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THE PROPERTIES OF STRAW BALES WALLS

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Abstract

The world today faces many challenges. The world population is growing, along with their needs, while natural resources are depleted and the environment threatened, sometimes beyond repair.

What we need to do know is to go back to the past, reaffirm the models and materials used back then, but reinvent them in a contemporary context.

Straw bales are by-products, almost free, but clearly proven in a series of studies to be a nearly perfect building material.

This paper has explored the characteristics of straw bales relevant to construction. Based on the results, a broad specter of opportunities is opening for wide straw bale application in residential building.

Key words: *straw bales, eco-material, modulus of elasticity, rheological properties*

1. INTRODUCTION

Straw has been used in construction for a couple of thousand years as a roof- and wall-covering material and insulation. The invention of baling machines in the mid-18th century and their massive use later on sparked the construction of straw bale buildings. Different kinds of straw – wheat, barley, oats, ray and rice straw – have been used. The first straw bale structures were erected in western Nebraska, USA, out of sheer necessity. Wood and stone, the most popular building materials at the time, were scarce in the region and the European settlers resorted to straw.

Straw is an inexpensive building material, easy to find in nearly unlimited quantities.

Straw is yearly renewable agricultural waste, the dry stalk of cereal plants after the grain, chaff and root have been removed.

Every year, seven million cubic meters of straw are left unused in the fields of Serbia. Even if only the superb-quality straw is used for construction, 100,000 houses sized 100 square meters can be built in Serbia every year. Depending on the species, the renewable period for wood is 30 years or more, whereas these enormous quantities of straw are available every year. Nearly all other construction materials come from non-renewable sources.

The qualities of straw bales are best demonstrated in the construction of load-bearing walls, and it is exactly on load-bearing walls that most of the tests are conducted.

This paper will summarize the tests conducted on individual wheat straw bales, and the new experience in the preparation of the bales for the building process. The optimum density was defined, along with the requirements for straw bales to meet and the modulus of elasticity.

The growing use of straw bales in the context of regular structural requirements for building safety and usability inspired the author to establish the rheological property of straw bales in a number of tests. Clearly, considerable settlement and long-term creep deflection can be expected. In order to guarantee the standards of living expected today, it is necessary to predict the behavior of straw bale walls over time based on the test results, and define constructive and technological precautions to be taken.

2. RHEOLOGICAL BEHAVIOUR

2.1. Straw Bales

The technology of straw bale construction requires the properties of straw bales to be defined very accurately, together with the requirements they need to meet to be used in straw bale building. The typical straw bale is

made by the standard field baling machine, and the degree of compression obtained in the process shapes its properties. It largely depends on the baler, but there is a very simple way to provide for the satisfactory compression levels. The author also studied the importance of binding the bales with ties. A simple twine is most commonly used for this purpose in Serbia, usually the cheapest and of very poor quality; it often snaps under the weight of bales. The bales tied in this way cannot be used in straw bale construction. Instead, baling wire, polypropylene string or best-quality twine must be used.

In this research the only two interventions were to increase the competiveness and use high-quality ties. Neither increased the price of straw bales. Straw bale construction is inexpensive as such, and the objective was to establish the properties of common straw bales and their standard application. The special interventions such as extreme additional compression and super-quality ties would certainly improve further the quality of bales, which can then meet more versatile construction demands. At a higher price though. The expectation is that more demanding straw bale construction will require special additional treatments as a standard in the future.

Straw is baled immediately after the harvest, still containing high moisture contents. To let it dry naturally is what the first instinct is. Being exceptionally cheap, the straw bales are usually stacked in the form of a cone and the outer bales and those directly on the ground are deliberately wasted.

As said before, moisture is practically the one “enemy” to straw bales. Different studies and builders learning from experience say that about 10% moisture content is considered the most optimal for the building purposes.

The two-string wheat straw bales of 35cmx45cmx89cm were used in this study. Only the highest-quality strings were used.

The bales were stored in a closed area, and the moisture content was checked regularly. The density of the standard straw bale averaged 115-120 kN/m³.

We have analyzed the behaviour of straw bales compressed to a different degrees (different density, standard dimensions). The density over 100kN/m³ can guarantee the properties most favorable for straw bale construction.

The two-string wheat straw bales were exposed to working and ultimate loads. Only the bales loaded flat were included in the study. The conclusion was the growing load increased the modulus of elasticity. Lighter, less compressed bales displayed poorer properties, as expected. Even when the values were close to ultimate loads, the bales would bounce back to the original height within no more than 24 hours – a clear demonstration of elastic deformation.



Figure 1: A Single Flat Wheat Bale

The modulus of elasticity measured for different working loads placed on unplastered straw bales was approximately 600kPa. Different straw bales showed slight discrepancies from the mean value.

Other researchers determined a modulus of elasticity of between 100kPa and 1500kPa. When an experiment involved highly-compressed straw bales (traditionally shipped overseas and pre-compressed to take up less storage space) the results were several times higher. The large discrepancies are the result of varying quality of the baled straw and non-standardized research methods.

In this study only flat bales were used, because the wall is thicker, and its thermal and acoustic properties far better. Other studies involve on-edge bales, which produce a less thick wall, but quite sufficient for certain climates. On the other hand, on-edge bales behave differently compared to flat straw bales. Deformations are

considerably reduced, but the strings would just snap for no evident reason. There has been no research to establish a clear link between the type and quality of the tie and the load-bearing capacity of the straw bale.

Plastered straw bales were also included in the research. The bales were rendered with extended plasters (the process will be described in detail in the text below). The modulus of elasticity for plastered straw bales averaged 1650kPa. The load bearing capacity of plastered straw bales depended directly on the bond between the straw and the plaster. The results indicate that earthen plasters provide for an excellent bond. They are less firm than other plasters, but the cohesive effect is the best. Damp straws demonstrate the properties similar to those of reinforcement (old records show that during the World War II bamboo sticks were used as reinforcing bars in makeshift concrete structures). The fire-resistance tests the author has carried out show, however, that it is critical that the straws do not penetrate too deep into the plaster matrix and, more importantly, into the final coat. If they do, the straws let the fire penetrate the wall mass and reduce otherwise excellent fire-resistance qualities of the straw bale walls.

1.2. Straw Bale Walls

This study also focused on the behaviour of straw bale walls, both plastered and unplastered. Depending on the purpose of a structure, rendering might not be a requirement. If it is, there is the most favorable moment for plastering, which needs to be carefully chosen.



Figure 2: The Plaster-Straw Bond

For the analysis of the rheological behaviour of straw bale walls, we prepared the walls the way the experience thought us was the most advantageous.

The wheat straw bales (35mm x 45mm x 89mm) were two-string type bound using a high-quality twine. The average moisture content at testing was around 10 percent, and the bulk density 115kN/m³.

In order to protect the straw bales against humidity, they were placed on a wood base plate (“the pillow”). Building directly on insulated concrete or stone foundations might allow for condensation on surfaces, and the moisture can wear away the straw structure over time. Steel rebar pins (diameter: ϕ 14mm; length: 35cm) were attached to the base (two per bale). Experience shows that this way of pinning the bales to the base is the most efficient. There are other methods, too, but whatever the method, straw bale building allows for nearly unlimited creative freedom. Each bale was additionally pound into place. This is a very good building practice providing for higher density; the higher the density, the better the properties. After the third row, wooden spikes (diameter: ϕ 35mm; length: 80 cm) were driven through the cores, two per bale, holding the three rows together. Two wooden spikes were added to pin the fourth row down.

Using the wooden spikes is a traditional straw bale building technique, which holds them together.

Attempts were made earlier to make the walls more compact by rendering, as with any other building blocks. The rendering, however, failed to produce good results, because high levels of deformation call for significant plaster quantities, and a coat is usually destroyed by load-induced deformation. Furthermore, the plaster surfaces constitute thermal bridges requiring further thermal interventions and actually eliminating a very good property of the typical straw bale wall.

Additional stomping into place of each row of straw bales is necessary.

Once the wall is completed, the wall surface is still uneven, with protruding straw fibers. Contemporary living has raised both the aesthetic and hygienic criteria, and these walls need to be plastered on both sides using vapour permeable renders. Trimming the walls first will reduce the amount of plaster needed, and packing the plaster tightly into the straw makes for a very strong bond.

Apart from the trimming, a quick, simple technique that gives excellent results, the walls were additionally compressed with wooden mallets. The result was a good, well-finished, firm surface. For all the operations to prepare and finish the walls only one instructor with quickly trained assistants are needed.

The experience also showed that the properties of the wall are improved with a mesh, be it a metal, polypropylene or another type of reinforcement mesh. The mesh prevents the plaster from cracking as a result of settlement, and the walls with a reinforced mesh performed better at testing. We used a wire mesh attached to the wall surface. The builders and researchers exchanging their findings often suggest that wooden wedges or special nails be used. The research shows that the strongest and most efficient bond is made by pulling wire through the wall to tighten the mesh. Two or three wires are needed per square meter of the wall.

Once prepared, two coats of plaster are applied on the walls. For the time being, this study does not involve experiments with earthen plasters, but rather lime and extended plasters (with a minimum cement ratio). The walls were rendered with three coats of a cement/lime/send plaster in relative proportions 1:4:6.

The composition of straw is similar to that of wood, which has to be taken into account while rendering the straw bale walls, as the adhesion differs very much compared to other building materials.

The first coast of plaster needs to be pressed tightly into the straw. One should do it very carefully, because the properties of this bond largely shape the properties of the walls. The composition of the straw prolongs the curing process significantly, compared to other building materials. The experiment was carried out in an aired, closed space, and the curing period was three days for each coat.

After the first, tightly packed coat, the base coat was applied. The cement/lime/send ratio was the same. After three days, the thinnest, finishing coat was applied. For the purposes of the experiment, the load was applied 28 days after the finishing coat was applied. The thickness of the plaster depends on the wall finishing and how even the wall is. In theory, the plaster thickness averages between 2.5cm and 3 cm. In this research, the figure varies between 3 cm and 4 cm.

The tests carried out in this study, along with those carried out by other authors, call for further research of the properties of the composite wall. The accepted practice is that the calculation model for the behaviour of straw bale walls plastered on both sides is the same used for reinforced concrete. Each component of the wall carries the load in proportion to its stiffness. In order for such a calculation model to work out, constructive measures need to be taken for the loads to be distributed evenly over the wall surface (plaster and straw), and to ensure the load distribution between the straw bale walls and the foundations. The wooden “pillows” on the top and bottom of the wall is the accepted practice meeting this requirement. The plaster coats are exceptionally thin, and it is necessary to form a proper bond between the plaster and the straw as a prerequisite for co-action. Even though the stiffness of the straw bales is incomparably lower than the plaster stiffness, it is the straw bales that prevent local buckling. When a reinforcement mesh wasn’t used in the testing, local failures occurred due to local buckling of the plaster skin. Local failures were also recorded where the loads were applied if the bond and load distribution over the plastered straw bale wall were poor.

Other researchers analysed the impact of increased plaster thickness and ultimate load-bearing capacity. Increasing the thickness, quality and firmness of the plaster increases the load-bearing capacity only to a degree.

Another observation is that in the model of behaviour for straw bale walls plastered on both sides the calculated load-bearing strength was higher than the experimental values. Depending on the type of the test and experimental methodology, the experimental strengths can be significantly lower (up to 30 percent) than the calculated values. The reasons may vary – a different testing method, varying plaster and straw quality or imperfections of the calculation model.

This particular research was designed to determine the finest calculation model and define the optimum thickness and quality of plaster. It is important to say that the problems we have mentioned are not overly significant when it comes to working loads in one-storey buildings. In the tests carried out up to the working loads, none of the problems described above occurred. The research is to establish a realistic model of behaviour for straw bale walls, and to open a possibility to build larger walls and multistory structures within the capacity of the building material. Following the latest eco-friendly trends, and based on other good properties, too,

different studies have promoted growing use of earthen plasters. There's no indication to the contrary when load-bearing walls of reasonable height are concerned.

Another line of research has concentrated on solving technical challenges in straw bale building, to offer constructive strategies and deliver construction detail solutions that might close the gap between the actual behavior of straw bale walls and calculation models defining their potential. Whatever the research, the solution must respect the quintessence of the building material, and one of its major advantages – the low price. For the time being, we cannot accept expensive concepts that as efficient as they might be can annul the chief advantage of straw – being almost free. The next step in this research is a model centered on efficiency, allowing for the use of straw bales in far more demanding constructive contexts.

Definition of Rheological Properties of Straw Bale Walls

The previous research of straw bales and straw bale walls defined the important properties of the building material. More importantly, a stress and strain ratio was clearly established at working and ultimate loads, along with the minimum bulk density of straw bales used in construction. Another vital property is that the deformation was extremely high, even under working loads, and that even at very high load levels, even close to the ultimate, the straw bales rebound completely within 24 hours.

Generally speaking, not many studies of the properties of straw bales and straw bale walls are available at this point. Published papers fail to offer enough elements for a comprehensive overview or reliable judgment.

Builders do tend to share practical problems and methods to address considerable deflection and long-term deformation.

The purpose of this research is to find out how the straw bale walls will behave under working loads, and to determine instantaneous deformation and long-term creep deflection under working loads.

Nearly all building materials show varying degrees of deformation under long-term constant loads. Depending on the nature of the building material, the reasons for this phenomenon differ. It is also common knowledge that different factors can influence the creep deformation, varying from one building material to another and depending on the features of the given building material, the conditions surrounding the structure or the sample, and also the type of the load and the speed at which it is applied.

The properties of the straw bale depend on the straw, the degree of compression, the type and quality of the bond and moisture content. The goal behind this study was to design a diagram to connect the deformation, time and behaviour at different loads.

The accepted technology of straw bale building is to load straw bales up on the existing foundations, prepare a roof-to-wall connection and build the roof structure in the end. The importance of the roof-to-wall connection and the need to render the walls were discussed before. The deflection of straw bales under working compressive loads might go up to a few centimeters, which multiplied by seven or eight rows adds up to considerable deflection rates. On the other hand, the actual building period is the most critical for straw bale structures, because poor weather and insufficient protection against atmospheric influences might challenge permanently the stability and safety of straw bale buildings.

This is why it's very important to define the behaviour of straw bale walls under compressive loads, calculate the level of deflection (instantaneous and long-term), define properly the building technology and establish a link between the necessary speed of building and the time needed for carrying out long-term pre-compression.

Within the experimental section of this study, three different walls were tested, all of them four bales high (the straw bale wall normally includes seven or eight rows). The nominal height of the wall was 140 centimeters. The assumption was that the models of behaviour resulting from the experiment were pertinent to a full-height wall as well, and that the conclusions would be universally applicable.

The temporary elastic deformation depends on the modulus of elasticity and stress, and also on the speed at which the stress applies. For initial deformations it is difficult to separate accurately the instantaneous elastic deformation from the early creep deformation. For the working loads, however, it is the accumulated realized deformation that is used for further analysis.

Out of the three straw bale walls prepared for the tests, two were unplastered, one plastered. In all other aspects, the walls were prepared as described above.

In order to obtain relevant statistics, the loads were applied in the following manner.

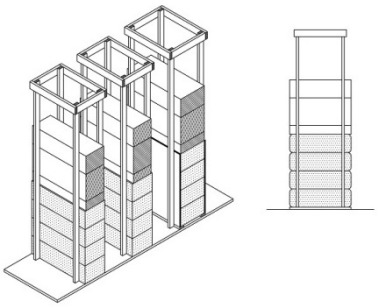


Figure 3: Disposition of the Model

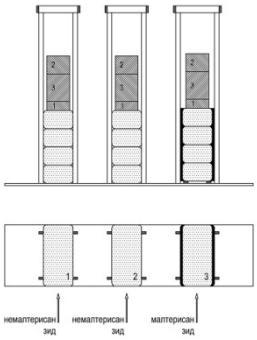


Figure 4: Disposition of the Model

Model 1 – The unplastered straw bale wall was loaded up to 1.16kN/m. The dead load applied corresponds with the weight of the straw bale wall. The resultant deformation was measured in a two-week period. The estimate was that it was the period required to build a straw bale wall and prepare everything for the installation of the roof structure. A dead load of 3.48kN/m was then applied as the equivalent of the load capacity of the roof structure, insulation and roofing in a typical family one-storey building. The deformation resulting from the total dead load was measured 28 days in total. After that, a load of 2.32kN/m, analogous to the snow load, was applied. The deformations caused by the accumulated permanent and temporary loads were measured in a period of seven days. After seven days, total moving loads were removed, and the deformations were measured for another seven days.

Model 2 – The unplastered straw bale wall was loaded to 6.96kN/m, and the deformations were measured for 56 days.

Model 3 – A dead load of 1.16kN/m was applied on the plastered wall. The sample was prepared as described above. The load matches the weight of a straw bale wall. The deformations were measured in a period of two weeks. It was approximately the time needed for building a straw bale wall and to complete the preparations for installing a roof assembly. A dead load of 3.48kN/m was added, approximating the load produced by the roof structure, roof insulation and roofing in a typical family one-story building. The subsequent deformations resulting from the total dead load were measured for 10 days. After that period, the wall was rendered as described above. After 28 days, a load of 2.32 kN/m was added to simulate a snow load. The deformations resulting from the total dead and live loads were measured the next seven days. After that period, the total moving load was removed, and the deformations were measured the next seven days.

The test was carried out in a closed space, at virtually constant temperatures and moisture content.

3. TEST RESULTS

The models were prepared as described above, the loads were applied and the deformations measured once a day.

Model 1 – After a load equal to its own weight was applied, the unplastered, 140cm straw bale wall deformed 6mm. Earlier tests showed that the total deformations in this experiment fall in the zone of elasticity. The modulus of elasticity of around 570kPa corresponds with the deformation – five (5) percent less than when individual straw bales were tested. This is yet another confirmation that there are discrepancies and different straw bale properties to be taken into account. The largest deformation occurred instantaneously, i.e. immediately after the load was applied. After that the deformations continued to grow, reaching a maximum on the first and second day upon the application of a load. They kept growing, but the increments were significantly slower. In the next 14 days, the total deformation doubled to 11mm. The total creep deformation was 5mm, averaging 0.36mm a day. Most of the deformation occurred in the first few days upon the application of the load. After 14 days, a load of another 3kN was added, and the instantaneous deformation of 20mm was measured. Again, the behaviour of the sample was nearly identical to the behaviour following the application of the initial load. The largest deformation was recorded immediately after the load application; after that the deformation kept growing visibly over the first few days, after which the increments were getting smaller. Twenty-eight days after the load application (42 days after the beginning of the experiment), the total measured deformation was 59mm; the creep deformation after the added load was 28mm, averaging 1 mm a day. In this case, too, the maximum deformation was recorded in the first few days, and the increments were dropping after that time. After 42 days, a 2kN load was applied to simulate a snow load. The instantaneous deformation of 12mm was measured, proving that the material was in the zone of elastic deformation. The load was effective seven days. The total deformation recorded was 78 mm, and the creep deformation averaged 1 mm a day. The total deformation was practically realized in the first few days, whereas deformations were negligible towards the end of the tested period.

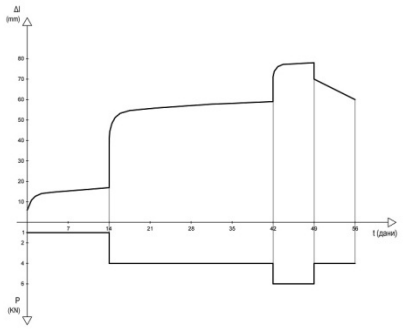


Figure 5: Model 1; Deformation/Time

After a week, the movable load was removed, and an instantaneous rebound was recorded to be 18 mm. Seven days on removal of the load the conclusion could be made that the total deformation was elastic, and the creep deformation reversible. The difference of 1mm falls within the margin of error, and is negligible.

In total, the instantaneous deformation was 38mm, nearly a half of the total deflection, while long-term deformations of 40mm also accounted for one half of the total deformation.

Model 2 – A total load was applied on the unplastered straw bale 140cm-wall, and a deformation of 32 mm was measured. The deformation is by some 10 percent smaller than in phased load application. A similar behaviour was recorded in other materials. After the total load was applied and instantaneous deformations measured, long-term deformations were recorded in the next 56 days. The instantaneous deflection was the largest, occurring immediately after the load application. The deformations continued to grow, reaching a maximum value on the first and second days upon the load application. They did grow further, but the increments were not as prominent. By the end of the measuring interval, the long-term deformations reached 28mm. Basically, the ultimate value of total deformation was reached in a 14-day interval after the application of the load, but the tests were carried out simultaneously on the walls, the measurements continued until the end of the testing period.

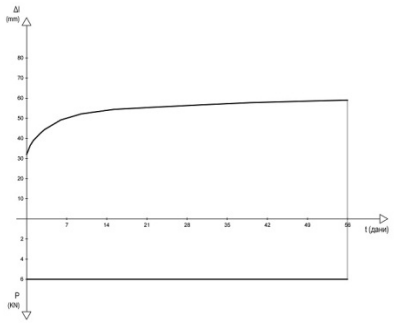


Figure 6: Model 2; Deformation/Time

Model 3 – After the application of its own weight, the unplastered straw bale wall of 140cm in height showed a deformation of 6mm. Earlier tests showed that the total deformation in this experiment was in the zone of elasticity. The deformation corresponds with a modulus of elasticity of around 570kPa, five (5) percent less than in individual straw bales. This is yet another confirmation that discrepancies and different straw bale properties do exist, and need to be taken into account. A possibility of measurement error aside, the deformation was still identical to the deformation recorded in the Model 1. The largest deformation was recorded instantaneously, immediately after the load was applied. After that the deformations continued to grow, and were the largest on the first and second days upon the load application. They continued to grow, but in smaller increments. Over the next 14 days, the total deformation reached 12mm, i.e. it doubled. The total measured creep deformation was 6mm, or 0.42mm a day. The wall largely deformed over the first few days after the load was applied. After 14 days, a load of 3kN was added, and an instantaneous deformation of 19mm was measured. Again, the behaviour of the wall sample was identical to the behaviour after the application of the initial load. The largest deformation was recorded immediately after the application of the load, after which the deformations continued to grow significantly over the first few days, and at increasingly small increments later on. The behaviour of the Model 3 is identical to the behaviour of Model 1. After ten days upon the application of the load, and 24 days after the beginning of the experiment, the total measured deformation was 52mm; the creep deformation after the additional load was applied was 21 mm, or 2mm a day on average. In this case, too, the maximum deformation rate was recorded in the first few days, and the increments dropped afterwards. At that point, the wall was rendered with a lime plaster, with a minimum quantity of cement added. The plastered, loaded wall was not exposed to any changes of the load for the next 28 days. After the 28 days, and 52 days after the beginning of the experiment, an additional load of 2kN was applied to simulate a snow load. An instantaneous deformation of 2mm was measured, proving that the wall was in the zone of elastic deformation. The load was effective seven days. At the end, the total deformation was 56mm; the creep deformation was 1mm. Only minimal deformations were recorded, falling within a margin of observational error. The total deformation was effectively realized over the first few days, but it was negligible at the end of the period. After seven days the movable loads were removed, and the instantaneous reversible deformation was 3mm. There were no additional rebounds after seven days. The conclusion is that seven days after the load was removed the total deformation was reversible.

In absolute terms, the instantaneous deformations were 27mm, approximately a half of the total deformations; long-term deformations were measured to be 29mm, also one half of the total deformation.

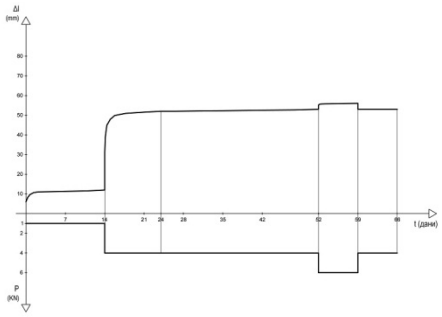


Figure 7: Model 3; Deformation/Time

On this model, the total dead load was applied (two-thirds of the total load), and the total instantaneous and long-term deformations were realized. After that the wall was plastered, and additional loads applied after reinforcement. The deformation was practically negligible (only a few millimeters).

4. CONCLUSIONS

The tests were designed to establish the behaviour of straw bales under load, and the behaviour over time when exposed to constant loads.

The preparation of the wall samples was used to verify a number of assumptions for practical applications in a pilot straw bale building project.

The tests confirmed that an emphasis needs to be placed on the baling process to produce properly compressed bales. Likewise, the quality of ties is as important, as the two characteristics put together are vital to the total load-bearing capacity of the straw bale wall.

It's always a good idea to pound the bales into place during construction, as this significantly improves the properties of the wall. It is difficult to establish the exact level of compression though, but the properties of the building material are improved by pre-compression and the safety ratio is increased. At any rate, the properties of straw bale structures cannot be discussed based solely on the exact values of modulus of elasticity and ultimate strength, but rather take into account the amplitude of these values, just like with other building materials.

Rendering considerably improves the strength, that is, ultimate bearing capacity of the straw bale walls. The rendering process is critical insofar as the bond between the plaster and the straw needs to be as strong as possible. It appears that earthen plasters provide for the best adhesion, but the properties of walls rendered with earthen plasters need to be tested in a separate study. The thickness of the plaster improves the features of plastered straw bale walls to a degree only, and it requires a separate research to establish a ratio between the thickness of the plaster and overall properties of the straw bale wall. A reinforcement mesh improves the bond between the plaster and straw, and enhances co-action of the materials in the composite wall. Local buckling can be avoided if the mesh is tied on both sides.

If exposed to working loads, the straw bales are in the zone of elastic deformations. Wheat straw bales loaded flat rebound within 24 hours upon removal of the load.

The rheological properties of straw bale walls entirely correspond with an ideally elastic body, with a note that the deformation is not instant, but happens in a relatively brief period of time. The model unplastered straw bale walls, placed under load, showed that elastic deformation occurs on the application of a load, and that it is fully proportional to the elastic modulus of the wall. After the instantaneous deformation occurs, the creep deformation proportional to the level of elastic deformation follow. The modulus of elasticity grows in pre-compressed straw bales and straw bale walls. At working loads, the slope of the stress and strain curve is virtually constant. The tests on the sample walls have confirmed this. When working loads were applied, the creep deformations are elastic and proportional. On removal of the load, the total deformation – the elastic and creep deformations put together – is reversible in a period not longer than seven days. For working loads applied on a 2.8m-wall, the total deformation (elastic and creep deformation) would be around 160mm. The instantaneous deformation is nearly one half of the value, and the creep deformation also a half of the total deformation.

Testing a sample on which the total load was applied shows that the instantaneous and long-term deformations are nearly 25 percent lower than in phased loading, similarly to the behaviour of other building materials.

When the dead load was applied first, and the wall was plastered after a period of time needed for the instantaneous and long-term deformations to realize, the deformations occurring subsequently upon the application of temporary loads were basically negligible. The instantaneous and long-term deformations were measured to be just a few millimeters.

By choosing the right technological procedure and rendering only after the total dead load is applied, vertical deformation is virtually eliminated and conditions created for the safe use of the structure.

The low modulus of elasticity and high deformability require a proper building technique. If the building technology cannot guarantee long periods between individual building stages, the results of the tests lead to the

conclusion that the same effect can be achieved by pre-compressing the walls by five to six percent of their original height. After the test, the author defined a few technical solutions to carry out the process.

If the circumstances surrounding the building process are such as to make time irrelevant (it's all about two or three weeks), it is enough to wait for settlement to finalize, and no other method is necessary.

This study has demonstrated the elastic behaviour of straw bales when exposed to working loads and defined qualitative diagrams to show the deformation/time ratio. It fails to define the values of individual ratios, because of not at all insignificant discrepancies that might occur in the basic mechanical properties of straw bales, which other authors have noted, too. The behaviour of the material depending on loads has been defined. Based on these indicators, it is possible to adjust the technological process to remove all possible challenges in the use of straw bale buildings.

The next research step in Serbia is to define the basic elements of a special building rulebook for straw bale buildings, as a major prerequisite for a more massive use of this building material

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