface area of the floor.

To measure the plain we used 3.0m long aluminum lata [12] and Wurth electronic caliper, as well as pencil and paper for recording. Figure 3 shows a device for measuring the surface flatness of the floor.

The results of the experiment, the surface plain, the obtained data graphically depicted in Figures 4 and 5. Figure 4 shows the curve when measured in the longitudinal direction of the building, while in Figure 5, when measurements are made in the building transverse. The curves shown in Figures 4 and 5 clearly show us the maximum and minimum values obtained as a result of the calculation, which is within ± 15mm. The values obtained are consistent with the standard floor usage. By eliminating the data obtained in the largest calculations up to a 95% limit [8]; [17], it is obtained that the maximum surface irregularity in both the longitudinal and transverse directions is within an acceptable range of 9.0mm.

Fig.2, Floor levelness measuring equipment (photo by M.Pavars).

Fig.3, Floor flatness measuring equipment (photo by M.Pavars).

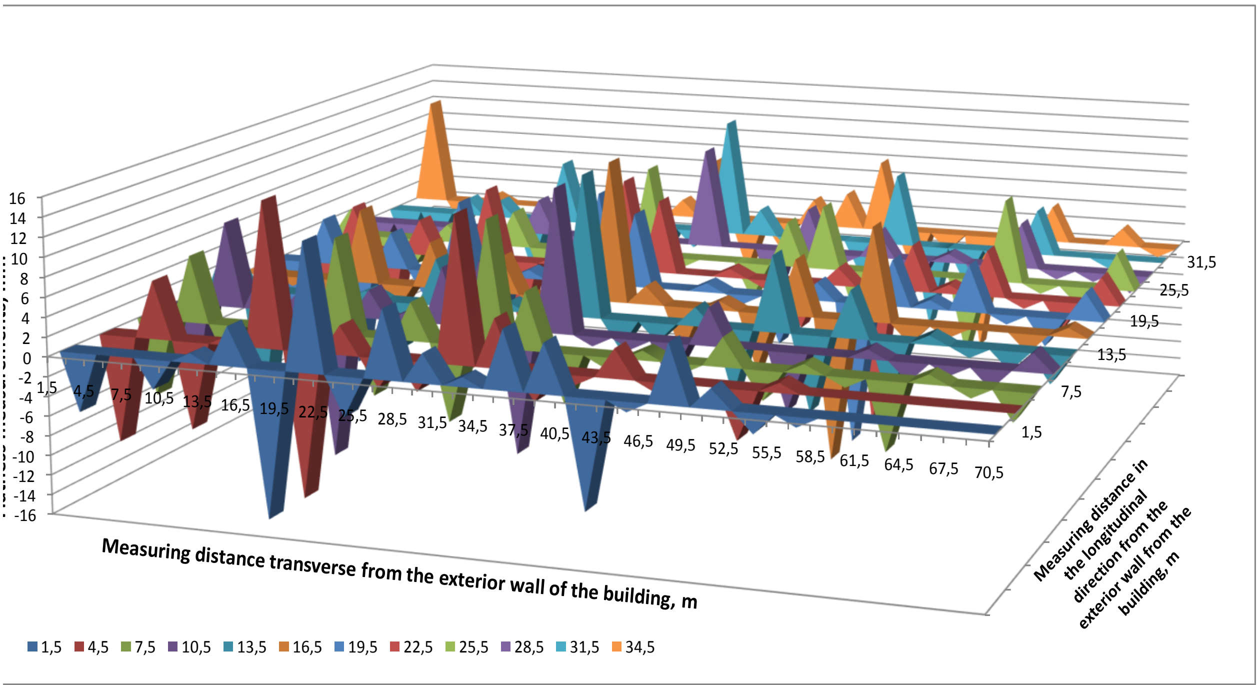


Fig.4, Graphic representation of the floor surface levelness in the longitudinal direction of the building (graph by M.Pavars).

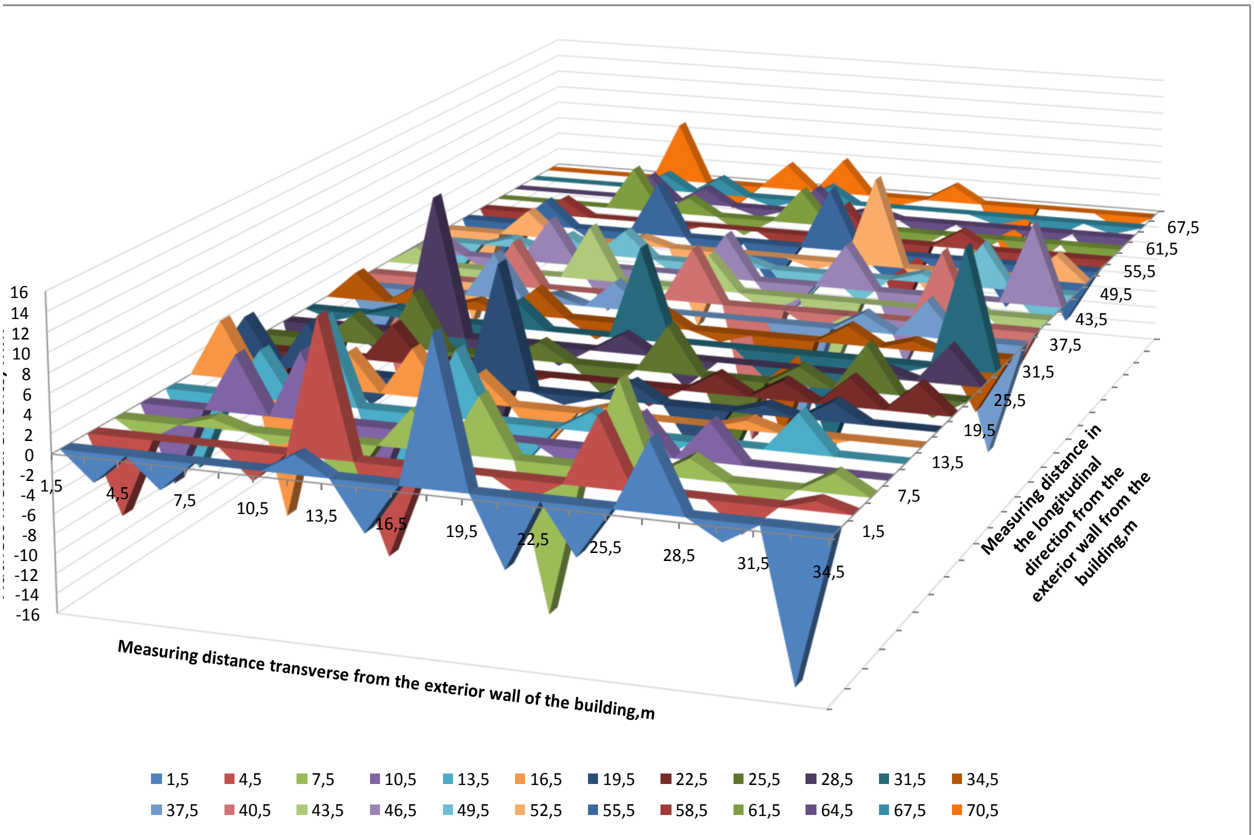


Fig.5, Graphic representation of the floor surface levelness in the transverse direction of the building (graph by M.Pavars).

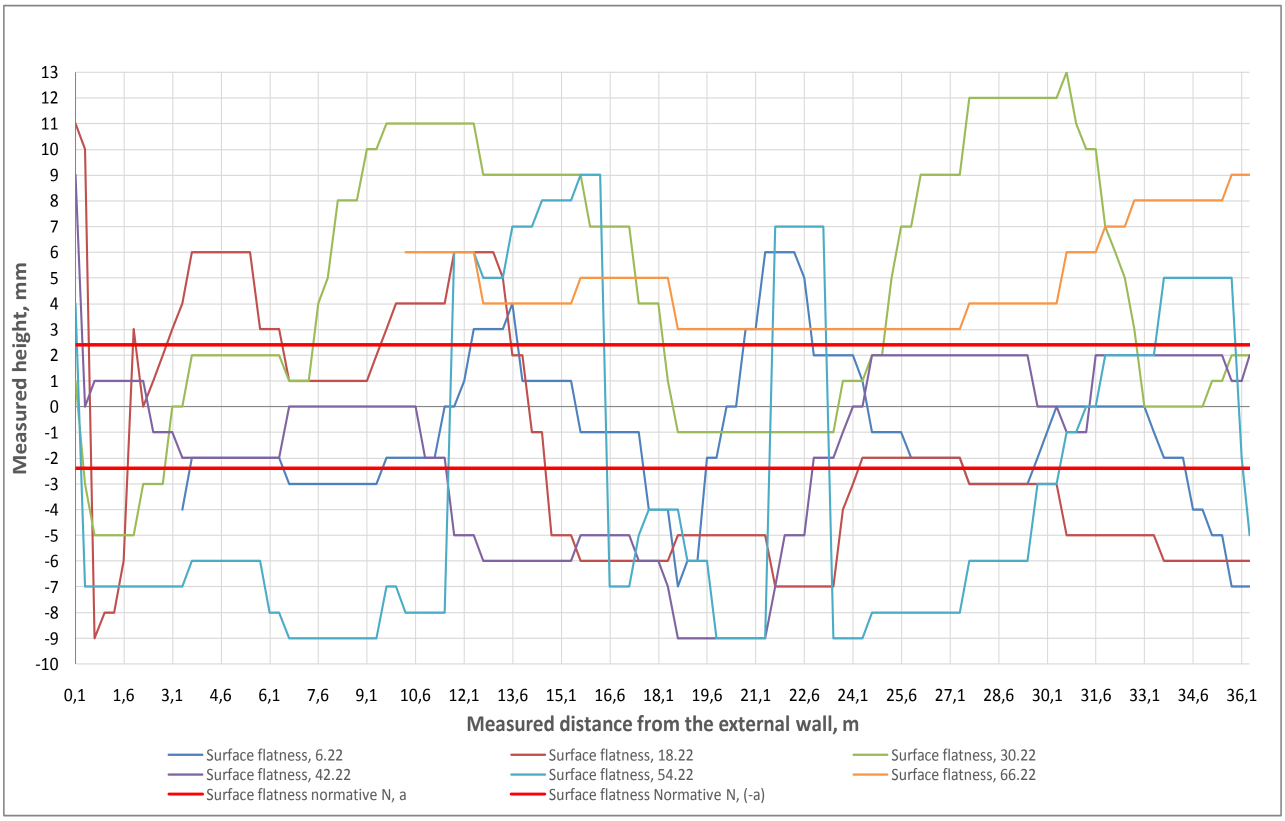


Fig.6, Graphic representation of the floor surface flatness measured in the transverse direction of the building (graph by M.Pavars)

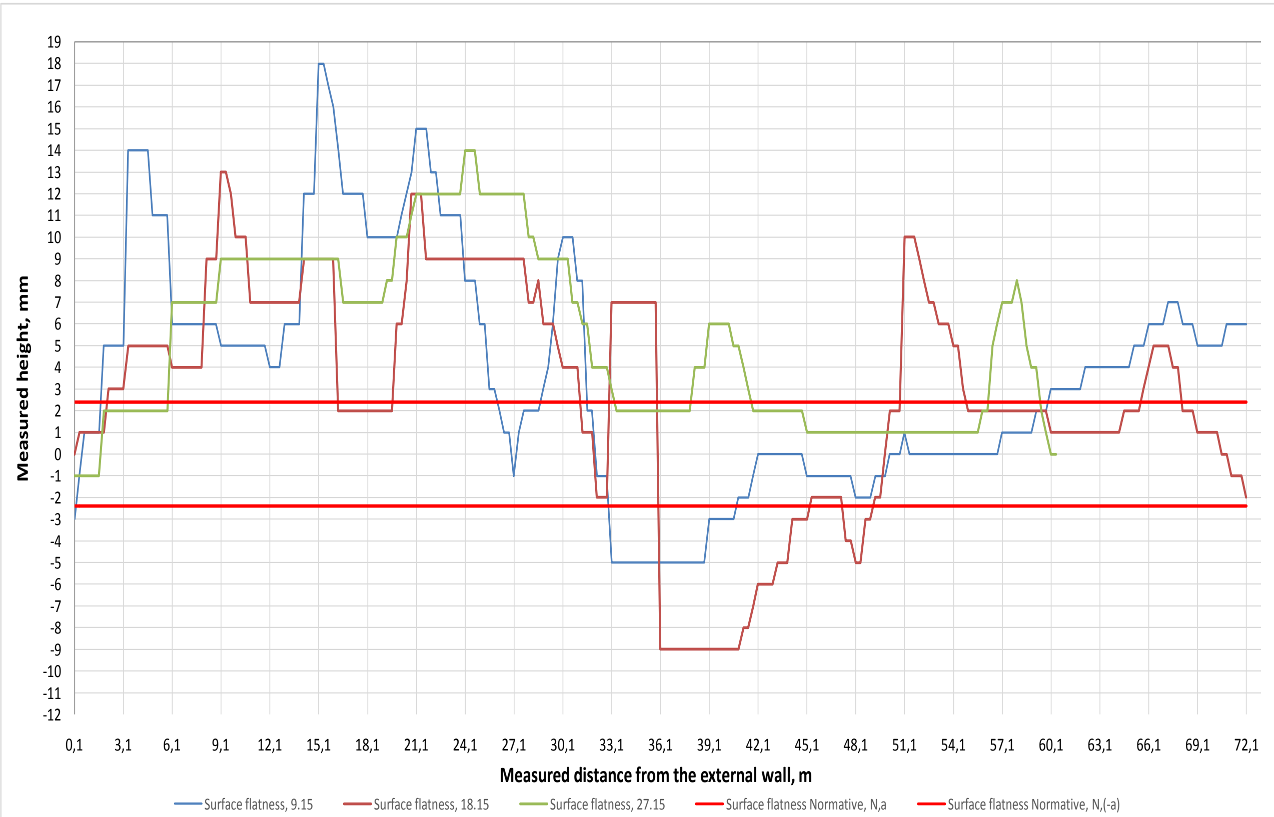


Fig.7, Graphic representation of the floor surface flatness measured in the longitudinal direction of the building (graph by M.Pavars)

Conclusions

With the concrete leveling technology used in this facility, it is not possible to obtain a standard floor surface maturity, while the surface plain is at a critical boundary reaching the maximum values specified in the Standard.

Responsible designers should, in the design process, include standard requirements for the floor use.

For Latvian buisnesmans engaged in the construction of concrete floors, think about the use of advanced technologies in their operation, such as „Laserscreed” installation equipment.

In Latvia it would be necessary, at the national level to develop appropriate standards for determining the quality of surfaces of industrial concrete floors.

References

[1] ACI 117 ACI 302-1 https://laticrete.com/ (Date accessed: 16.02.2018)

[2] ASTM F Number System https://face-consultants.com/ (Date accessed: 19.02.2018)

[3] Face Consultants LTD Global flooring consultants https://face-consultants.com/ (Date accessed: 19.02.2018)

[4] Technical Report 34 Concrete Industrial Ground Floors - Fourth Edition A guide to design and construction Publish by The Concrete Society https://concretebookshop.com/ (Date accessed: 19.02.2018)

[5] Frederic Bosche, Emeline Guenet: Automating surface flatness control using terrestrial laser scanning and building information models, School of the Built Environment, Heriot-Watt University, EH14 4AS Edinburgh, UK, 2014 https://sciencedirect.com/ (Date accessed: 23.02.2018)

[6] Central Statistical Bureau of Latvia. [online]. Available at: http://www.csb.gov.lv/statistikas-temas/buvnieciba-galvenie-raditaji-30294.html (Date accessed: 20.02.2018)

[7] Central Statistical Bureau of Latvia. [online]. Available at: http://www.csb.gov.lv/statistikas-temas/buvnieciba-galvenie-raditaji-30294.html (Date accessed: 20.02.2018)

[8] Giuseppe Loprencipe, Giuseppe Cantisani: Evaluation methods for improving surface geometry of concrete floors: A case study. Sapienza University of Rome, 2015. p. 19 https://sciencedirect.com/ (Date accessed: 23.02.2018)

[9] Gusta, Sandra. Sustainable construction in Latvia – opportunities and challenges/Sandra Gusta//15th International scientific conference "Engineering for rural development": proceedings, Jelgava, Latvia, May 25 - 27, 2016 [elektroniskais resurss] / Latvia University of Agriculture. Faculty of Engineering. Jelgava, 2016. Vol.15, p. 1291-1299, URL: http://tf.llu.lv/conference/proceedings2016/Papers/N260.pdf, URL:

[10] Gusta S. Building as long-term environmental development and preservation condition Civil engineering '11: 3rd International scientific conference: proceedings, Jelgava, Latvia, 12-13 May, 2011. Latvia University of Agriculture. Faculty of Rural Engineering. Department of Architecture and Building. Department of Structural Engineering. Jelgava, 2011. Vol.3, pp. 256.-262. [online] [12.02.2016]. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84866326998&partnerID=40&md5=25078de9c878077725d64adbc526b4db

[11] HardikLokhandwala, Prof. Jayeshkumar Pitroda, Prof. J.J.Bhavsar Laserscreed technology: An opportunity to ease in construction sector http://researchgate.net/ (Date accessed: 15.01.2018)

[12] DIN 18202 https://conwest.ru (Date accessed: 31.01.2018)

[13] Floor Flatness (F_F) and Floor Levelness (F_L) https://laticrete.com/ (Date accessed: 31.01.2018)

[14] 2017.gadā būvniecības apjomi nozīmīgi pieauga [online] Available at: https://www.em.gov.lv/lv/nozarespolitika/buvnieciba/statistikapetijumi/ (Date accessed: 10.01.2018)

[15] Information on http://www.allenface.com (Date accessed: 15.01.2018)

[16] Information on http://burgessconcrete.com (Date accessed: 26.02.2018)

[17] Information on www.elsevier.com/locate/autcon (Date accessed: 15.01.2018)
[18] Information on www.researchgate.net/publications (Date accessed: 15.01.2018)
[19] Information on https://www.scopus.com/inward/record.uri?eid=2-s2.0-84976540070&partnerID=40&md5=ebf1ce7afa229966c6bb7e95e23b5a47 (Date accessed: 15.01.2018)
[20] Information on http://www.icosados.com (Date accessed: 12.03.2018)

Proceedings of the 8th International Conference on Safety and Durability of Structures
ICOSADOS 2018
May 23 - 25, 2018, LLU, Latvia

PHYSICAL AND MECHANICAL PROPERTIES OF PARTICLEBOARD *P4* DEPENDING ON MOISTURE CONTENT

Regino Kask[1a], Harri Lille[1b], Jaanus Ljahov and Aleksander Rebane

[1a,b]Institute of Forestry and Rural Engineering, Estonian University of Life Sciences, Tartu, [a]email:Regino.Kask@emu.ee, [b]e-mail: hlille@ emu.ee

Keywords: Particleboard, modulus of rupture, modulus of elasticity, static hardness, thickness swelling, linear expansion

Introduction

Strand type composite panels such as particleboard is one of the wood based engineering products, which is most commonly used for cladding of wall and ceiling indoors or outdoors, as a floor decking material and wind barrier. The particleboard panel as a wood-based sheet is a hygroscopic material and its mechanical and physical properties depend on its moisture content and on surrounding temperature. This type of material is also applied for structural purposes in load bearing structures as rigidity material only for use in dry conditions (e.g. *P4* (EVS-EN 312:2010 [1]). Test methods determined by the European Standard (EN) were applied to study changes in modulus of rupture (MOR), modulus of elasticity (MOE) at bending, thickness swelling (TS), linear expansion (LE) and Janka hardness (JH) at different moisture contents. Changes in MOR, MOE, JH, TS and LE for different soaking times were investigated in a Master's thesis [2, 3].

The basic method involves soaking of specimens in water for a controlled period of time (2; 4; 6; 8; 16 and 24 hours), at room temperature (22±1°C), and testing them after pre-treatment in water with the universal test machine INSTRON 3369; drying (48 hours) of specimens in a ventilated drying box at 65±1°C, in order to determine moisture content. These procedures are followed by output of data and analysis of obtained results. The sensitivity of the measured data was studied and the expanded uncertainties of the computed mean values are presented.

A logarithmic function was used for approximation of the change in the physical and mechanical properties of the samples depending on their moisture content.

Experimental procedure and method

Four commercial of 2600×1200×22 mm panels made of particleboard *P4* (EVS-EN 312:2010 [1]).

The MOR and MOE at bending were found by three point bending using the test machine INSTRON 3369 (Fig. 1a). Deflection for calculating MOE was measured by an optical gauge (Advanced Video Extensometer 2663-821). The test bending specimens with dimensions (490×50×22 mm) were cut in different directions from the board: one half of them in the longitudinal ∥ direction (lengthwise) and the other half in the transversal ⊥ direction (crosswise). Experiments were made with 18 series (minimum number of specimens in a series was twelve).

a) b)

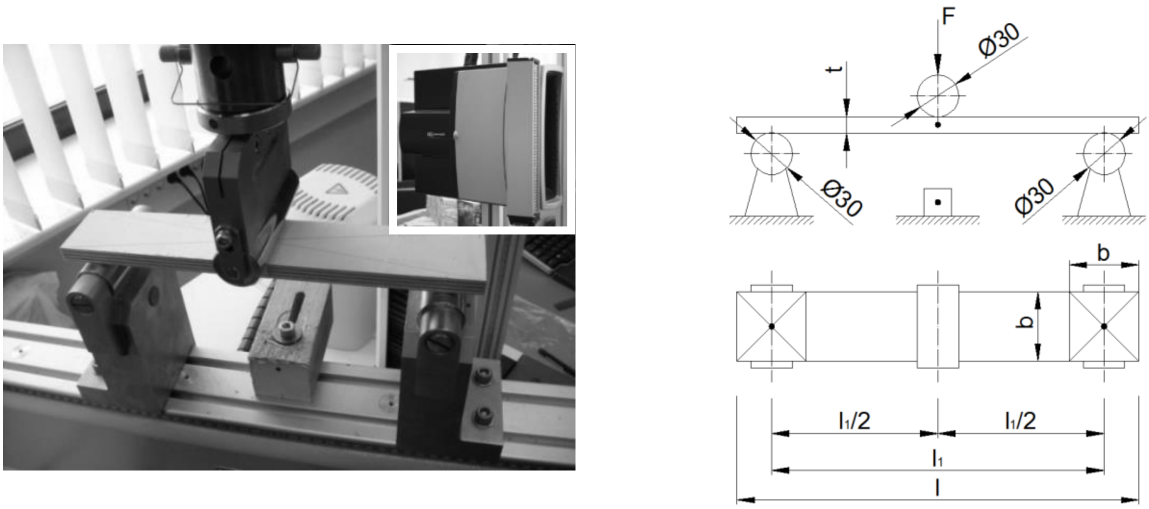


Figure 1. Three point bending and the points of deflection measurement: a) photo, an advanced video extensometer is in the upper right corner, b) scheme, l_1 = 440 mm.

The dimensions, length, width and thickness of the specimens extracted from the panels were measured using the calliper Preisser RS-232 with an accuracy of 0.01 mm, and a digital calliper and a micrometer gauge with an accuracy of 0.001 mm; the mass of the samples was measured by the electrical balance Kern EW 220-3NM with an accuracy of 0.01 g. The specimens of the first series were dried (48 hours) in a ventilated drying box at 65 ± 1°C to a moisture content of 0 %. The test specimens of the second series were tested at a moisture content of 5.1 and 8.7 % (purvey dry). The other remaining test specimens were placed in a tank with cold water (22±1°C) for 2, 4, 6, 8, 16 and 24 hours. Before testing, the specimens were conditioned in a climatic chamber at a relative humidity of 65 % at 21°C. Moisture content was determined using a weighing method according to the EVS-EN 322:2002 [4] standard and was 20.7, 31.2, 35.4, 40.0, 48.0 and 53.0 %, respectively, depending on soaking time.

All specimens were tested, following three point bending, with the use of the computer-controlled mechanically actuated universal testing machine Instron 3369. Deflection for calculating the modulus of elasticity was measured by an optical gauge (Advanced Video Extensometer 2663-821). A force was applied at constant speed so that failure occurred in 60±30 seconds (700 N/min).

Standard EVS-EN 310:2002 [5] was applied to evaluate MOR and MOE, through bending deflexion, in the longitudinal ‖ direction and transversal ⊥ direction of the specimens and calculated according to EVS-EN 310:2002. Calculation of the uncertainty of the measurements was done according to EVS-EN 326-1:2002 (at a confidence level of 95 %) [6].

The parameters of dimensional stability were determined before the bending test: TS according to EVS-EN 317:2000 [7] in the middle zone of the specimens (see Fig.1b) and for LE the length of specimen was measured on centreline bilaterally. The JH was determined in the middle of the end area (50×50 mm) of the specimens (see Fig. 1b) before the bending test in accordance with ISO 13061-12 [8]. The following analytical function was used to approximate the obtained experimental data for the investigated properties, depending on the number of the soaking/oven-drying cycles [2, 3].

$$y(x) = y_0 \cdot e^{-(a \cdot x)^2} \quad (1); \qquad y(x) = y_f \cdot e^{\left(\frac{-a}{x^2}\right)} \quad (2),$$

where y_0 is the calculated initial values of parameter (x = 0), y_f is the final value of parameter (x →1); x is moisture content (fibre saturation point + free water), in these formulae a proportionate part of total; and a is a constant. The initial and final values of the properties and the constant should be determined so that the measured experimental data are approximated in the best way by minimizing the square of error (least squares regression). This problem was solved by using the program *Mathcad 15.0* with the regression function *genfit(vx,vy,vg,F)*. The formulae (1; 2) allowed predict to a certain extent the mechanical and physical properties of the specimens when a limited number of values of their moisture content were known.

Results

The obtained MOR, MOE are presented in Fig. 2 and Fig. 3, respectively. The mean values of the experimental data for one series, approximated by formula 1, are presented.

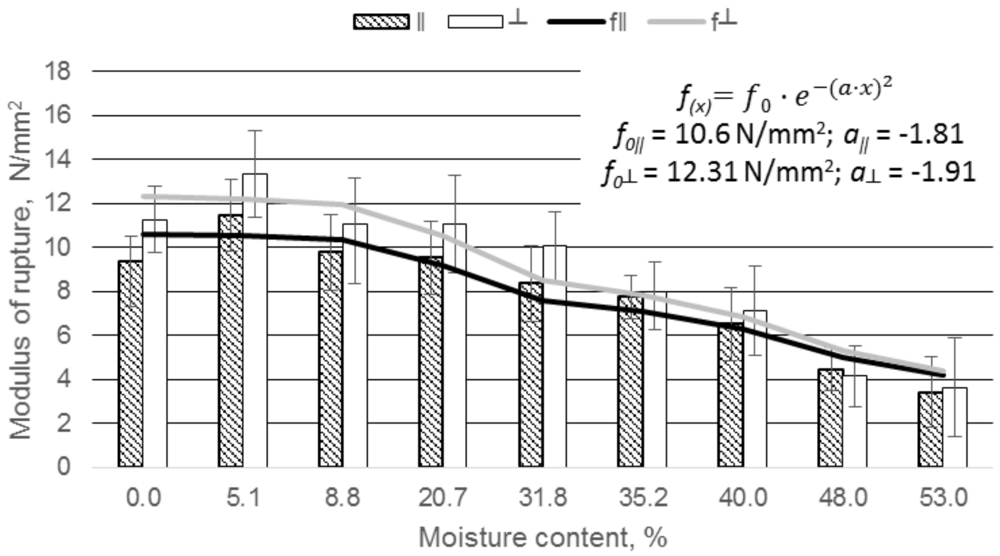


Figure 2. MOR depending on moisture content and the curve of approximation.

Two hours of soaking did not practically reduce the bending strength of the specimens. At a moisture content of 0 %, the strength could be reduced as the volume of timber was decreasing and cavities were forming in the matrix. The properties of the specimens decreased most intensively at soaking between 4 h and 24 h: ‖MOR from 7.71 N/mm^2 to 4.06 N/mm^2 and ⊥MOR from 8.63 N/mm^2 to 4.41 N/mm^2; ‖MOE from 1313 N/mm^2 to 589 N/mm^2 and ⊥MOE from 1633 N/mm^2 to 772 N/mm^2. MOE decreased significantly even at a slight increase of moisture content. The same was noted for TS and JH see (Fig.4 and Fig. 6).

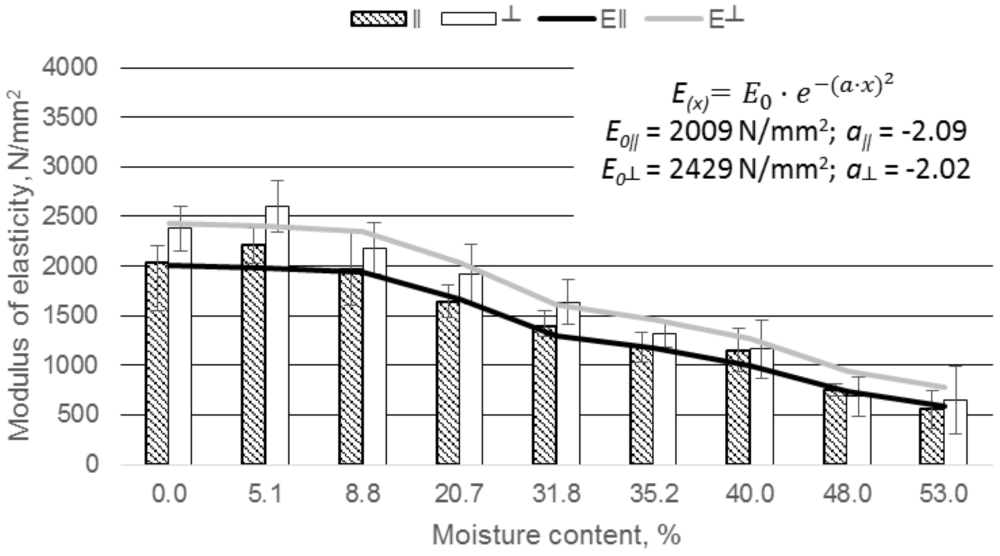


Figure 3. MOE depending on moisture content and the curves of approximation.

There was practically no difference in the results of MOR and MOE in case the specimens were cut from the board in the parallel or in the transversal direction. The values of the other properties were similar.

The mean values of dimensions changes parameters TS and LE are presented in Fig. 4 and Fig. 5, respectively. They parameters are approximated by formula 2.

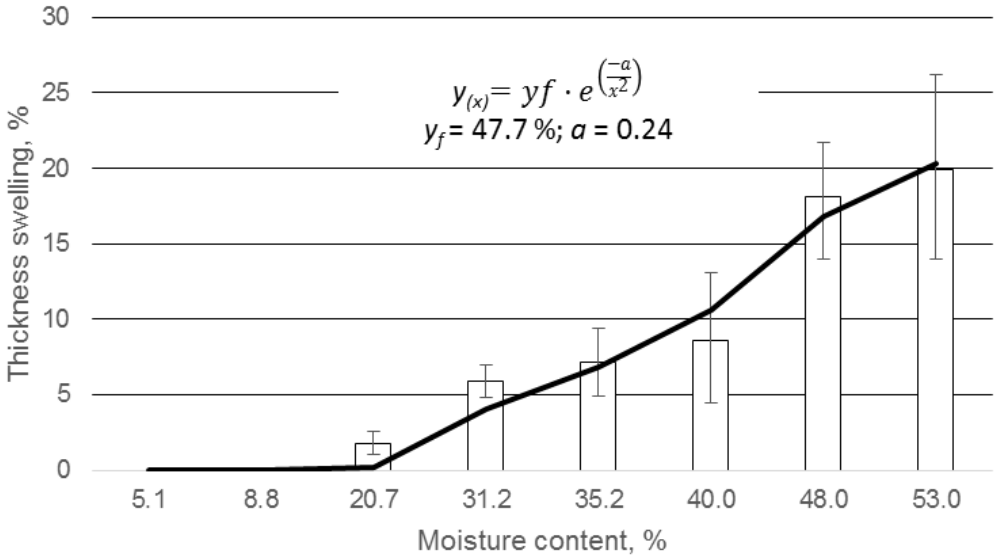


Figure 4. TS, depending on moisture content, in the end zone of the sample and the curve of approximation.

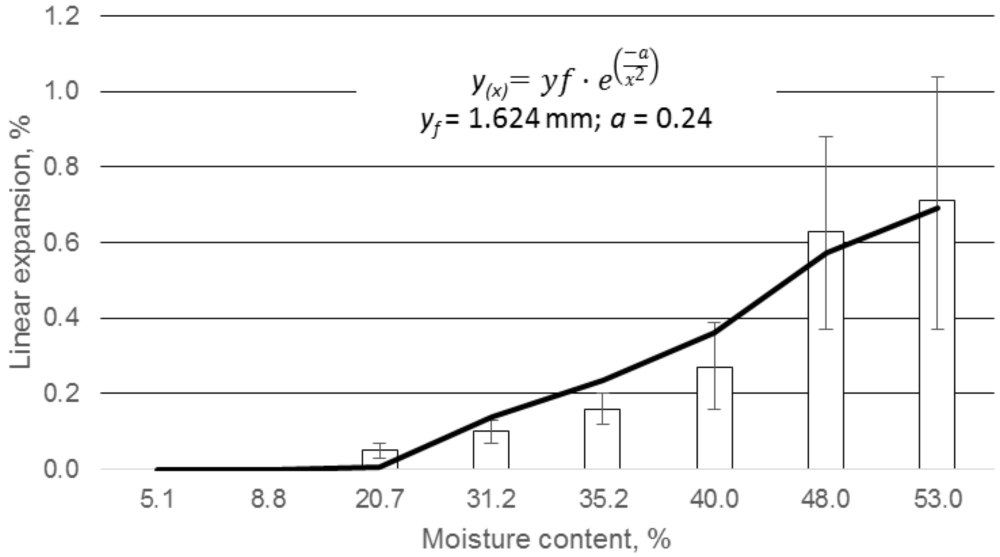


Figure 5. LE, depending on moisture content, measured in the longitudinal direction of the sample and the curve of approximation.

TS of the specimens for the 4 h and 24 h water soaking tests ranged from 4.44 % to 20.3 % and LE ranged from 0.15 % to 0.69 %. The change in dimensions intensified significantly when the samples were soaked longer than 4 h. Then obviously, the fibre saturation point is reached (about 30 % [9]) at which the total amount of water is present within cell wall is exceeded and the moisture content of specimens increases at the expense of free water.

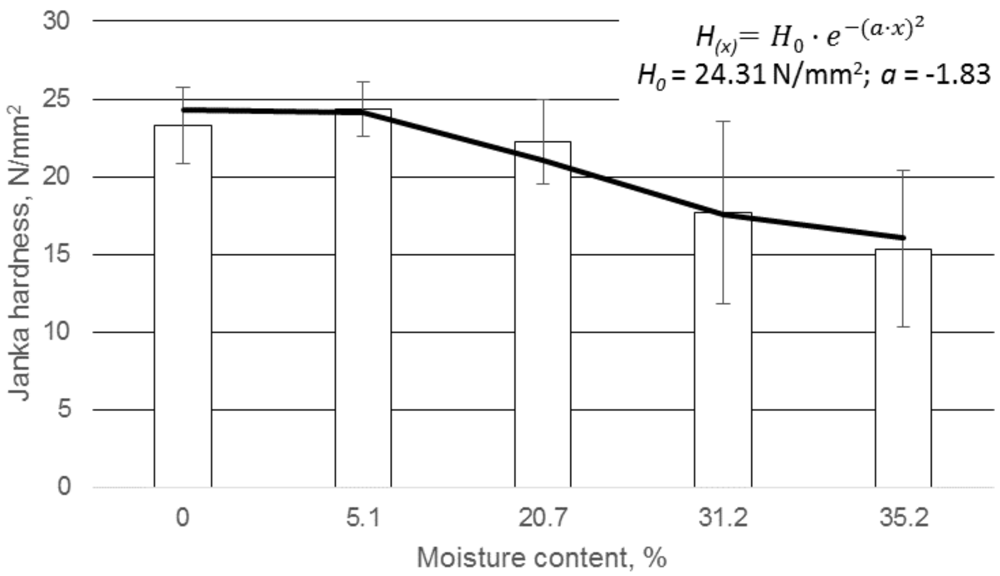


Figure 6. JH, depending on moisture content, measured in the end zone of sample and the curve of approximation.

The values of JH decreased similarly to the values of MOR and after 2 h of soaking u they decreased from 24.3 N/mm^2 to 21.1 N/mm^2.

IT is evident that the proposed analytical formulae (1; 2) approximated the experimental data satisfactorily.

Conclusions

The investigated properties were affected by soaking time (2; 4; 6; 8; 16 and 24 hours), at every measured moisture content, their values decreased significantly: MOR and MOE more than three and four times, respectively, irrespective of the fact if the specimens were cut from the test board in the longitudinal or in the transversal direction.

The investigated properties of the test specimens changed significantly starting from 4 h (moisture content 31.2 % up to the fibre saturation point): ǁMOR from 7.71 N/mm^2 to 4.06 N/mm^2; ǁMOE from 1313 N/mm^2 to 589 N/mm^2 and, in particular TS, from 4.05 % to 20.3 % and LE from 0.14 % to 0.69 %.

An analytical function is proposed for approximation of experimental data, which allows, in the case of limited experimental data, to predict the investigated properties depending on moisture content.

The presented analysis is limited to the data obtained from the above described experiments.

Acknowledgement

We would like to express our gratitude to Ms. Ester Jaigma for linguistic help with this paper.

References

[1] EVS-EN 312-2010 Puitlaastplaadid. Spetsifikaadid. Particleboards. Specifications. Tallinn: Eesti Standardikeskus. 20 p. (in Estonian).

[2] Jaanus Ljahov. Particleboard`S Physico-Mechanical Properties on Water Content. 2007. Master's Thesis, Estonian University of Life Sciences, Estonia/Tartu. 83 p. (in Estonian).

[3] Aleksander Rebane**.** Particleboard´s Dependence of Physical and Mechanical Properties on Humidity. 2008. Master's Thesis, Estonian University of Life Sciences, Estonia/Tartu. 87p. (in Estonian).

[4] EVS-EN 322:2002 Puitplaadid. Niiskussisalduse määramine: Wood-based panels – Determination of moisture content. Tallinn: Eesti Standardikeskus. 9 p. (in Estonian).

[5] EVS-EN 310:2002 Puitplaadid. Paindeelastsusmooduli ja paindetugevuse määramine: Particleboard. Determination of modulus of elasticity and bending strength. Tallinn: Eesti Standardikeskus. 7p. (in Estonian).

[6] EVS-EN 326-1:2002. Puitplaadid. Plaatide mõõtmete määramine. Osa 1: Paksuse, laiuse ja pikkuse määramine.Wood-based panels. Sampling, cutting and inspection. Part 1: Sampling and cutting of test pieces and expression of results. Tallinn: Eesti Standardikeskus. 14 p. (in Estonian).

[7] EVS-EN 317:2000 Puitlaastplaadid ja puitkiudplaadid. Pundumise määramine paksuses pärast leotamist: Particleboards and fibreboards. Determination of swelling in thickness after immersion in water. Tallinn: Eesti Standardikeskus. 10 p. (in Estonian).

[8] ISO 13061-12 Physical and mechanical properties of wood. Test methods for small clear wood specimens. Part 12: Determination of static hardness (Switzerland: International Organization for Standardization). 10 p.

[9] Salim Hiziroglu. Dimensional Changes in Wood. Oklahoma Cooperative Extension Service. 4 p. http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Rendition-3624

Proceedings of the 8th International Conference on Safety and Durability of Structures
ICOSADOS 2018
May 23 - 25, 2018, LLU, Latvia

RECONSTRUCTION OF "THE CASTLE HOUSE" IN LAMEGO

Carla Teixeira[1,a], António Moutinho[2,b] and Isabel Bentes[3,c]

[1]Atelier, Praceta do Coura,13, 5100-218 Lamego, Portugal

[2]Civil Engineering Student of UTAD, Vila Real, Portugal

[3]Associate Professor of UTAD, Centre of Materials and Building Technologies UBI/UTAD, Vila Real, Portugal

[a]carlateixeira83@gmail.com, [b]antonio_moutinho@hotmail.com, [c]ibentes@utad.pt

Keywords: housing, reconstruction, heritage

Introduction

The recent economic crisis has decreased the rhythm of new housing construction in Portugal but during the last forty years, especially in the eighties and nineties there was a large increase of new housing construction.
According to the National Statistical Institute of Portugal [1], in 2011, the number of existing houses in Portugal was 45% higher than the number of families, corresponding to approximately 1.8 million of housing units in excess. These excess dwellings correspond to second homes or vacant houses, usually in poor condition and located in the historical areas of the cities.
To safeguard the identity of historic centers and the built heritage is urgent to rebuild these buildings.
Since most of these buildings are private, rehabilitation has to be done by the owners involving, usually, higher investments than to new housing. However, according to the authors [2] [3], if the economic and the environmental factors are considered, the reconstruction may be the most interesting option.
This increase of costs is due to demolitions but it is also related to the difficult accessibility of materials to the works (in general narrow streets and often rugged topography), the difficulty in setting up the construction site and the conditions imposed by the municipalities' plans, obliging to maintain the facades and the use of traditional materials, among others. It is an high-risk investment since, in addition to the high investment, there are constraints related with very restricted potential market because most of these houses have very small areas and no garages.
Therefore, the architecture solutions must be very versatile, concerning the study of the spaces in order to increase the range of potential clients; otherwise, they may become uninteresting investments.
Thus, this work aims to present a case study of a small house building located in the historic area of Lamego city, in Portugal. The proposed solution was designed for tourist accommodation or, in

alternative, to sale or rent to youth or couples without children, which prefer small spaces in the center of the city. Besides a brief description of the existing house, it is intended to emphasize architectural rehabilitation design, the costs of intervention and the technical challenges to be faced.

Case Study

Context

The building object of this case study is located in the city of Lamego, in the urban zone inside the walls of the castle, Fig. 1a) and b).

a)Picture b) Plant

Figure 1- The castle house location

Lamego is considered the cultural capital of the Douro, which was the first demarcated wine region in the world and classified by UNESCO as a world heritage site, Fig. 2.

Figure 2- Douro wine region, world heritage

Lamego is the cultural capital of the Douro due its high cultural and built heritage since it is a city that had a great political importance (where the first king of Portugal was acclaimed), economic (linked mainly to the production and trade of wine in special Port wine) and religious (it was the first diocese of the country). It has a large built heritage much of them connected to the church and nobility. Because of its high constructive quality much of this heritage resisted over the years.

In this context, the city of Lamego has some old building nucleus needed urgent preservation and the municipality delimited seven priority zones of intervention, Fig. 3.

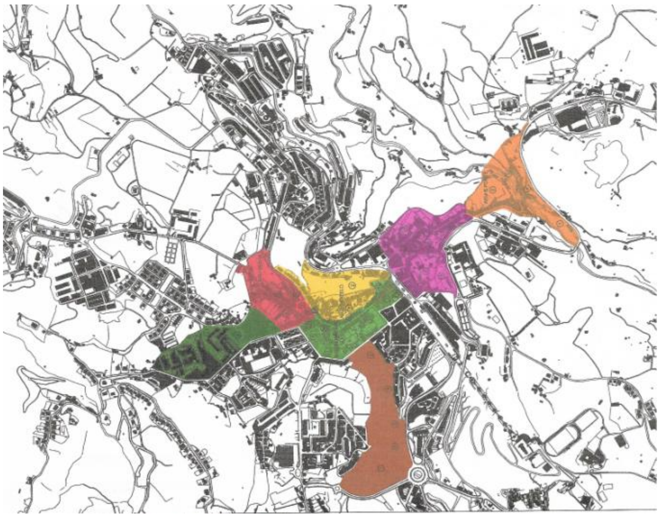


Figure 3- Priority zones of rehabilitation [4]

One of these nuclei is the castle zone where the "Castle House" is included. The houses of this urban nucleus are, in the great majority, houses of a very simple architecture, with a small area of implantation without great constructive quality.

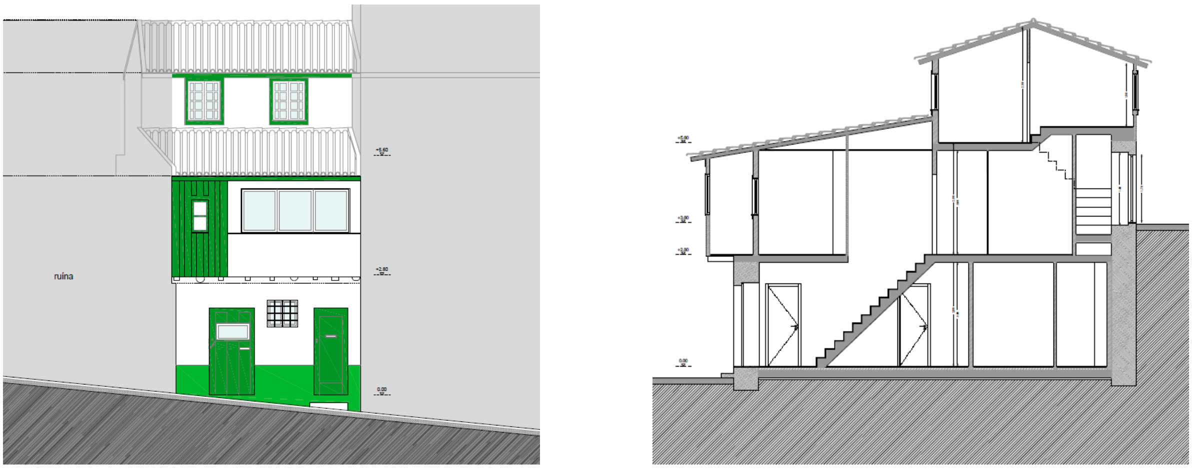
Architectural Solutions Considered

“The Castle House " is a small house with 55m^2 of implantation, very simple architecture, without great constructive quality in ruin except the facades, Fig. 4 a) and b) but very important in the urban set.

a) North elevation b) South elevation

Figure 4 – “The Castle House” north and south elevations

The building has three floors, the ground floor and the first floor communicating internally through stairs, with entrance by the north elevation. The second floor, with smaller area, has entrance by the south elevation through a doorway with 1,70m, only. The south elevation in ground and 1st floor levels are totally and partially buried, respectively, presenting no air or natural light entrance. This south elevation at the ground and 1st floor levels is one of the castle stone walls that work, in this case, as a support wall and building wall, Fig. 5.



a)North elevation b)Transversal cut

Figure 5- North elevation and transversal cut

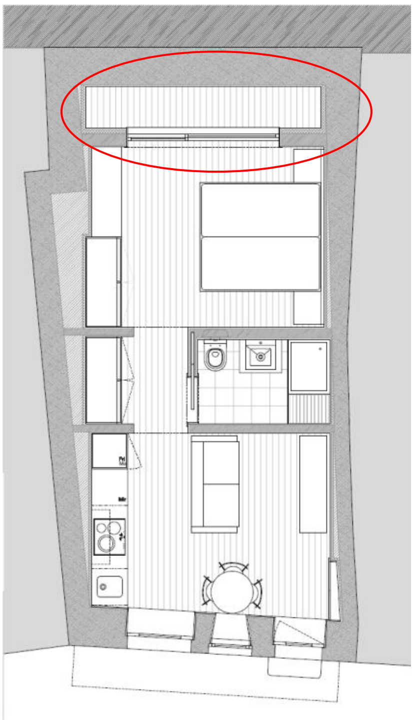
It is intended that this building will be rehabilitated for touristic accommodation, providing for three small apartments, one in each floor and each one with one bedroom.

"The Castle House" is part of a consolidated area which, although degraded, presents morphological, architectural and environmental characteristics that it is important to preserve. As such, it is proposed to maintain existing exterior spans and to promote the preservation of facades preserving previous historical framework. The main concern of the municipality is the integral maintenance of the façades, which can only be changed under very particular conditions to overcome constraints like function, health and comfort currently required in a dwelling.

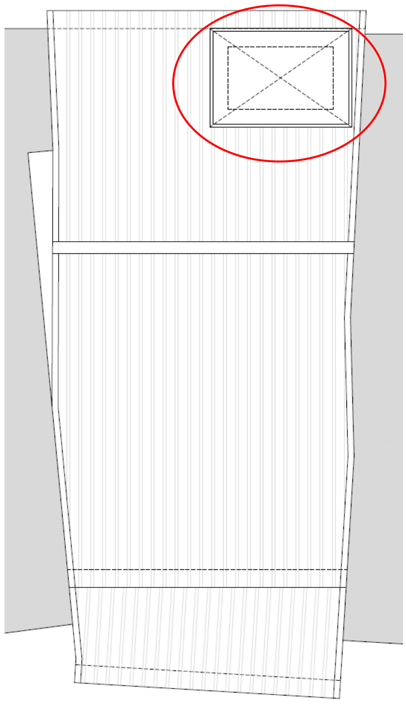
In this sense, the main constraints placed at the architectural level in this project were:

- The lack of natural lighting and ventilation at the ground floor and the first floor, in the southern elevation;
- The needed to maximize the use of the space because of the small implementation area, but in order to have a viable investment;
- The compatibility between the facades maintenance and the space valorization concerning functionality, wholesomeness and comfort;
- Maintenance of the building height due the existence of two small windows in the nascent elevation of the neighboring dwelling.

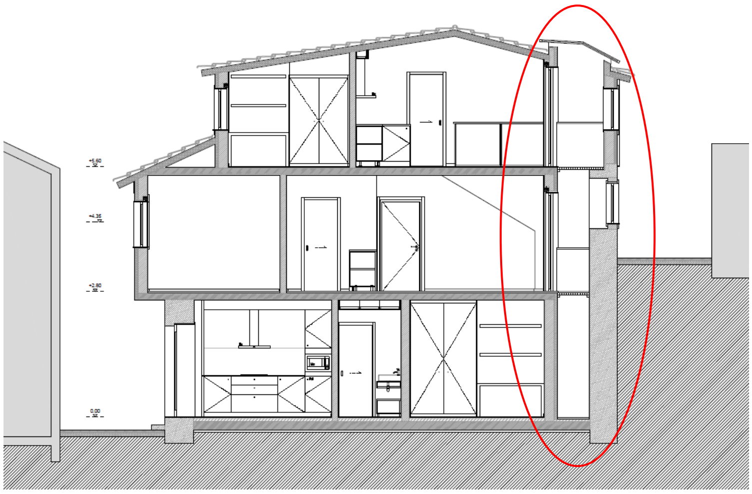
In order to be able to have ventilation and natural light in the ground floor and on the first floor, without losing too much area, a wall was created 0.70 m distance from the castle wall in the south elevation. It works as an exterior wall and in the coverage is planned to open a ventilated skylight. The stone wall of the castle could be seen from inside the house working as a decorative element that, in the context of a historic element, also values de dwelling. This space works like a ventilation and lightening column, Fig. 6.



a) Ground floor design



b) Coverage design



c) Longitudinal cut

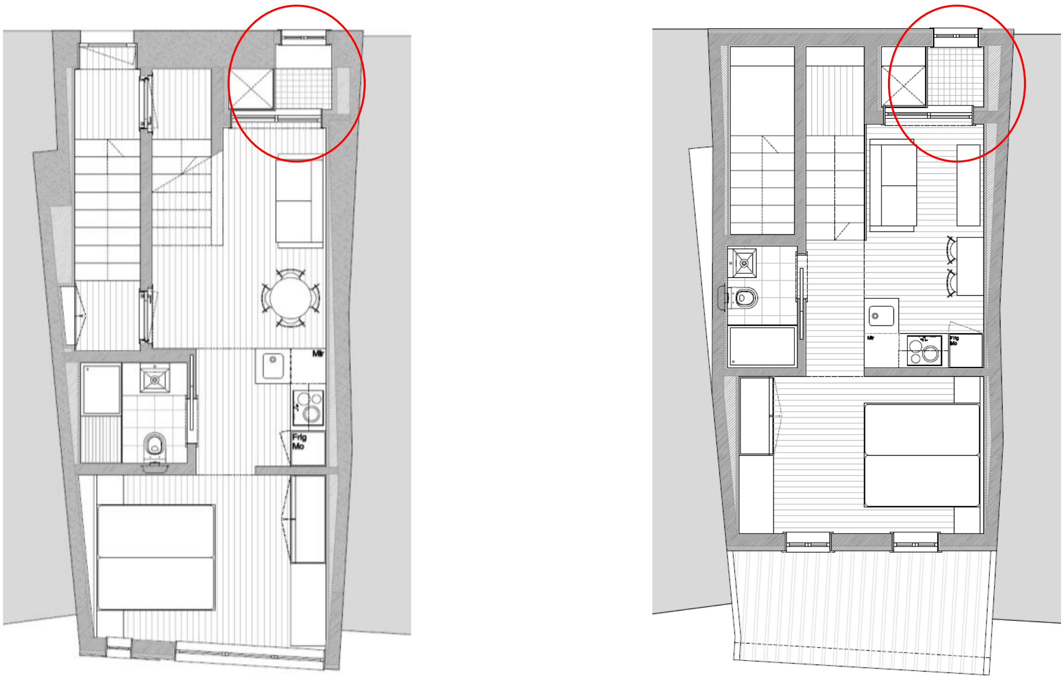
Figure 6- Space working like a ventilation and lightening column

With the objective to maximize the use of the space and, simultaneously, to have a more balanced organization of the 1st and 2nd floors as well as to have a doorway with a regulatory height, it was proposed the access to the 1st and 2nd floors by the south elevation in a higher quota. It allows a doorway with 2 meters height (the existing has 1.70 meters) and the utilization of the original doorway for placing a window taking advantage in more efficient lightening and ventilation of the 1st floor and the ground floor, Fig.7.

a) Existing south elevation b) Proposed south elevation

Figure 7- Existing and proposed south elevation

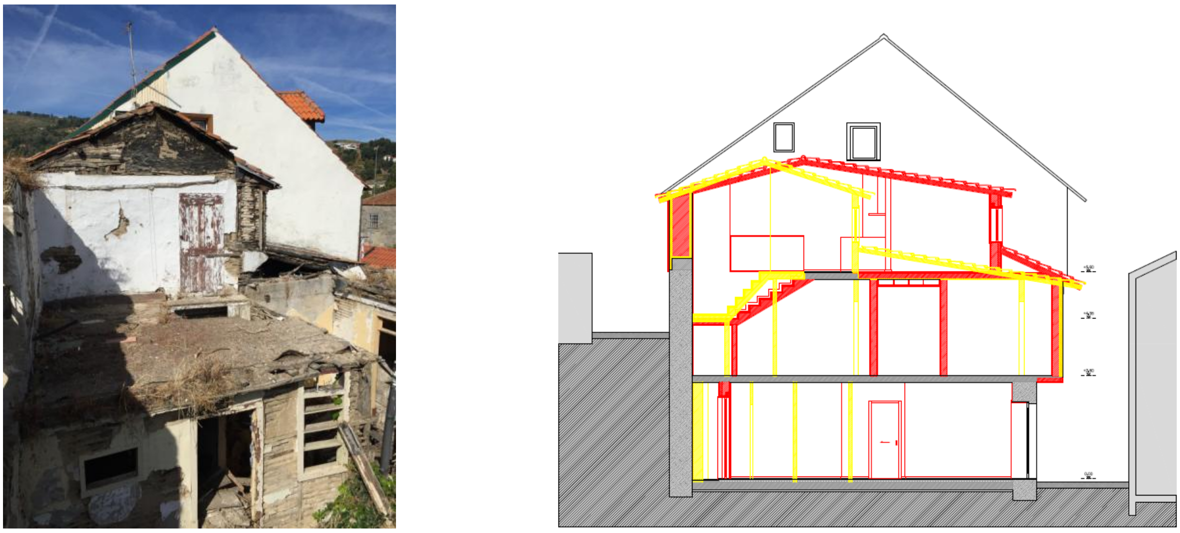
The access to the windows of the first and the second floor will be done through a small balcony with a glass floor, Fig. 8.



a) First floor design b) Second floor design

Figure 8 - Access to the windows of the first and the second floor

Concerning the maintenance of the building height due to the existence of two small windows in the nascent side of the neighboring dwelling the presented propose foresees the resizing of the 2nd floor not interfering with these openings but promoting a more balanced framing of the building's roof neighbor, Fig. 9.



a)Existing b) Existing and Proposed

Figure 9 – Nascent Elevation

Coasts of the reconstruction

The expected construction cost is 1010 €/m^2 (1203 €/m^2 including the property acquisition), a very high value when compared with 1117€ that is the median value per m^2 of the dwellings sales (€) with 1 room in the Douro region (NUT III) where Lamego is included and with 1111€/m^2 that is the median value per m^2 of the dwellings sales (€) in Portugal [5]. The coast of dwellings sales (€) includes in addition to the construction cost, the cost of the land, studies, projects and all other expenses and the seller's profit.

The costs grouped by the main types of work to be carried out are presented in Fig. 10, highlighting the high weight of the construction site and demolitions, 5% of the total work, and the high cost of the structure, 23%. The construction site and the transport of demolition waste are almost always critical aspects of a building reconstruction in historic areas with little availability of space and difficult accesses. On the other hand, the high cost of the structure is related with the stell structure used, compulsive situation in buildings reconstruction in the historic area of Lamego Castle (it can also be made in wood), which is much expensive than reinforced concrete, the most traditional building material used in Portugal [2].

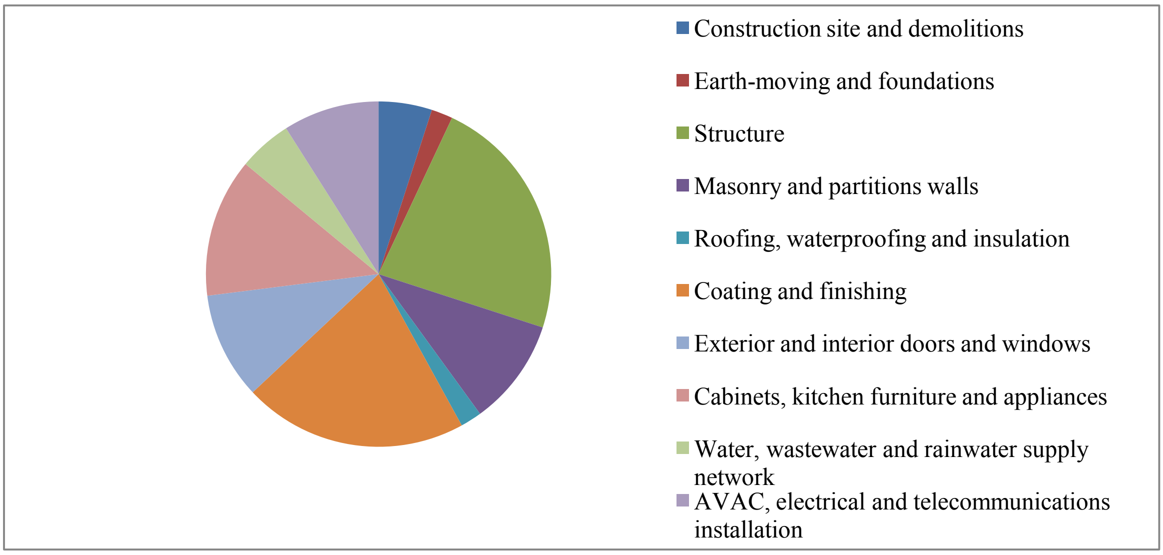


Figure 10 - Costs grouped by the main types of work

Conclusions

This paper presents the architectural proposal of a small house in a historical area of Lamego city, the Castel zone. The aim of this intervention was to obtain a built-up space full of functionalism and simultaneously the preservation of the façades. It is also an objective to satisfy the needs of the owner in order to maximize the use of the space.
The existing volumetric and built framework is the origin of the building proposal, which is based on a preservation language and in the use of new elements in the interior. They will function as a milestone of the existing patrimonial values in a building but having the actual requirements.
Thus, the recommended solution is the result of the weighted development of the constraints of the existing building and the new building program where the main constraints of the project were the existence of small construction area and to provide natural lighting and ventilation. These aspects were the main focus of this work but a brief cost analysis was also carried out.

Acknowledgements

The authors thank Kymagem for providing the photographs Fig. 1a) and 2) and the partial support of FCT (Portuguese Foundation for Science and Technology) through the project PEst-OE/ECI/UI4082/2013 (C-MADE).

References

[1] Instituto Nacional de Estatística de Portugal. Estatísticas da Construção e Habitação. 2017, Instituto Nacional de Estatística. ISSN 0377-2225

[2] Ferreira, J.; Duarte Pinheiro, M.; de Brito, J. (2015) - Economic and environmental savings of structural buildings refurbishment with demolition and reconstruction - A Portuguese benchmarking. Journal of Building Engineerin 3 (2015), pp. 114-126 (doi: 10.1016/j.jobe.2015.07.001)

[3] Alba-Rodríguez, M.; Martínez-Rocamora, A.; González-Vallejo, P.; Ferreira-Sánchez, A.; Marrero, M.(2017) - Building rehabilitation versus demolition and new construction: Economic and environmental assessment. Environmental Impact Assessment Review. 66 (2017), pp. 115-126 (doi: 10.1016/j.eiar.2017.06.002)

[4] http://www.cm-lamego.pt/images/pdf/ARUS/ARUS-LAMEGO-SINTESE.pdf (Date accessed: 20.03.2018)

[5] Instituto Nacional de Estatística de Portugal, Median value per m^2 of dwellings sales https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0009595&contexto=bd&selTab=tab2 (Date accessed: 20.03.2018)

Proceedings of the 8th International Conference on Safety and Durability of Structures
ICOSADOS 2018
May 23 - 25, 2018, LLU, Latvia

Reuse of Old State Buildings In Cabeceiras de Basto

Vítor Magalhães[1, a], Anabela Paiva[2,b] and Jorge Pinto[1,c]

[1]Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, 5000-801 Vila Real, Portugal

[2]Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, 5000-801 Vila Real, Portugal. C MADE – Centre of Materials and Building Technologies.

[3]Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, 5000-801 Vila Real, Portugal. .C MADE – Centre of Materials and Building Technologies.

[a]vitor88marques@gmail.com, [b]apaiva@utad.pt, [c]tiago@utad.pt

Keywords: state buildings, old primary schools, rangers´ houses, railway station, rehabilitation, reuse.

Abstract

There is an expressive amount of old state buildings in Portugal that have been neglected for a long time, namely primary schools, rangers´ houses and railway stations. Some of these buildings, although they are not yet considered as heritage buildings, are very interesting and worth being carefully studied. These buildings, some of them abandoned for a long time, are no longer viable? Should they be demolished?

This research work focus on studying these types of buildings in Cabeceiras de Basto County, in Portugal. Field work has been carried out in order to characterize a number of different buildings, namely by registering their exact location, construction solutions, architecture solutions and the level of conservation, among other technical aspects. Some buildings that have been already rehabilitated are also reviewed.

The information gathered has been studied in order to devise new purposes for the use of the studied buildings after rehabilitation.

INTRODUCTION

In Portugal, during the Estado Novo (New State) or the Second Republic, in the 1940's and 1950s, a large amount of public real estate was built, such as primary schools [1], rangers' houses and railway stations, which are still part of the Portuguese heritage. The county of Cabeceiras de Basto, in the north of Portugal, was no exception.

These buildings were spread in this area, as can be seen in Figure 1, in a total of 41 buildings, including 28 primary schools, 12 rangers' houses and a railway station. The exact location of each building under analysis was defined by Magalhães [2], [3]. This was a very difficult task, because in some cases did not exist their exact location and usually their accessibilities, mainly in the rangers' houses, were very poor.

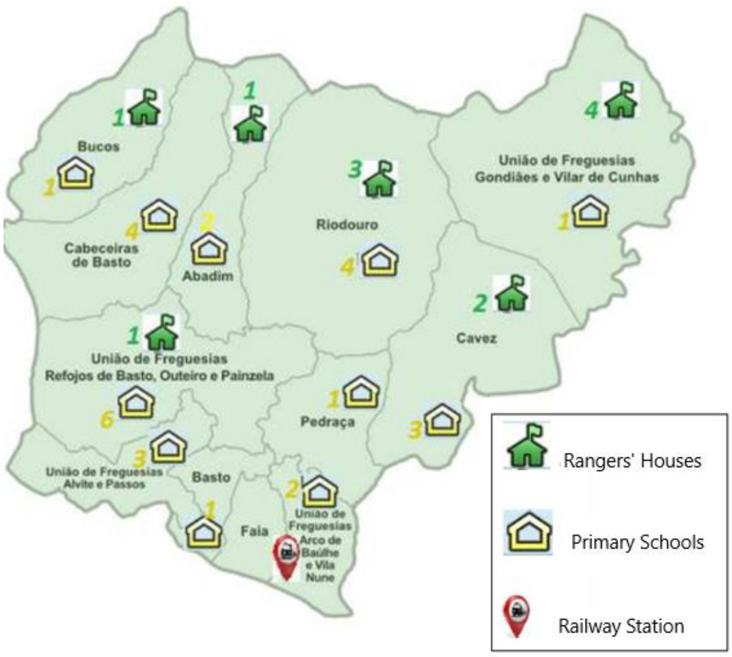


Figure 1: Distribution and number of studied buildings per parish of the county of Cabeceiras de Basto. Adapted from site of this county [4].

The main goal of this article is to present the work developed, in order to characterize the construction solutions used in these buildings, their current state of conservation, the rehabilitation interventions already carried out and their potential for reuse.
The methodology carried out in order achieve the goal referred above, was the following:

- Identification of the location of the buildings;
- Development of a data collection sheet, which will be duly filled in at the time of the visit of the various buildings, accompanied by a photographic survey, in order to collect as much information as possible about their characteristics and anomalies;
- Analysis of the collected data.
- Suggestion of possible alternatives of use to be applied to the abandoned buildings.

Primary Schools

The old primary schools of the county of Cabeceiras de Basto are distributed by their various parishes, according to the needs they had at the time, in terms of population and/or students.
There are twenty-eight former primary schools in this county. Only the primary school of Gondarém continues to be used as a school, Figure 2.a). The remainder are closed or were released to different types of entities, such as the Bucos' school, Figure 2.b). This old primary school reopened in 2012 as "Casa da Lã" (Wool House). In this case a deep intervention was required, taking into account the new functions attributed to the building. The Sta. Senhorinha - Basto primary school was also rehabilitated. Since 2017, Basto's Leisure Center, the Association of Friends of Basto and the Parish Council of Basto have been operating there, Fig. 2 c). Although, most of the schools assigned to institutions have been used after a small-scale rehabilitation or without any rehabilitation, as happened to the school of Toninha-Rio Douro, Figure 2.d).

The construction solutions of this type of buildings were based on the application of natural and local materials. As this county is rich in granite and pine wood, it has strengthened their application in the construction of these buildings.


a) Gondarém b) Bucos


c) Sta. Senhorinha – Basto d) Toninha – Rio Douro

Figura 2. Primary schools of the county of Cabeceiras de Basto.

Rangers' Houses

In this county 12 ranger's houses were also built, their construction took place in the year of 1954. In 20th of August 20, 1998, part of them were given in to the City Council of Cabeceiras de Basto, according to the protocol of collaboration signed with the Regional Directorate of Agriculture of Entre Douro e Minho.

All of them have identical architectural characteristics. They only have a ground floor with seven rooms, kitchen, common room, office, storage room, bathroom and two bedrooms. These houses were inhabited by former rangers and their families.

The construction solutions of this type of buildings are similar to the ones used in the primary schools. The materials used in their construction were also the granite and pine wood.

Nowadays, three different types of use can be observed for these houses. Four of them are still inhabited by former rangers and their families or only by their families, as for example the old rangers' house of Cambeses-Rio Douro, Figure 3 .a). Other four were rehabilitated for rural and tourist purposes by the City Hall, such as the house of Veiga-Bucos, Figure 3.b) [5]. And the remaining four are abandoned, the house of Magusteiro-Rio Douro, shown in Figure 3.c) is an example of this situation.

a) Cambeses- Rio Douro

b) Veiga- Bucos

c) Magusteiro- Rio Douro

Figura 3. Rangers' Houses of the county of Cabeceiras de Basto.

Railway Station

In the village of Arco de Baúlhe in the county of Cabeceiras de Basto there is an old Railway Station. This was inaugurated on 15th of January of 1949 and was part of the Tâmega railway line [6].

This station was composed by a set of buildings and space: the main building and complementary buildings with different purposes, such the engine drivers house, the warehouse for goods, two stables, a coal deposit, a water tank, a loading and unloading dock, a crane that served as a support for the supply of the carriages, a turntable whose function was to change the direction of the trains, a public place and a garden in its surroundings.

The main building was used by the passengers of the station and is the only two-floor building. On the ground floor there was a room, a waiting room and a large space intended to support the passengers, and on the upper floor there were seven divisions: a dining room, a kitchen, a bathroom and four bedrooms, to be used by the staff of the station.

After 41 years, in 1st of January of 1990, it was closed. Years later, in January of 2000, the management of these buildings was given to the City Council of Cabeceiras de Basto, and later, on 23rd of May of 2004, the museum Núcleo Ferroviário de Arco de Baúlhe (Arco de Baúlhe Railroad Center) was opened, Figure 4 a). Also, the "Casa dos Maquinistas" (house of the engine drivers) was rehabilitated and became the Employment Center of Basto.

a) Núcleo Ferroviário de Arco de Baúlhe b) Employment center of Basto

Figura 4. Railway Station of Arco de Baúlhe, county of Cabeceiras de Basto.

Construction Characteristics of the Buildings

The construction solutions used to built all these buildings are the same. With respect to the exterior appearance of these buildings, it is generally found that there is a lower row of stone masonry along its contour, in which small openings can be seen. These openings allow the natural ventilation of the wooden floor, Figure 5. This solution prevent the direct contact of the wood with the soil, in order to guarantee its greater durability, avoiding, for example, rotting due to contact with the soil moisture and the attack of the wood by xylophages agents.

Figura 5 - Natural ventilation openings.

Other outstanding construction solution, in these buildings, are the thickness and consequent robustness of their stone masonry walls, the plaster of lime-based mortar or cement and the white paint finishing. The windows sills, jambs and head jamb are made of stone (granite). They have pitched roofs covered with traditional ceramic tiles. The windows and doors have timber frames. This material was also applied with structural functions in the construction of floors, ceilings and roofs. The partition walls were made with hollow bricks.
The expressive thickness of the stone walls was due to their structural performance, but it improves also their acoustic performance and their thermal inertia.

Pathologies / Anomalies

Over the years the aspect of these buildings keep changing, due to use and aging of the materials, so it is important to carry out maintenance and rehabilitation work to minimize the risk of degradation. Even so, the non rehabilitated buildings studied have a very satisfactory state of conservation.

Against the above, most of the houses released to different types of entities, still in use, were subjected to minor rehabilitation work, such as wall painting, wood varnishing and occasional replacement of some materials.

These buildings are thought, that they did not have any maintenance over time, which justifies the existence of some pathologies. The main pathologies that occur in these buildings are: cracking, rotting of the elements of wood, corrosion of metallic elements, absence and cracking of ceramic tiles, damp spots, water runoff on walls and window sills, detachment and blistering of plaster, deterioration of window frames, damaged bricks / tiles, moss appearance and absence or breaking of glass, Figure 6 and 7.

b) Rotting of the elements of wood

c) Moss and painting's degradation

d) Rotting of the timber elements

e) Absence and cracking of ceramic tiles

Figure 7 - Pathologies in the studied buildings

Figure 7 - Moss and painting's degradation

Alternatives for use

Taking into account the heritage value of these buildings, the good state of conservation and the versatility of rearrangement of space and the fact that almost 50% of them are still abandoned, decisions must be taken for their reuse.
Some of them are already being used for touristic and social purposes. The abandoned ones can also be used for these and other purposes. The primary schools can be used as day care centers, study centers, libraries and tourist offices, among others. The rangers' houses, due the relevance of these heritage buildings in the preservation of the forest, for more than 40 years, they should be rehabilitated and used for the same purpose. At the moment, and given the fires that broke out in our forests in 2017, it is urgent to take measures in order to rehabilitate them, so they can house again the rangers and their families.

Conclusions

The studied buildings, in the county of Cabeceiras de Basto, have very similar construction characteristics and similar construction techniques were used. They were built using natural and local materials, mainly granite and wood. The foundations and external walls were made of granite and the floors, roof structure, window frames and doors were made of timber.
The state of conservation of these buildings is good and consequently their rehabilitation would not be complex and expensive. But, if no decisions are made their rehabilitation will become progressively more complex and expensive. However, it should be noted that, although, some of the buildings, in this county, have been rehabilitated, most of them only had very simple interventions, that did not eliminate the causes of the pathologies, but only the pathology itself. In the course of time, these pathologies reappeared, this already occurred in some of these houses. On the other hand, the absence of maintenance, even after being subjected to interventions, leads to the appearance of anomalies.
In summary, a range of anomalies are present in these buildings, the main ones being the presence of cracking and rotting of the timber elements, corrosion of metal elements, absence and cracking of ceramic tiles, humidity spots, painting degradation, detachment and blistering of the plaster, deterioration of window frames, appearance of mosses and absence or breakage of glass.

References

[1] Féteira, J. P. F. S. (2013), "O Plano dos Centenários - As Escolas Primárias (1941-1956). Dissertação de Mestrado em História da Arte Contemporânea, Faculdade de Ciências Humanas e Sociais da Universidade Nova de Lisboa. Lisboa. Portugal.

[2] Magalhães, V.M.M. (2018), "Potencial de utilização de edifícios tradicionais", Dissertação de Mestrado na Área de Engenharia Civil, Universidade de Trás-os-Montes e Alto Douro.

[3] Vítor Marques, Anabela Paiva, Jorge Pinto (2017). "Potencial de utilização de edifícios tradicionais Portugueses - caso de estudo do concelho de Cabeceiras de Basto". Congresso da Reabilitação do Património (CREPAT), 29 a 30 de junho de 2017, Universidade de Aveiro, Decivil, Aveiro, Portugal. ISBN 978-989-20-7623-2. pp. 587-589.

[4] Site of the City Council of Cabeceiras de Bastos. https://cabeceirasdebasto.pt/concelho-mapa-de-freguesias. Accessed in January 2017

[5] Site of house of Veiga-Bucos. http://cabeceirasdebasto.pt/turismo-casas-florestais-turismo. Accessed in March 2017.

[6]. http://cabeceirasdebasto.pt/museu-das-terras-de-basto-nucleo-ferroviario-de-arco-de-baulhe. Accessed in March 2017

Proceedings of the 8th International Conference on Safety and Durability of Structures
ICOSADOS 2018
May 23 - 25, 2018, LLU, Latvia

Influence of fatigue load on bearing capacity of STEEL PLATES IN bolted connections.

Kamil Pawłowski[1, a], Janis Kreilis[2, b] and Agata Włóka[1, c]
[1] Wrocław University of Environmental and Life Sciences
[2] Latvia University of Agriculture, Latvia
[a] kamil.pawlowski@upwr.edu.pl, [b] janis.kreilis@llu.lv, [c] agata.wloka@upwr.edu.pl

Keywords: steel properties, fatigue effect, test results.

Introduction

Many of currently used steel structures are very old, but due to their historical nature, it is worth keeping them in a good state of repair, as they constitute an important element of our history and cultural heritage. These structures often require intervention in form of reinforcement or modifications connected with their adaptation to the binding regulations and usage-related requirements. As most of historical types of steel are non-weldable, all repairs must be conducted with use of bolted connections. Apart from non-weldable steel that completely excludes the possibility to join elements with use of welding, there are also weldable types of steel whose mechanical properties may be deteriorated as a result of local overheating. The factors that affect it include, among others, the manufacturing process of such steel. The St3M carbon steel that is widely used in bridge construction has good welding parameters if it has been manufactured in Simens-Martin furnaces, but it loses its properties when cast with use of the Thomas method and it becomes very sensitive to "cold" processing. Due to high phosphorus content, it is prone to brittle cracking, in particular when subjected to dynamic loads, which occur quite frequently in bridge structures [4]. Old structures often do not have any archived documentation that would contain detailed data at least concerning the materials used to erect them. This always hinders designing with use of such elements. Such designs should always be prepared very carefully, because the influence of long-term operation of the structure, apart from the obvious wear and tear, e.g. corrosion, also changes the mechanical properties of the structural material. This requires the designer to use such ways to modify the existing structure that will not expose it to additional damages caused by incorrect technological processes. Due to the above, it seems reasonable to use bolts to connect elements in existing structure. Much easier technology of preparing bolted connections in-situ and the fact that their quality will more likely be high are strong arguments supporting the use of such solution.

However, designers may face the issue how to determine the bearing capacity of such connection that was constructed with use of new connecting elements and "old" sheets of metal. It is particularly important to determine the mechanical properties of the material in the connected

that was constructed with use of new connecting elements and “old” sheets of metal. It is particularly important to determine the mechanical properties of the material in the connected elements, in which, for example, a significant part of the bearing capacity was used due to fatigue.
In order to determine the influence of fatigue on the bearing capacity in bolted connections, the authors of this paper used samples collected from elements of a railroad bridge that had been in use for approx. 70 years. The structure of the bridge consisted of two T-girders braced to each other. The theoretical span of the bridge was L_t =13.48 m. The double T-girders of a height h=1.2 m, chords of a width of approx. 300 mm and a varied thickness along the length of the bridge, from 16 mm above the bridge support to 28 mm in the span of the bridge. The view and the basic dimensions of the bridge structure are shown in Figures 1 and 2.


Figure 1. View of the bridge before disassembly.

The bridge was located at 13.110 km of railroad line No. 81 between Chełm and Włodawa, in the eastern part of Poland, near the Ukrainian border. Line 81 was constructed in 1887, for military purposes. Over time, its nature has changed. Currently, the railway line is being reactivated. In the future, it will operate both passenger and freight transport. Data made available by the Polish State Railways show that in the period when the analysed object was a part of the railway line, it operated freight transport - four trains a day. This gives a total of approx. 160 000 trains crossing the discussed bridge.

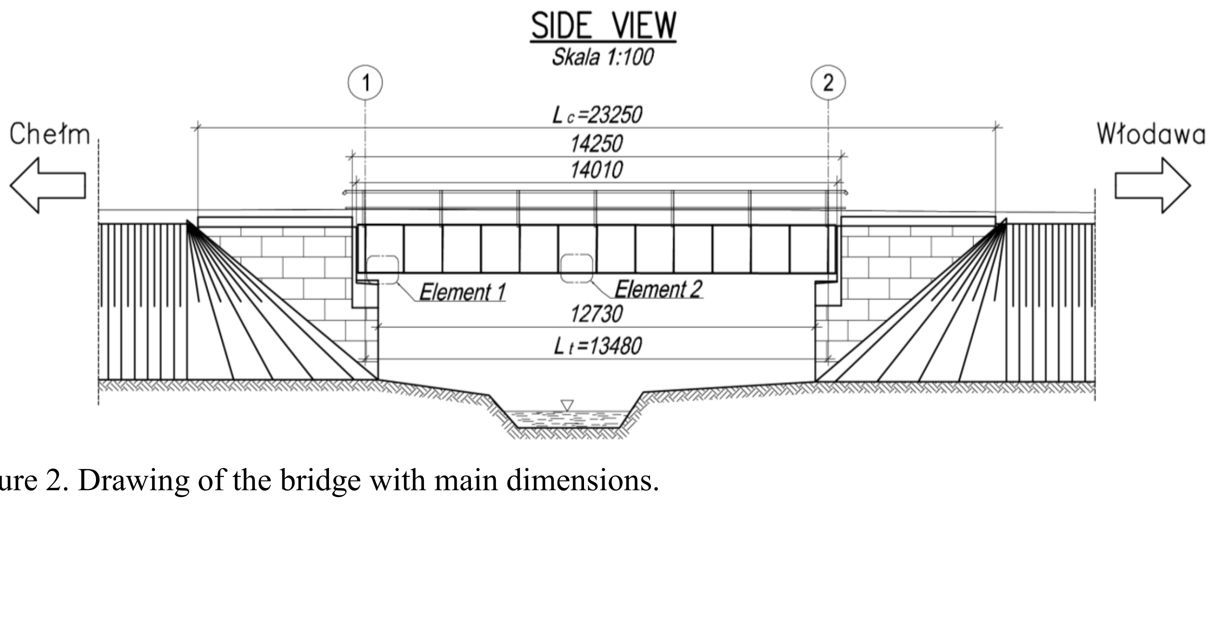


Figure 2. Drawing of the bridge with main dimensions.

Methodology of the tests

The conducted research involved static tensile strength tests of steel conducted on samples collected from bridge elements. The aim of the test was to assign the analysed type of material to a specific strength category. These tests enable to determine the specific modulus (Young modulus), yield strength of steel (R_e) and its tensile strength (R_m) [4]. Samples were cut out with use of a numerically controlled machine that uses a stream of water for cutting. This is the best method, as it prevents the influence of temperature during the preparation of samples. Samples were prepared in compliance with the guidelines provided in PN-EN ISO 6892-1:2010. The dimensions and shape of the samples are shown in Figure 3. Samples were collected from the web of the analysed elements. The location of samples used for tests is shown in Figure 4.

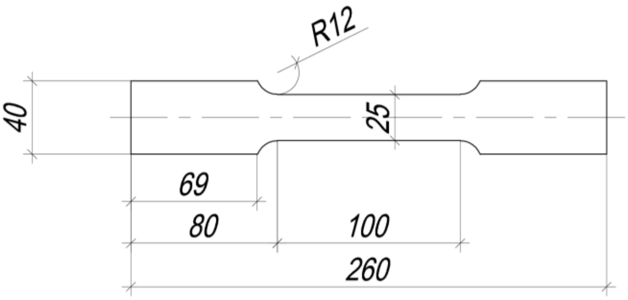


Figure 3. Sample for strength testing, prepared in compliance with the guidelines of the PN-EN ISO 6892-1:2016-09 standard.

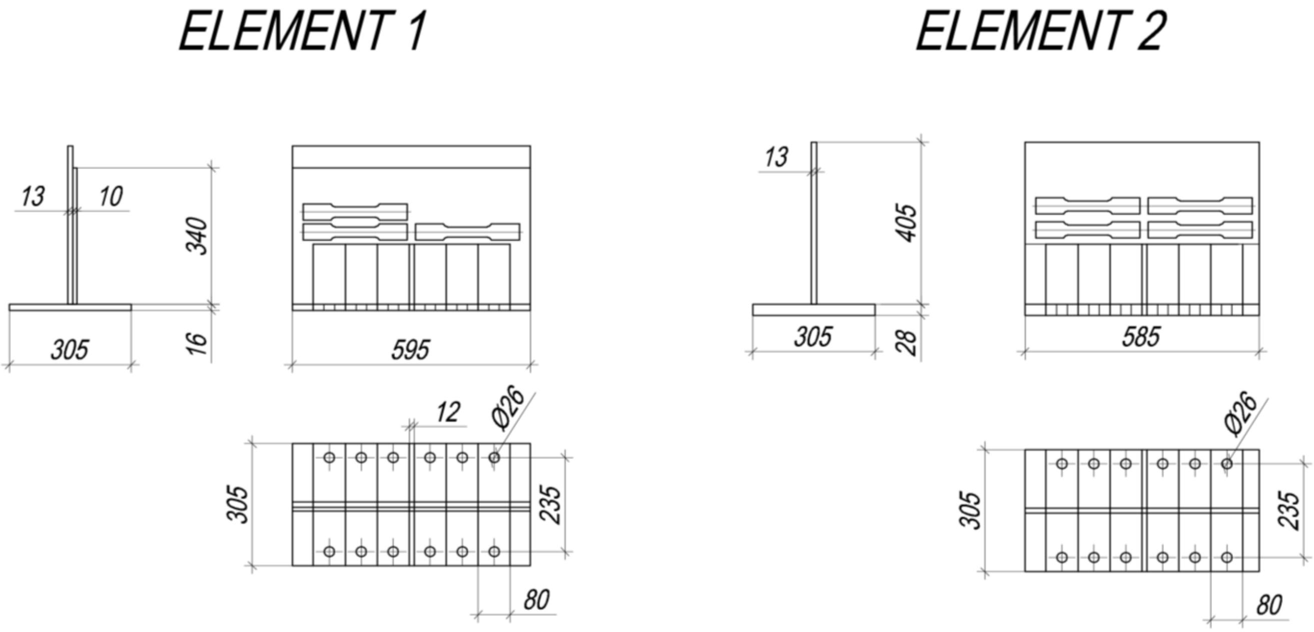


Figure 4. General view of placing the samples on element.

Samples for the bearing capacity tests of bolted connections were T-shaped. The endplate of the connection was a belt of the main girder of the bridge. Due to the simply supported beam design, element 2 cut out from the middle section of the bridge span was the element exposed to the highest influence of fatigue load. As a result, analyses of this element are even more valuable, as they demonstrate the influence of fatigue on the bearing capacity of the newly designed connection, which uses elements of the existing structures. The Authors previously analysed the influence of long-term fatigue load on the bearing capacity of structural elements and the possibility to operate it safely [2], [3]. Samples collected from element 1 will serve as reference samples for the determination of the influence of fatigue on bearing capacity.

Results of tensile strength tests

In order to verify the type of steel and the influence of fatigue on its basic characteristics, static tensile strength tests were conducted. As a result of the conducted tests it was determined that the steel is characterised by a yield strength fy of approx. 300MPa, and a tensile strength of approx. 450 MPa. This means that this is a very strong type of steel, whose properties are much better than those of S235 steel. Tables 1 and 2 below present the results of tensile strength tests of steel from elements 1 (Table 1) and 2 (Table 2). Figures 5 and 6 show the diagrams of the σ-ε correlation for the analysed samples.

Table 1. Basic mechanical properties of steel determined in the tests of samples collected from the element 1.

Sample No.	R_m	R_{eL}	R_{eH}	R_z	ε_{max}
	MPa	MPa	MPa	MPa	mm/mm
N-1	450	285	308	330	0.3203
N-2.	452	325	304	321	0.3156
N-3	446	287	330	318	0.2961
MIN	446	285	304	318	0.2961
MAX	452	325	330	330	0.3203
Average	449	299	314	323	0.3107
Standard deviation	3	23	14	6	0.0129
Coefficient of variation	1%	8%	4%	2%	4%

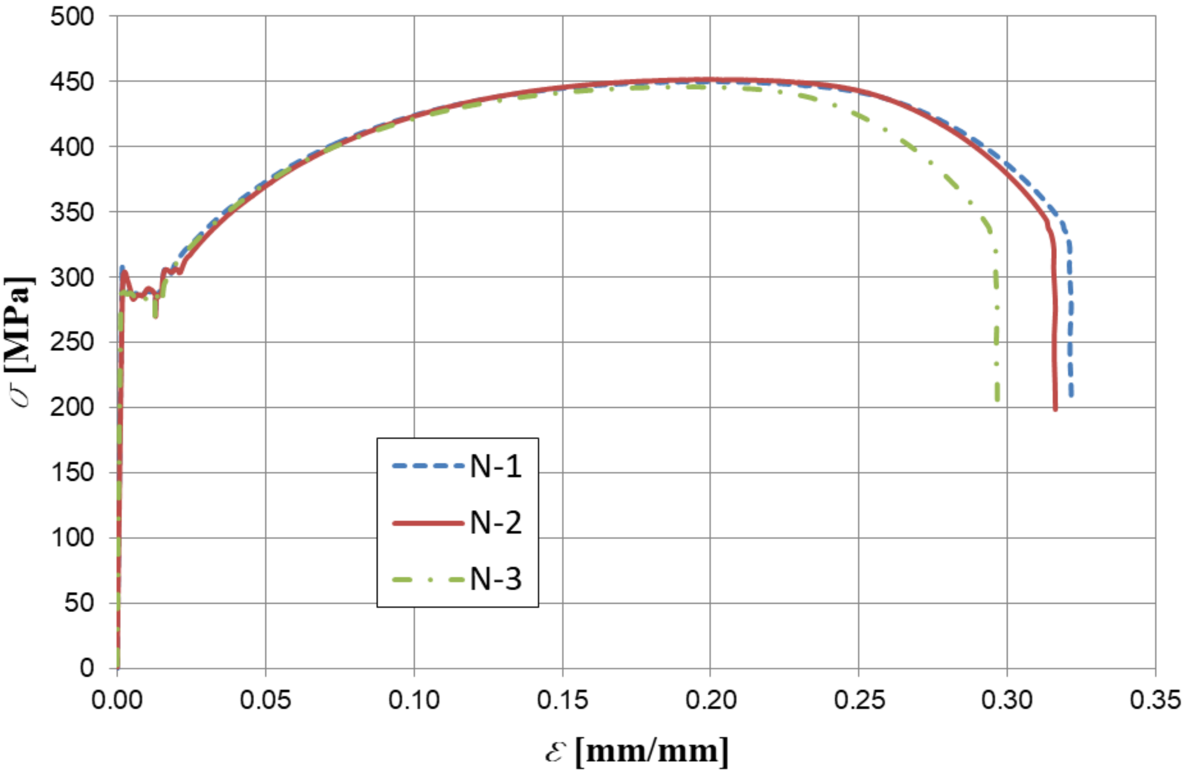


Figure 5. Diagram of the strain-deformation relation for samples cut out from element 1.

Table 2. Basic mechanical properties of steel determined in the tests of samples collected from the element 2.

Sample No.	R_m	R_{eL}	R_{eH}	R_z	ε_{max}
	MPa	MPa	MPa	MPa	mm/mm
Z-1	449	281	295	318	0.3212
Z-2	447	274	293	324	0.3279
Z-3	444	272	284	324	0.3326
Z-4	445	284	289	324	0.3340
MIN	444	272	284	318	0.3212
MAX	449	284	295	324	0.3340
Average	446	278	290	323	0.3289
Standard deviation	2	6	5	0	0.0032
Coefficient of variation	0%	2%	2%	0%	1%

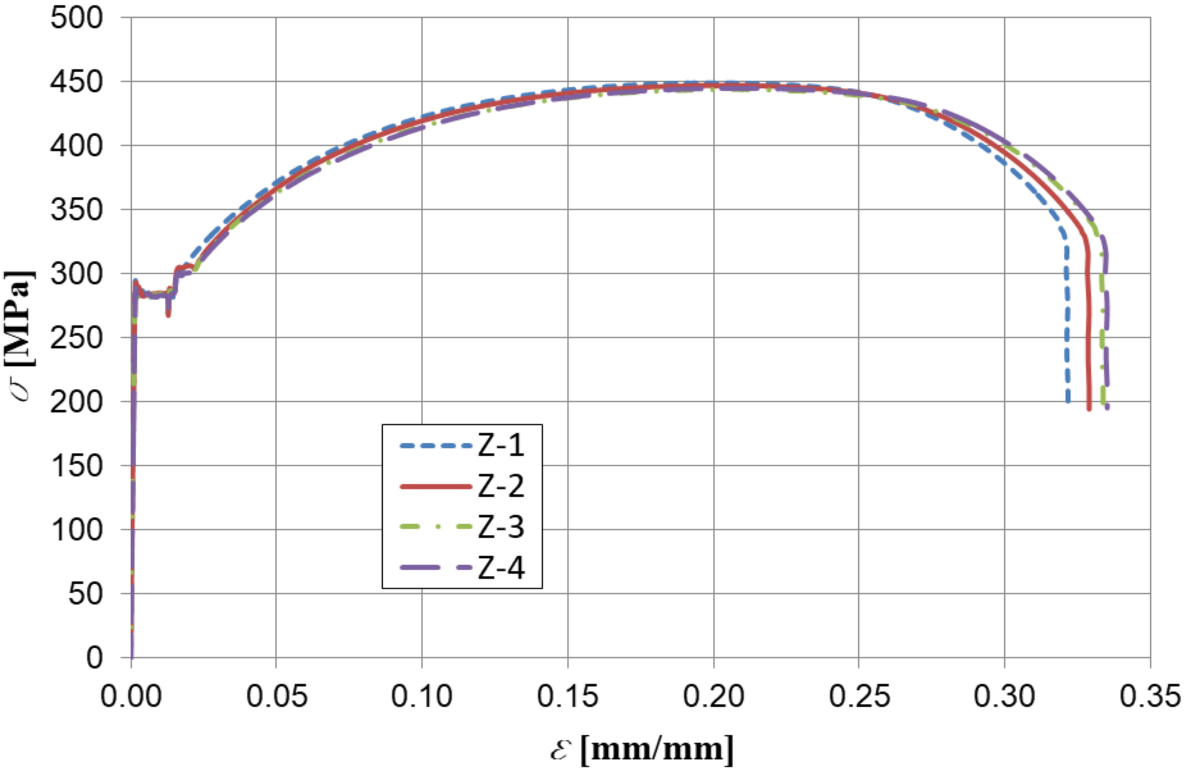


Figure 6. Diagram of the strain-deformation relation for samples cut out from element 2.

The presented results lead to a conclusion that the strength characteristics of steel collected from the bridge span are much lower than those of samples collected from above the bridge support. For the yield strength f_y this influence equals 8%. As far as tensile strength is concerned, this influence is lower and the difference is only 1%.

Results of finite element method analysis

Then, a numerical model was created of a bolted connection analogical to the one that was later analysed experimentally. The non-linear characteristics of the material used were consistent with those of experimental test results. The application of RFEM software enabled us to implement a detailed characteristics of steel strength diagram. The geometry of the numerically analysed connection did not take into account the corrosion cavities that existed in elements used in experimental tests. Figure 3 shows the view of a bolted connection deformed as a result of tensile load, respectively, view a) shows the connection of 16 mm endplates and view b) the connection of

28 mm thick endplates. The aim of the numerical analyses was to obtain such shape of the connection in geometrical terms and such selection of connectors that would result in the endplates being destroyed during the tensile strength test as a result of the developed yield. Such destruction was important due to the aim of the conducted research, which was to determine the bearing capacity of elements constructed from the materials of an already existing object.

a) b)

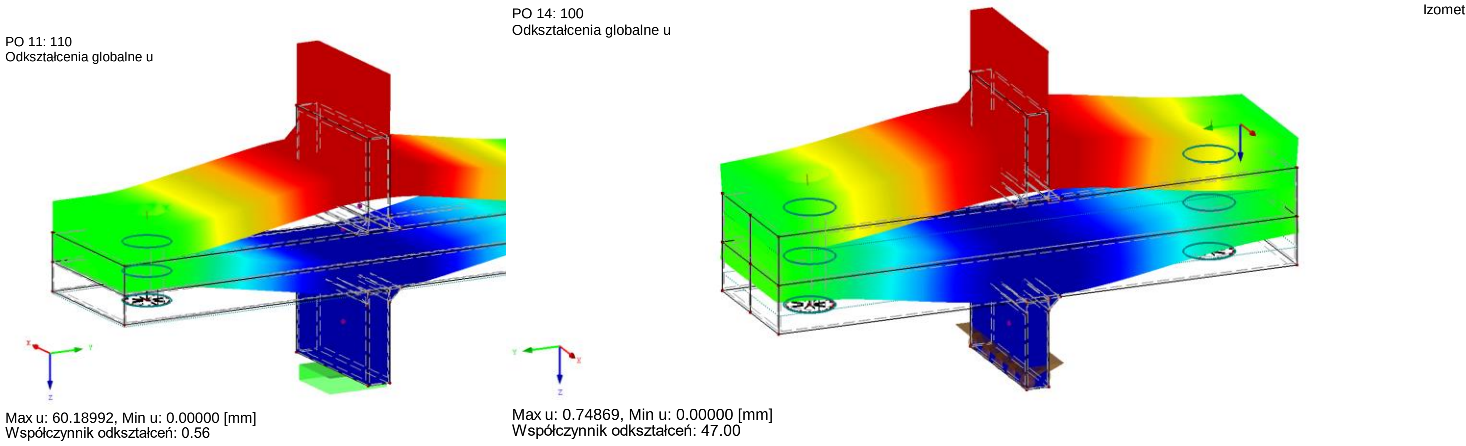


Figure 7. Diagram of the deformation of bolted connection – RFEM analysis, a) endplate 16mm; b) endplate 28mm

The diagram below (Fig. 8) shows the dependence of the relation between force and deformation for a bolted connection with 28 mm endplate. Similar calculations were also performed for the connection with a 16 mm endplate.

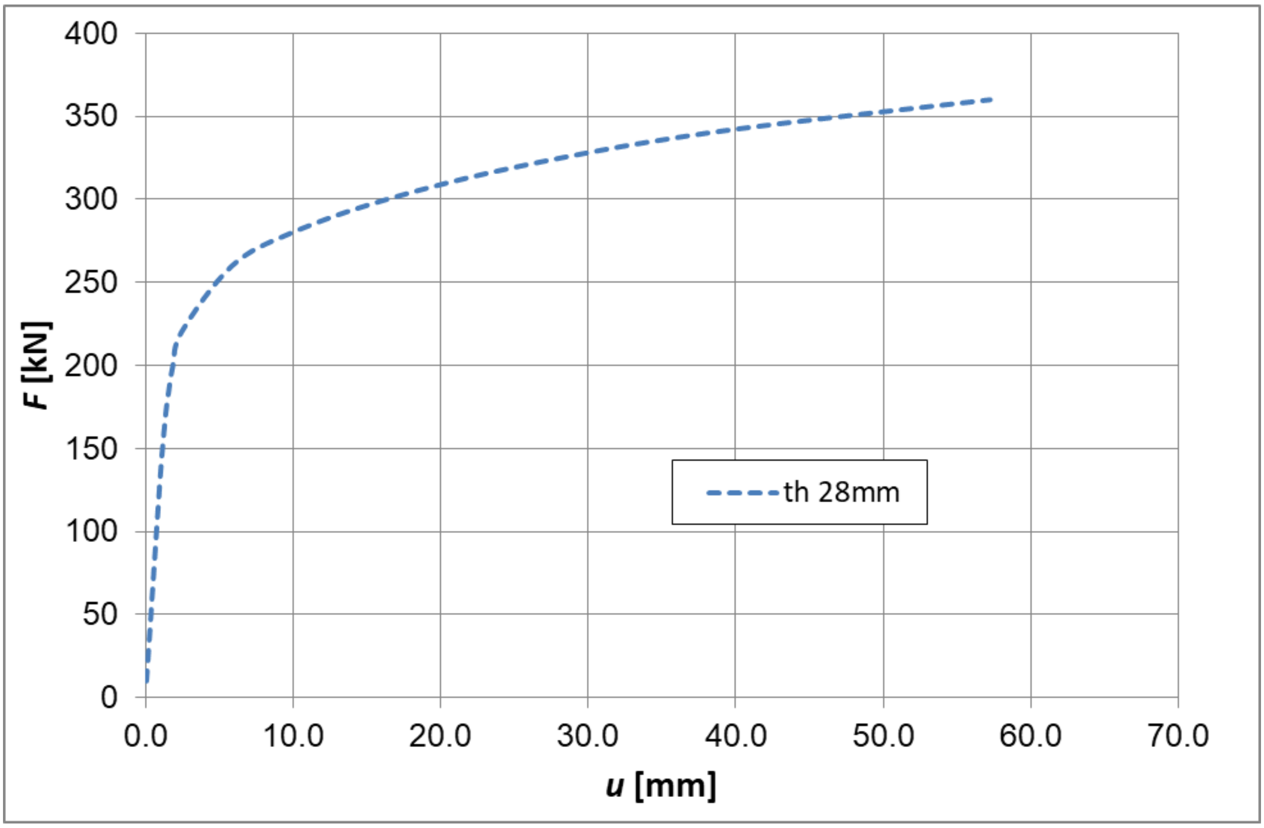


Figure 8. Diagram of the force-deformation relation for connection with 28mm endplate.

Results of tensile strength tests of bolted connection

The experimentally analysed connections were constructed from two T-shaped samples joined with use of two bolts of a diameter of 24 mm. Depending on the thickness of the connected elements, 12.9 class bolts were used (connection with 28mm endplates) and 8.8 class bolts (for 16 mm endplates). The selected classes of bolts were based on the results of the numerical analysis, which determined the maximum axial forces that would exist in the bolt while stretching the connection. Figure 9 shows the analysed connection in the test apparatus during tensile strength test. It is noticeable that the model of destroying the connection by bending the endplates was achieved. 3 connection of each element were analysed during the tests.

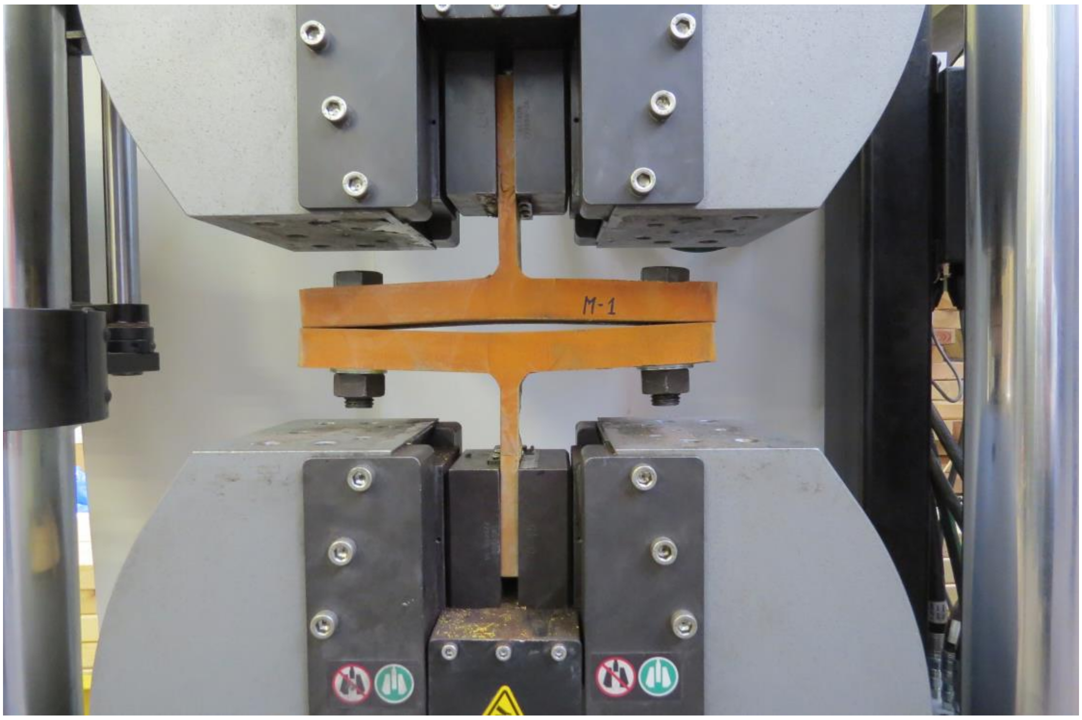


Figure 9. View of a bolted connection during tests in the Instron strength test apparatus.

Figures 10 and 11 show diagrams that illustrate the correlation between force and deformation for all the analysed connections. The diagram presented in Figure 10 shows the results of laboratory tests for samples collected from element 1.For comparison purposes, the diagram also contains a line representing the numerical results obtained in the software for finite element method analysis. The convergence of the obtained results is satisfactory. The course of force-deformation curves is very similar for all samples and for the numerical analysis results. This confirms that the applied numerical model is correct.

The diagram in Figure 11 shows the results obtained for samples collected from element 2. In this case the results of numerical analyses have also been added. One may notice that the divergence is quite significant although the same calculation procedure was used, i.e. the model corresponded to the analysed element and the material characteristics obtained from samples subjected to tensile strength tests were implemented. The difference between the bearing capacity obtained in numerical analyses and that resulting from laboratory tests is approximately 12%, which means that the actual connection bearing capacity is considerable lower than the bearing capacity determined by the numerical model.

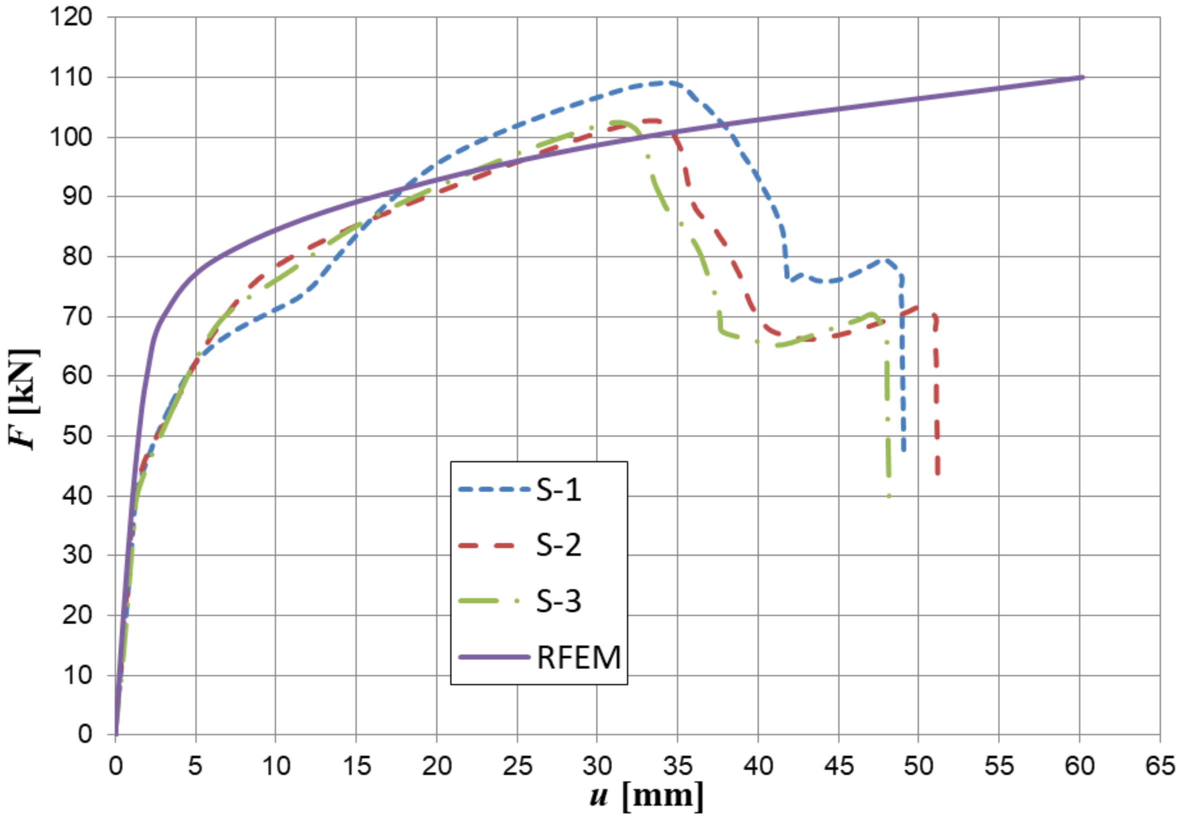


Figure 10. Diagram of the strain-deformation relation for samples cut out from element 1.

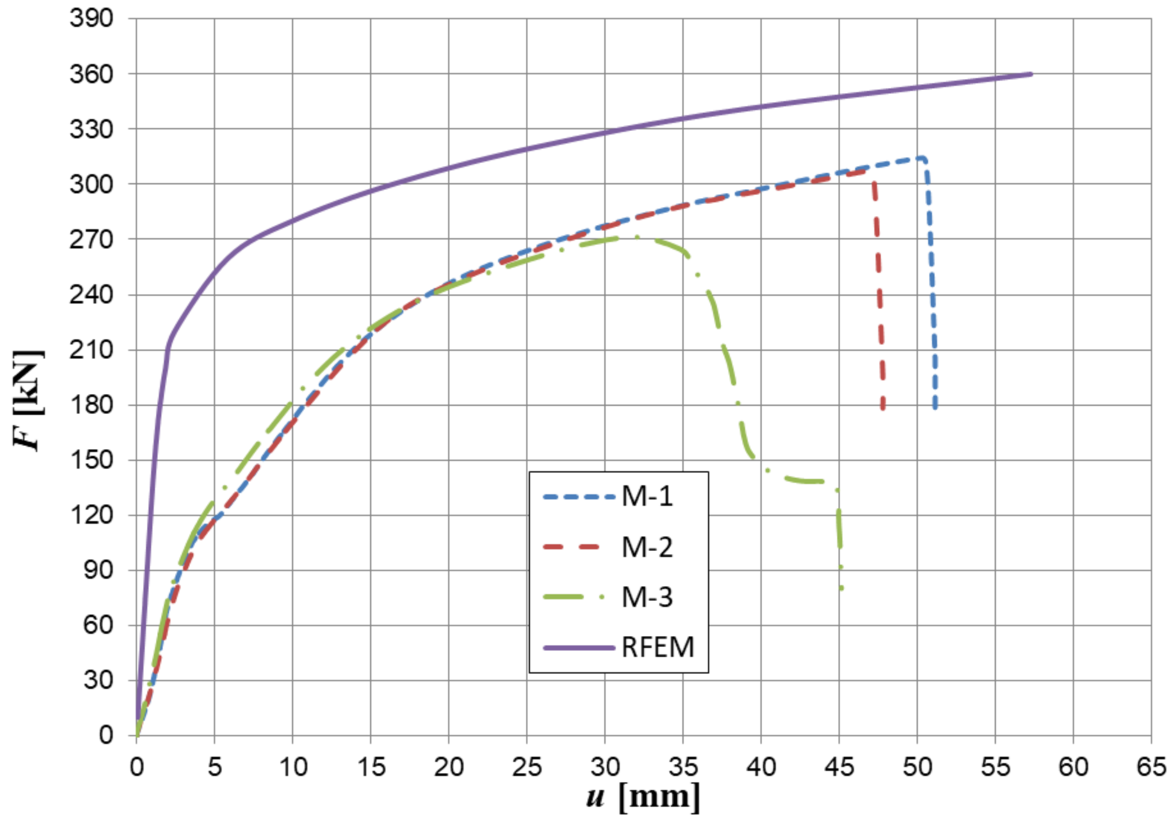


Figure 11. Diagram of the strain-deformation relation for samples cut out from element 2.

Conclusions

The conducted research consisted in static tensile strength tests of steel samples collected from the main girders of a railroad bridge that had been used for many years. It is estimated that it had been subjected to a load of approx. 160 000 trains during that time. Steel from bridge elements was used to construct bolted connections that were then subjected to static tensile strength tests. In order to compare the actual bearing capacity of the bolted connection constructed from bridge steel with the theoretical bearing capacity, a calculation model was created in the RFEM software.
The conducted analyses demonstrate that:
- The value of yield strength of steel collected from element 2 (middle of the span) analysed in the static tensile strength test is approximately 8% lower than that of steel collected from element 1 (support zone – low fatigue influence). This confirms the reduction of strength parameters of steel as a result of fatigue.
- The bearing capacity of samples cut out from element 2 is approx. 12% lower than that determined analytically with use of software.
- The bearing capacity of connection constructed from elements not affected by fatigue determined in laboratory tests is convergent with the bearing capacity of a similar connection calculated with use of numerical analysis.

The above leads to the conclusion that connections constructed in existing structures with use of the existing steel elements that were previously subjected to fatigue loads should be treated with a high dose of uncertainty and that their bearing capacity should be limited for safety purposes. This conclusion is very important due to frequent attempts to introduce modifications to existing steel structures. In case when new connections are added to existing structure, they should be placed in areas of the structure where influence of fatigue loads was minimal. Operation on existing constructions can be classified as difficult engineering because often we do not have sufficient data for design. Therefore each time it is necessary to collect as much data as possible. Most important are static schemes, the history of the applied load and the material properties from which the construction was made. All doubts should be explained at the design stage and confirmed, if it is necessary, by research.
The issue discussed in the paper requires further research in order to determine the exact influence of fatigue on the bearing capacity of connections and to provide specific guidelines for designers.

References

[1] Collins J.A. Failure of Materials in Mechanical Design. John Wiley and Sons. 1981
[2] Kamil Pawłowski, Agata Włóka. Influence of impact strength for possibility of usage and repair of steel structures. 7th International Conference on Safety and Durability of Structures ICOSADOS. Procedings 2016 May 10-12 UTAD, Portugal.
[3] Kamil Pawłowski, Robert Swierzko, Agata Włóka Determination reserve of bearing capacity for steel, with influence of long-term fatigue load, used in structures in case of fire. Recent progress in steel and composite structures. Tylor & Francis LTD. London. 2016
[4] Kazimierz Rykaluk. Metal constructions, Volume 1. 2016. ISBN 978-83-7125-261-7 (Print) pp. 30-72
[5] Franciszek Szelągowski. Steel bridges. 1966. pp 9-42

Proceedings of the 8th International Conference on Safety and Durability of Structures
ICOSADOS 2018
May 23 - 25, 2018, LLU, Latvia

IMPROVEMENT OF STRENGTH AND DURABILITY OF FOAM GYPSUM ACOUSTIC PLATE

Kristaps Pulkis[1, a], Santa Soloveiko[2, b] and Juris Skujans[3, c]
[1,2,3] Akademijas street 19, Jelgava, Latvia, LV-3001
[a]k.pulkis@gmail.com, [b]santa.soloveiko@gmail.com, [c]juris.skujans@llu.lv

Keywords: foam gypsum, acoustic plate, sound absorption, strength and durability

Abstract
Fast rate of development in the field of information circulation and technologies has facilitated the appearance of new construction materials that can simultaneously provide ever growing requirements regarding construction materials in terms of improving the surrounding environment and people's health, sense of comfort, as well as the related expenses for the construction of buildings and their management. Such construction materials can be considered as sustainable and are appreciated and supported by many governments and international organizations. [1] During the previous research foam gypsum has proven itself with good sound absorption and fire – resistance qualities that are dependent on the density of the material and thickness of the product, wherewith it is necessary to provide simultaneously sufficient strength of compression and flexure of the material. The research shows that the bending strength of 40 mm thick foam gypsum material is possible to increase depending on added amount of the high resistance gypsum for the gypsum mass in the mixture and overall water-gypsum proportion. Previous research has shown significant influence of physical and mechanical qualities of the porous elastic material in the formation of the sound absorption coefficient. The research is supplemented with changes of the sound absorption coefficient which have resulted from increasing of foam gypsum bending strength by adding high - resistance gypsum in different proportions.

Introduction
Sound absorbing materials have been evolving into more and more complex materials over the past years. The concept of health, environment and energy economy has resulted in the development of safer, lighter and more optimized building materials and their entry into the market. [2]
Foam gypsum showed highly appreciated results for sound absorption and fire resistance in previous research papers, but material bending and compressive strength is considered as the main disadvantage. The aim of the research is to add new additives to foam gypsum composition to improve the bending strength of foam gypsum simultaneously not decreasing the sound absorption coefficient.

Materials and methods
Previous studies have shown that producing foam gypsum composition using the three stage method can reduce the water-gypsum ratio. A decreased water-gypsum ratio forms an optimal pores structure of foam gypsum for higher bending strength and better sound absorption. Foam gypsum

samples were produced by using beta hemihydrate β $CaSO_4$•$0.5H_2O$ and alpha hemihydrate α $CaSO_4$•$0.5H_2O$. Gypsum powder in a different alpha hemihydrate and beta hemihydrate proportion was mixed together with a surface active substance (SAS) STHAMEX®–AFFF 3 % F-15 and water.
Changing the beta hemihydrate and alpha hemihydrate proportion in foam gypsum compositions also changes the water-gypsum ratio which has an influence on the bending strength and sound absorption coefficient. Standard consistency of each formulation of foam gypsum was tested to decrease the water-gypsum ratio.
Foam gypsum samples in dimensions of 40x40x160mm at a density of 450±30 kgm^{-3} were prepared and tested in a three-point bend with 100mm distance between the supports and compression test by using equipment *Shimadzu AGS-X 10 kN* and computer programme *TRAPEZIUMX single.* [3]

The equipment of *Sinus* impedance tube was used to determine the average weighted sound absorption coefficient (α_w) in the range of frequencies from 250 Hz up to 4000 Hz according to ISO 10534-2:2001 and ISO 11645:2000. [4] Seven sets of samples with circular shape of Ø40 mm at a density of 450±30 kgm^{-3} were produced to test the sound absorption coefficient. The foam gypsum layer of 40mm thickness has been approved as the optimal thickness for sound absorption from previous studies. [3]

Results and discussion
Material density, thickness and pore structure directly affect the sound absorption coefficient. Lower density foam gypsum composition affects sound absorption coefficient at all frequencies in comparison with foam gypsum composition with higher density. Previous studies have shown that the sound absorption coefficient in the frequency range of up to 160 Hz for flexible porous materials depends on the porosity, in a frequency range of 160-1000Hz the dominant effect is on the density of the material, in the frequency of 1250Hz and more significant effect is on the thickness and form but in higher frequencies from 1250-5000Hz the main factor is the material's porosity. [5]
Figure 1 shows the foam gypsum structure by changing the foam gypsum composition by adding alpha hemihydrate. Porous structure in foam gypsum changes by reducing the water-gypsum ratio.[6] Lower water-gypsum ratio of foam gypsum decreases the average diameter of pores and increases the sound absorption coefficient in the high frequency range.

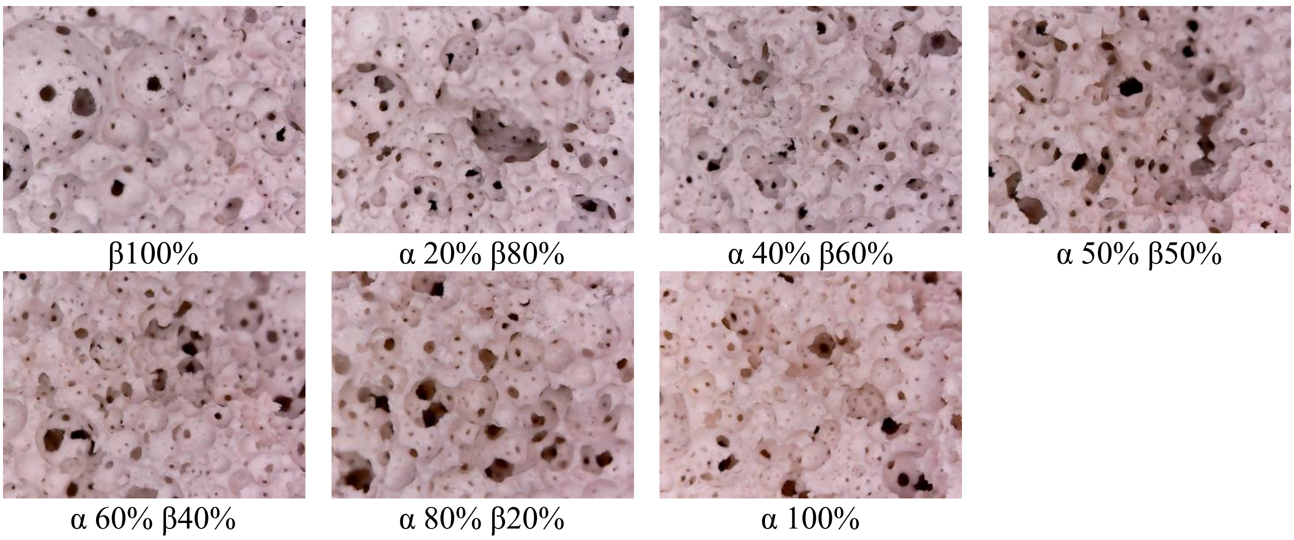


Fig.1. Foam gypsum pores depending on the producing technology

Table 1 shows the average weighted sound absorption coefficient in the frequency range of 250 to

4000Hz depending on the alpha hemihydrate amount in foam gypsum composition. The research shows a higher sound absorption coefficient in the frequency range of above 1000Hz. All sample sets with added alpha hemihydrate indicate the average weighted sound absorption coefficient value increasing by 0.05-0.20 in the frequency range of 250-4000Hz in comparison with foam gypsum without the added alfa hemihydrate. As all sample sets were produced at an average density of 450±30kgm^{-3} the sound absorption coefficient in the frequency 250Hz was changed by 0.05.

Table 2 Sound absorption results

Sample set ID	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	Average
β100%	0.40	0.45	0.50	0.60	0.65	0.50
α 20% β80%	0.45	0.60	0.60	0.65	0.70	0.65
α 40% β60%	0.45	0.55	0.55	0.60	0.60	0.60
α 50% β50%	0.45	0.65	0.65	0.70	0.75	0.55
α 60% β40%	0.45	0.60	0.55	0.60	0.60	0.60
α 80% β20%	0.40	0.75	0.75	0.80	0.80	0.70
α 100%	0.45	0.55	0.60	0.70	0.75	0.60

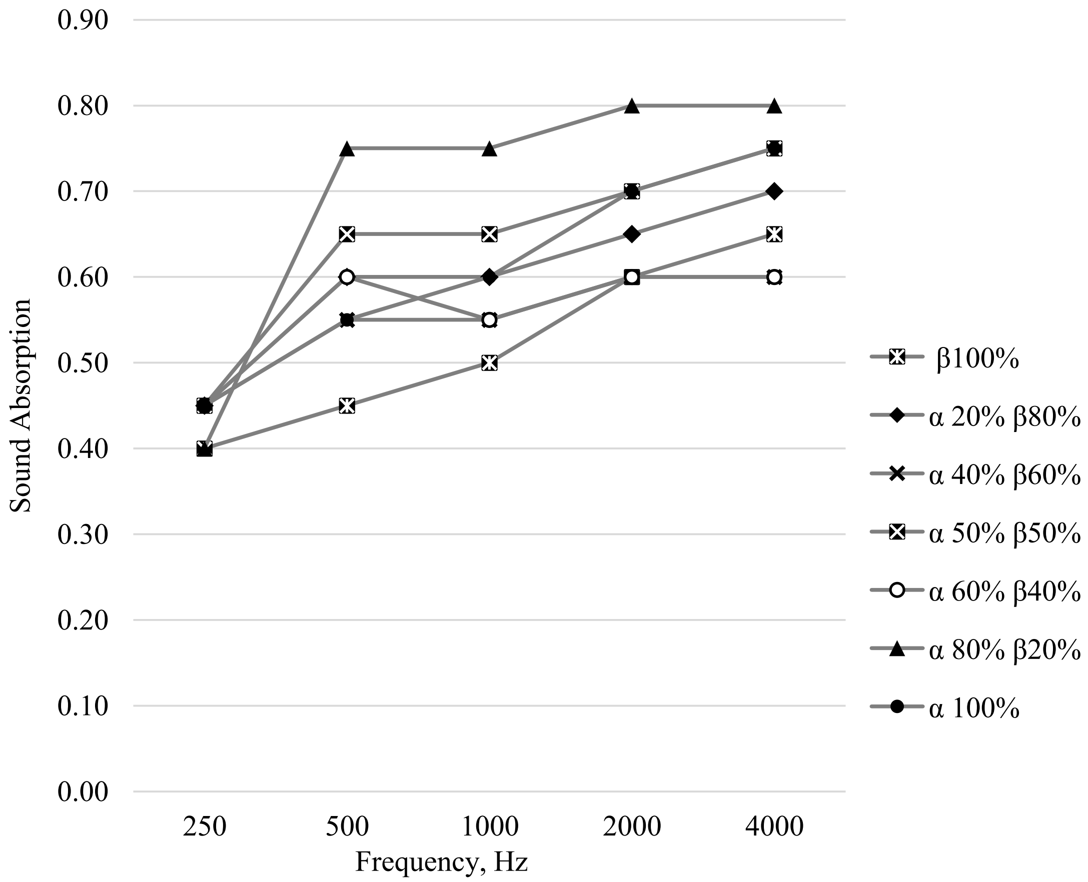


Fig.2. Sound absorption at different alpha hemihydrate proportions

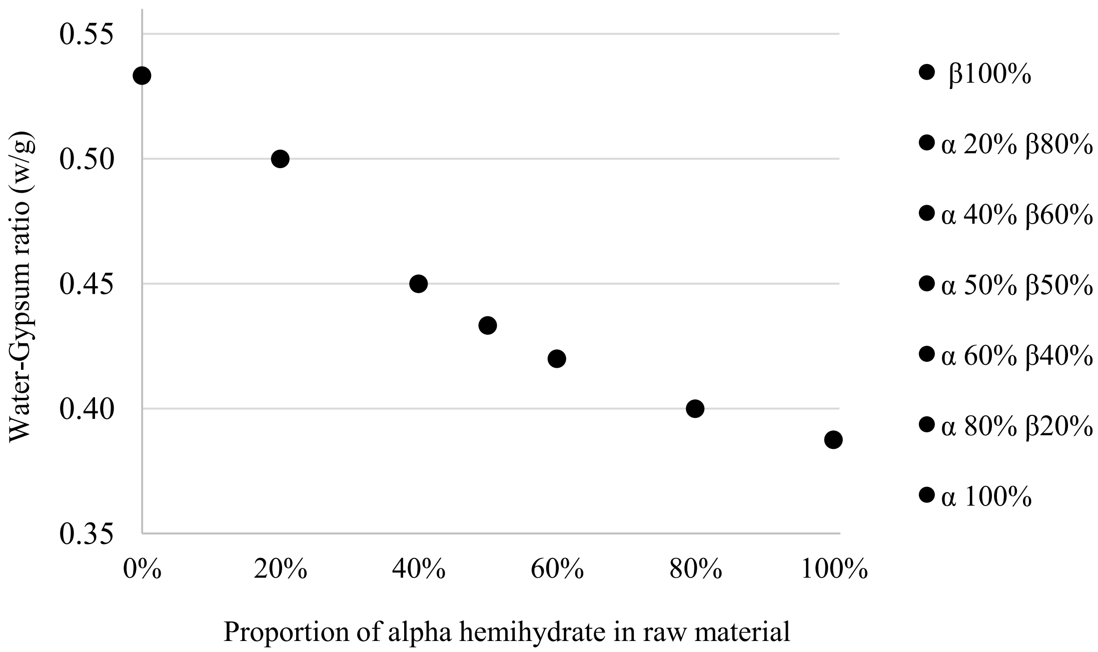


Fig.3. Water-gypsum ratio depending on alpha hemihydrate and beta hemihydrate proportion

Figure 3 shows water-gypsum ratio depending on added alpha hemihydrate proportionally in raw material. Test results show that additional 20% of alpha hemihydrate in foam gypsum composition reduces the amount of water by 3-10%. One of the most energy consuming processes in foam gypsum production is the drying process. By adding alpha hemihydrate it is possible to decrease the amount of heat and reduce the time for drying which influences the expenses of production form gypsum.

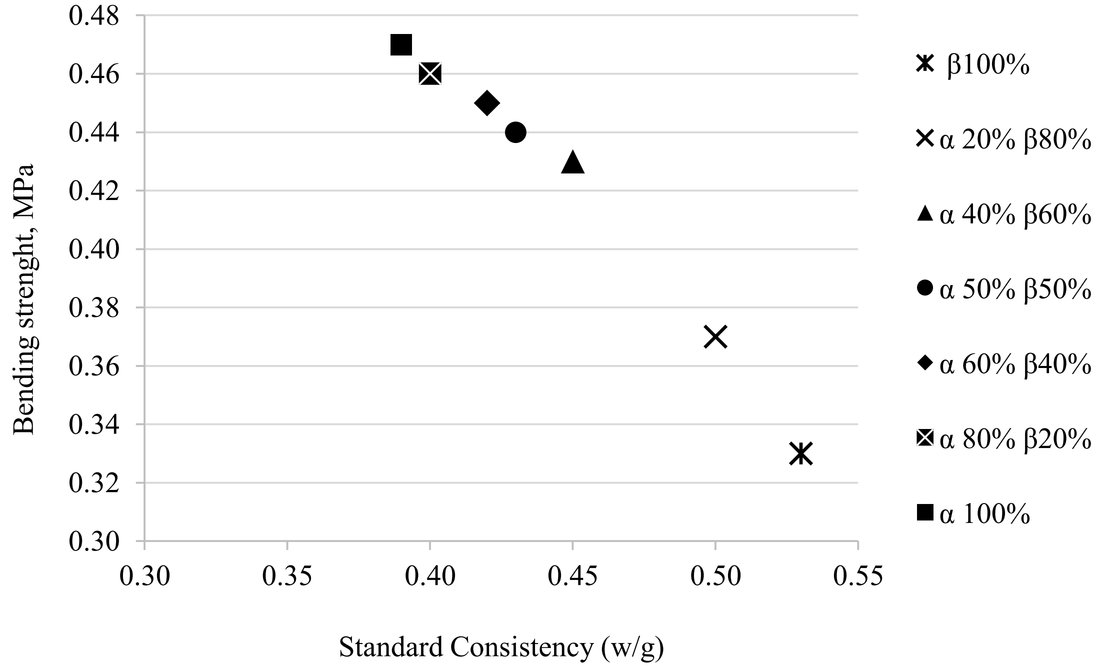


Fig.4. Bending strenght depending on the water-gypsum ratio

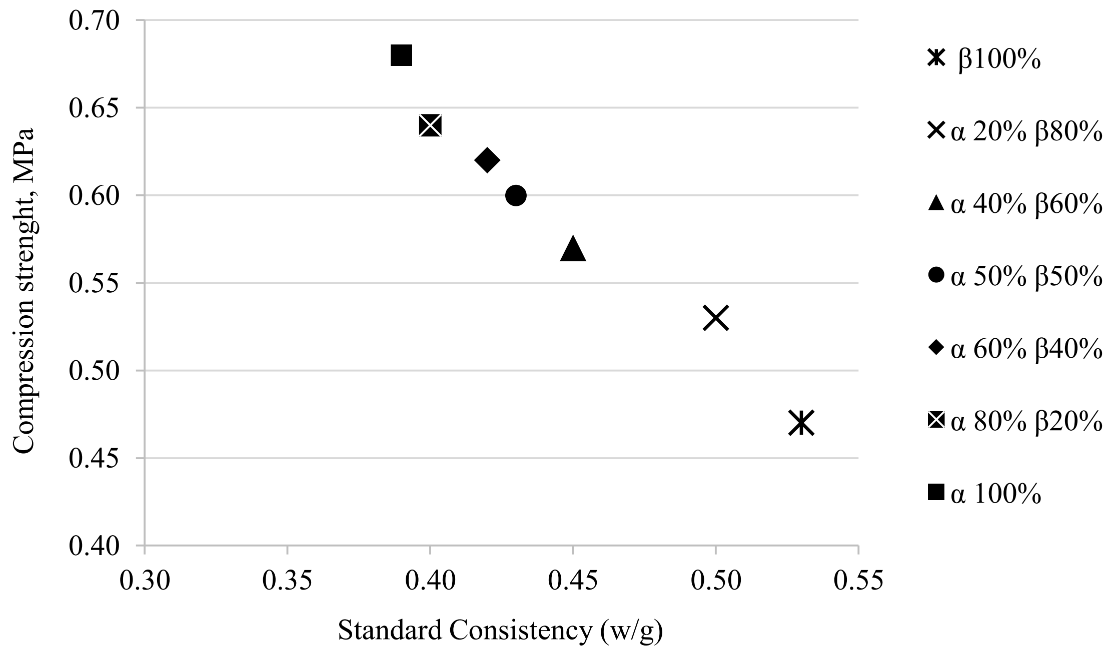


Fig.5. Compression strenght depending on water-gypsum ratio

The bending and copressive stength tests show the water-gypsum ratio influence on the total strength. By adding alpha hemihydrate and reducing the water bending strength increases by 12-42%, but the compressive strenght increases by 11-26%.

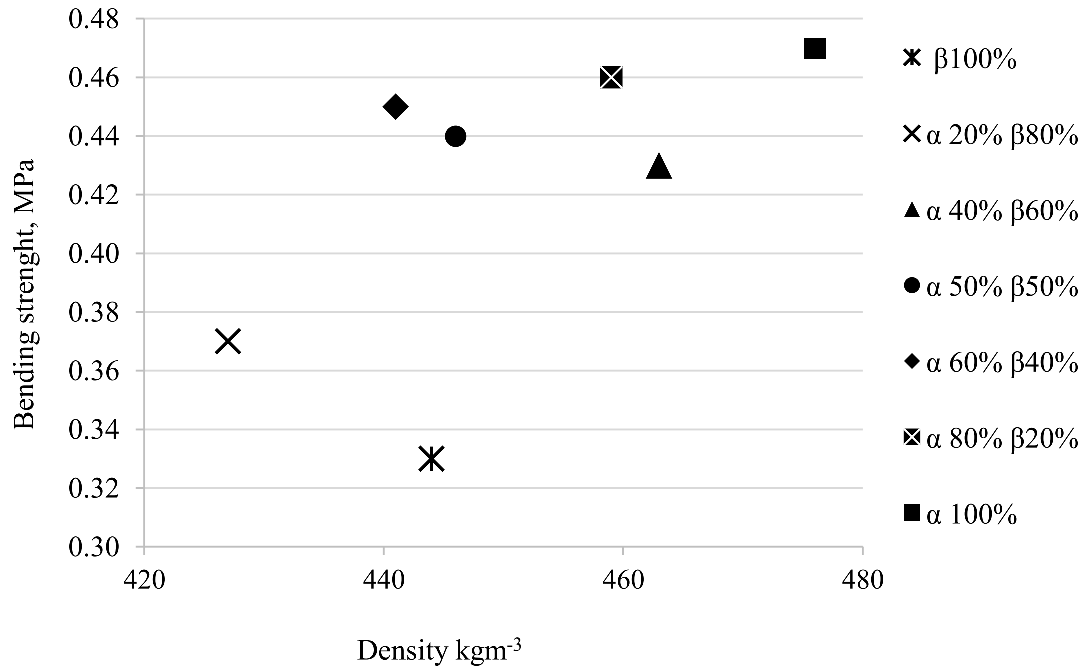


Fig.6. Bending strength depending on density.

The foam gypsum which was produced from 100% bata hemihydrate of a 40mm thichness has a mean density of 450±30kgm^{-3} and an average bending strength of 0.33 MPa and compressive strength of 0.47 MPa. Figures 6 and 7 show that foam gypsum made from 100% alpha hemihydrate increases the bending strength by 0.14 MPa or 42% and the compressive strength increases by 0.21 MPa or 26% compared to foam gypsum made from 100% beta hemihydrate. Figure 6 shows that the density of the material has a major influence on foam gypsum bending strength. Bending and compressive strengths for the sample sets in a close density area are more similar.

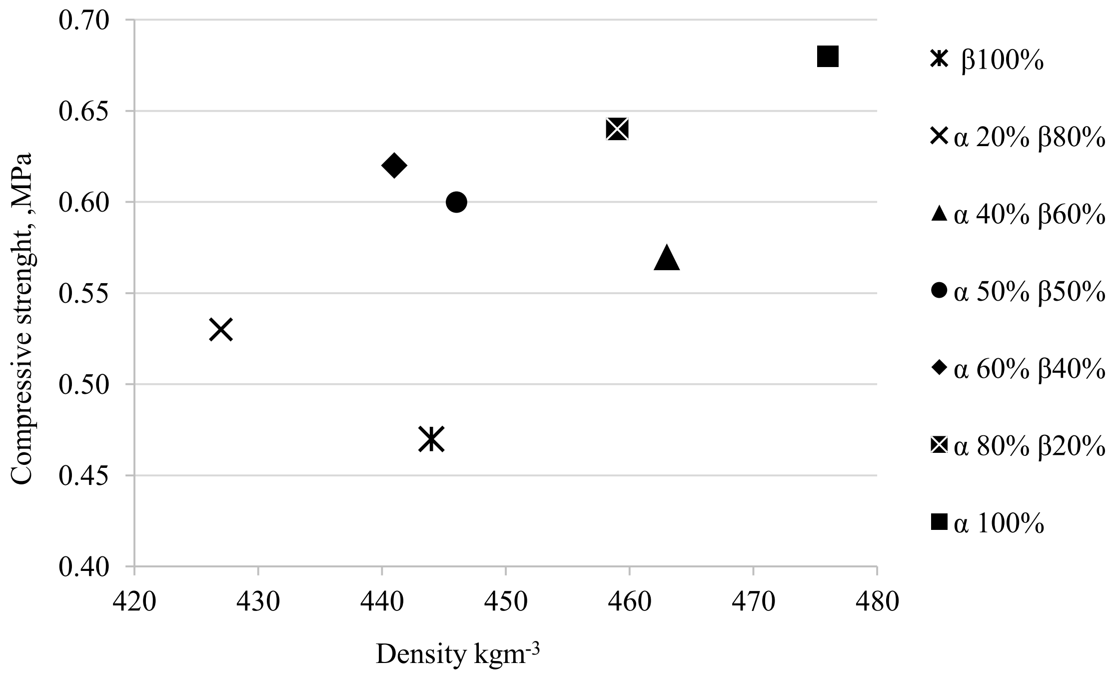


Fig.7. Compresive strength depending on density.

Conclusions

The study confirms that adding alpha hemihydrate per/for every 10% of the total amount of raw material reduces the necessary amount of water by 3-10%.

The result of the bending strength and compressive strength shows that the foam gypsum with proportionally added alpha hemihydrate at a density of 450±30kgm^{-3} has an increased bending strength by 12-42% and a compressive strength by 11-26% depending on the water-gypsum ratio.

The improvement of bending and compressive strength depends on the density of foam gypsum. The proportion of alpha hemihydrate affects the water-gypsum ratio which affects the average density.

Foam gypsum with added alpha hemihydrate (thickness of 40mm) increases the average sound absorption coefficient by 0.05-020 in the frequency range of 250-4000Hz.

References

[1] Jorge P.Arenas, Malcolm J.Crocker. (2010) Recent Trends in Porous Sound-Absorbing Materials. Sound ans Vibrations, Volume 7, p/12-17.

[2] M. Pedroso, J. de Brito, J.D. Silvestre (2017) Characterization of eco-efficient acoustic insulation materials (traditional and innovative), Energy and Building 140 (2017), 221-228 p.

[3] Pulkis K., Soloveiko S., Brencis R., Skujans J. (2016) Research of Improvement of Safety and Durability of Foam Gypsum Acoustic Plate by Using Multilayered Board. Proceedings of the 7th International Conference on Safety and Durability of Structures ICOSADOS 2016, May 10-12, 2016, UTAD, Portugal.

[4] EN ISO 11654:1997, Acoustics, Sound Absorbers for Use in Buildings, Rating of Sound Absorption.

[5] Brencis R. Foam gypsum technology development for sound absorption material production: Thesis for Doctoral Degree in Engineering Sciences. Jelgava: Latvia University of Agriculture, 2013. 119p.

[6] Elkhessaimi Y., Tessier-Doyen N., Smith A. (2017) Effects of microstructure on acoustical insulation of gypsum boards, Energy and Building 140 (2017), 24-31 p.

ISBN 978-9984-48-299-6