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Hygrothermal Properties and Performance of Sea Grass Insulation

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Summary: *In the attempt to obtain knowledge of the hygrothermal properties of sea grass as thermal insulation, experiments have been carried out in the laboratory to determine the thermal conductivity, sorption properties and the water vapour permeability of the material.*
In order to investigate the hygrothermal performance in the field, four test walls have been built. The relative humidity and temperature in the constructions have been measured during a winter period and are presented in this paper.

1. Introduction

Historically, sea grass has been known and used for years as thermal insulation. However, it is not recognized as a contemporary building material, and thus information regarding its hygrothermal properties and performance in modern constructions is scarce.
As an organic building material it is of interest, however, to investigate the hygrothermal properties and performance of sea grass as thermal insulation. This is done by performing experiments in the laboratory as well as measurements in the field. The laboratory experiments consist of determination of thermal conductivity, determination of hygroscopic sorption properties and determination of water vapour transmission properties. Similar experiments have previously been performed on other alternative insulation materials such as paper wool, sheep's wool and straw, however, results concerning sea grass have been difficult to identify. The measurement in the field consists of measurement of temperature and relative humidity throughout the constructions.

2. Description of sea grass insulation

Sea grass is an excess product from the sea. The width of one straw is typically 3-6 mm, while the length varies from a few centimetres to pieces as long as 50 cm. The material investigated is a loose fill material having a density of 53 kg/m^3.
In this paper investigations are performed with both regular and washed sea grass. The regular sea grass is going through an initial process, where it is washed and dried naturally outside and then baled. Since the material is not further processed, it might contain salt, when used in buildings as thermal insulation.

3. Determination of thermal conductivity

To determine the thermal conductivity of regular sea grass, a hot plate apparatus was used. A sketch of the equipment as well as a photo can be seen in Figure 1.

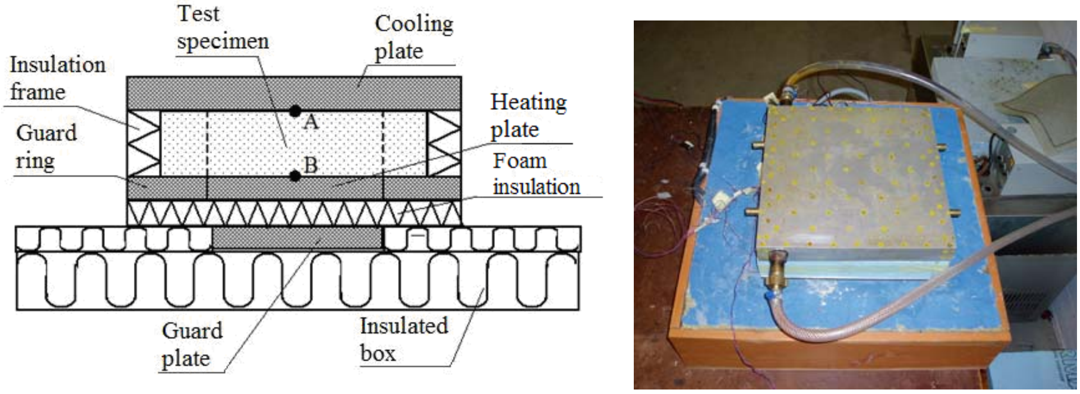

FIG. 1 Equipment used for determination of thermal conductivity of regular sea grass.

To investigate the correlation between density and thermal conductivity a number of measurements have been carried out on regular sea grass with different densities. The results of these experiments are shown in Figure 2.

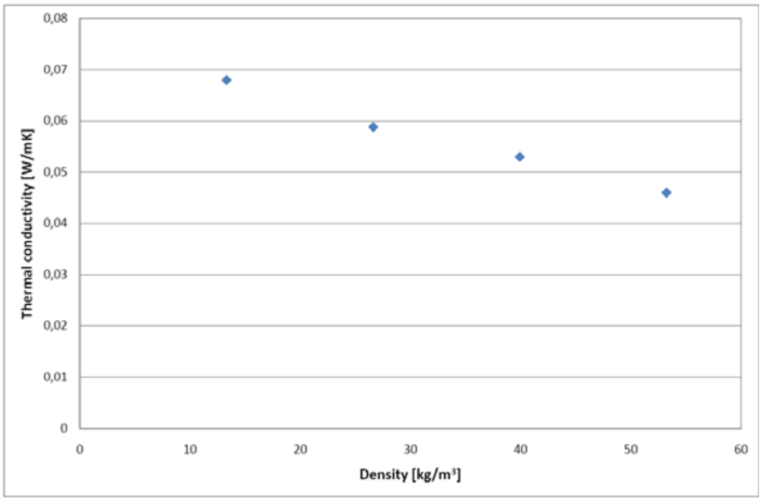

FIG. 2: Thermal conductivity of regular sea grass insulation as a function of density.

As can be seen from the results, the thermal conductivity is decreasing with an increasing density, and an approximately linear correlation between density and thermal conductivity can be seen. The lowest thermal conductivity of 0.046 W/mK is obtained at a density of 53 kg/m^3.

4. Determination of hygroscopic sorption properties

As previously mentioned regular sea grass contains salt, which is known to have a great influence on the hygroscopic sorption properties. Therefore, the hygroscopic sorption properties of both regular and washed sea grass have been determined.

The determination of the sorption properties is performed in a climatic chamber according to ISO 12571 (2000) where the temperature in the chamber is sought maintained at 23 °C while the relative humidity is altered. The specimens are arranged in fine-meshed bags of polyester, which are tacked in order to prevent the specimens from falling to the bottom of the bags. After finalizing the measurements, the specimens are dried at 105 °C until constant mass is reached. A sketch and a photo of the arrangement of the bags inside the climatic chamber with automatic weighing equipment can be seen in Figure 3.

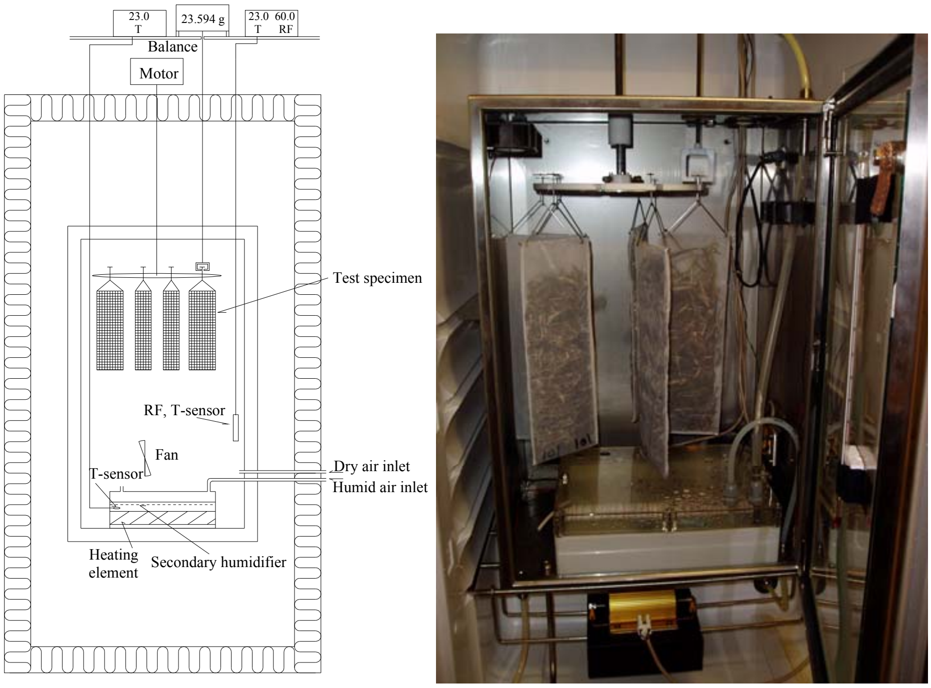

FIG. 3: Arrangement of bags with specimens in climatic chamber.

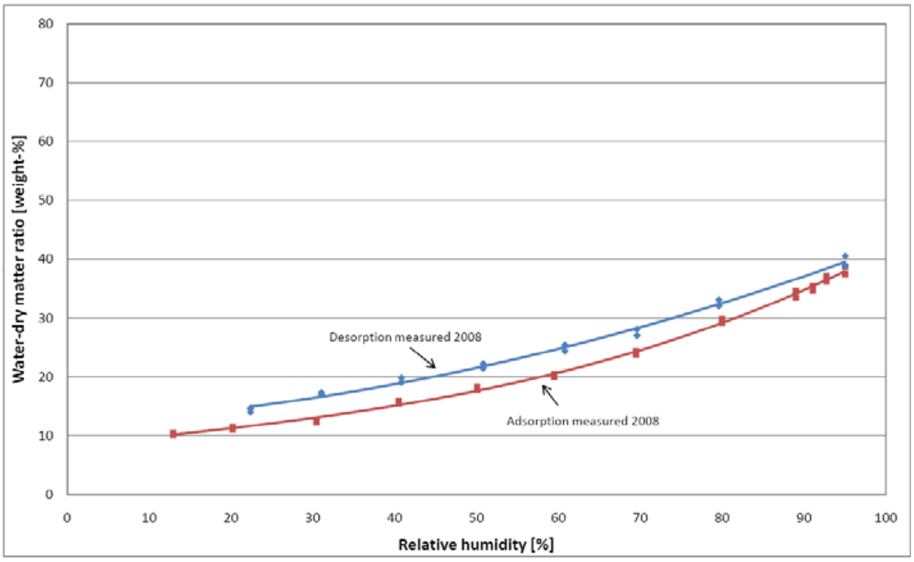

FIG. 4: Sorption properties of washed sea grass dried at 105 °C.

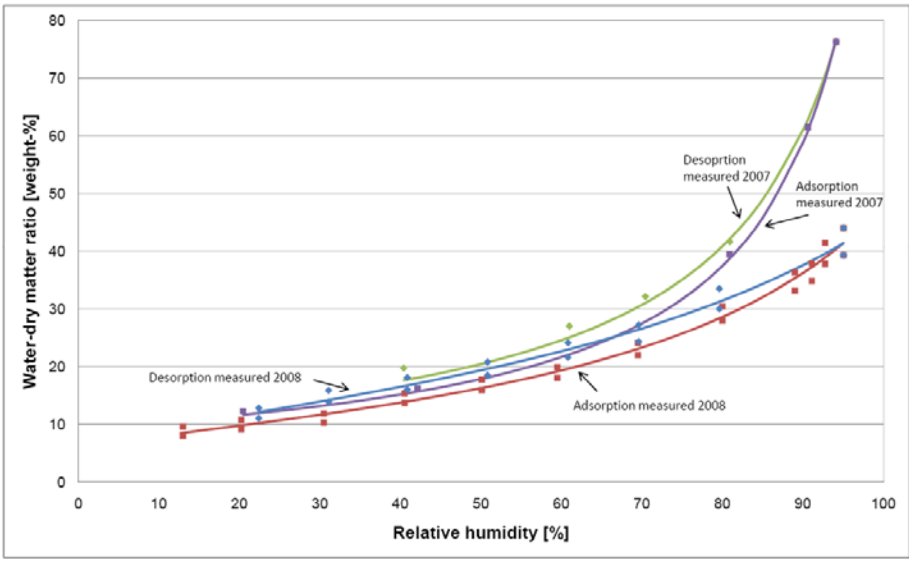

FIG. 5: Sorption properties of regular sea grass dried at 105 °C.

The results show that sea grass can be characterized as a hygroscopic material. It is seen from Figure 4 and 5 that the regular sea grass absorbs more water than the washed sea grass at a relative humidity above 70 %.
In Figure 5 the results of two separate experiments are shown, and as can be seen the difference in the results are significant. Yet, the specimens investigated are from the same batch of sea grass.
This difference between the measurements might also be caused by the lack of systematic processing of the sea grass, such as if it had been an industrial product, and therefore it may indeed be a rather inhomogeneous material with diverse hygroscopic properties.

5. Determination of water vapour transmission properties

Determination of the water vapour transmission of regular sea grass is performed using the wet cup method according to Hansen & Hansen (1999). However, since the sea grass is a loose fill material, the design of the cup used in this experiment is changed. Instead of the cup, a double bucket is used. In the bottom of the top bucket a fine mesh is placed to keep the specimen in place. The lower bucket is a cut off from the bottom of another bucket, and is used to contain a saturated salt solution. These two parts are fastened to each other using waterproof tape to seal the double bucket. At the top of the specimen inside the top bucket, a metal net is placed in order to keep compression on the specimen to achieve the desired density at 53 kg/m^3. The principle of the bucket and the arrangement can be seen in Figure 6.

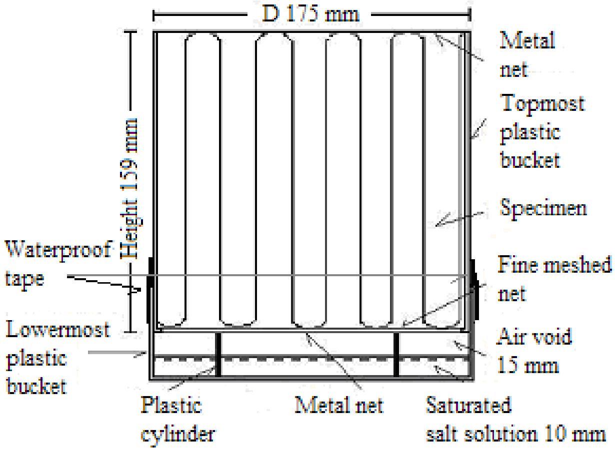

FIG. 6: Section of bucket used for determination of water vapour resistance (left) and photo of buckets in climatic chamber (right).

The results of the experiment can be seen in Table 1.

TABLE. 1: Water vapour resistance and permeability of regular sea grass.

Specimen	Specimen no. 1	Specimen no. 2	Specimen no. 3
Water vapour resistance [m²sGPa/kg]	1.4	1.3	1.4
Water vapour permeability [µg/(m·s·Pa)]	8.9	8.1	8.6

6. Measurements in the field

In order to be able to investigate the actual temperature and relative humidity distribution in an exterior wall containing regular sea grass insulation at a density of 53 kg/m^3, four test elements were built in a test shed where it was possible to control the indoor climate. The shed was located in an outdoor area at the Technical University of Denmark. Each element has the dimensions given in Figure 7 below. Five sensors of the type Sensirion SHT75 are placed in each element in order to measure temperature and relative humidity through the construction. The placement of the sensors can be seen as the dots also marked with A, B, C, D, and E in the cross sections of the elements.

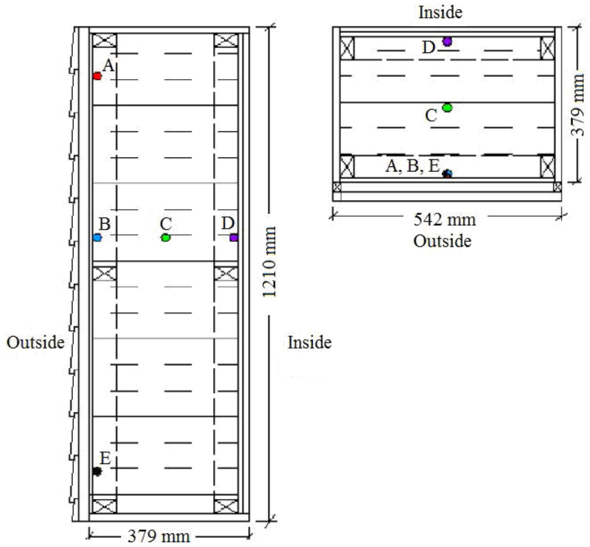

FIG. 7: Vertical and horizontal cross sections of test elements used for measurements in the field.

The different layers inside each of the four test elements are listed in Table 2. Element no. 1 is the reference element and only one parameter is changed for each element compared to this element.

TABLE 2: Description of test elements.

	Element no.1	Element no. 2	Element no. 3	Element no. 4
		Inside		
26 mm	Gypsum	Gypsum	Gypsum	Gypsum
	0.17 mm PE Vapour barrier	-	0.34 mm Eco-vapour retarder	0.17 mm PE Vapour barrier
343 mm	Regular sea grass	Regular sea grass	Regular sea grass	Glass wool
9.5 mm	Wind-proof gypsum	Wind-proof gypsum	Wind-proof gypsum	Wind-proof gypsum
25 mm	Ventilated void	Ventilated void	Ventilated void	Ventilated void
10.5 mm	Wood facing	Wood facing	Wood facing	Wood facing
		Outside		

The eco-vapour retarder used in element no. 3 consists of two layers of kraft paper unified with a mesh of fibreglass and polyethylene glue. The water vapour permeability is found to be $9.8 \cdot 10^{-5}$ μg/(m·s·Pa) using the cup method referred to in Section 5.

Investigations of relative humidity inside the constructions are interesting, since too high relative humidity will cause high moisture content for a shorter or longer period which can damage the surrounding construction as well as increase heat transmission through the construction. The measurements will show where high relative humidity occurs and for how long a period.

Temperature and relative humidity were measured in a winter period from 18th of December 2007 till 17th of January 2008. During this period the relative humidity indoors was kept at approximately 60 % and 20 °C to obtain a significant difference in vapour pressure between inside and outside and thereby increasing the moisture flow. Before the measurements began, the elements had been situated in the shed from February 2007. During this period the relative humidity and temperature were only held constant at 60 % and 20 °C respectively until May 2007.

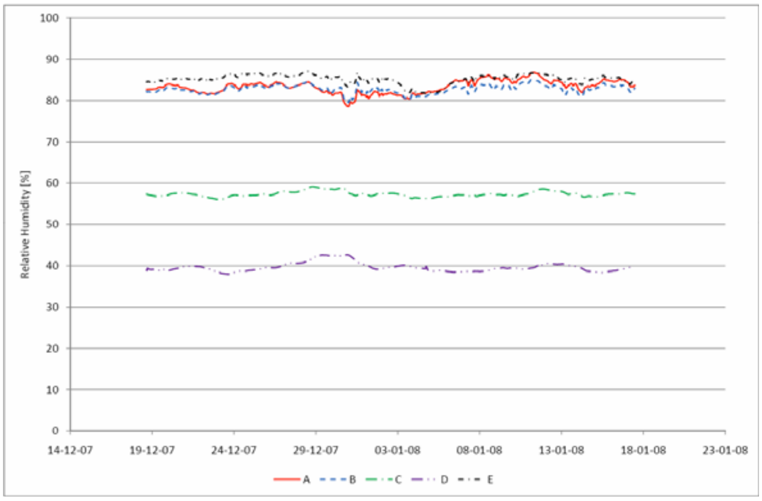

FIG. 8: Measured relative humidity in Element no. 1

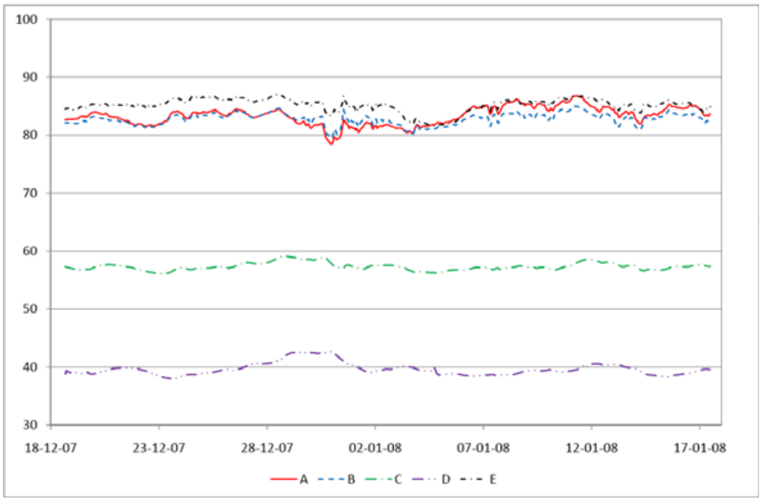

FIG. 9: Measured relative humidity in Element no. 2.

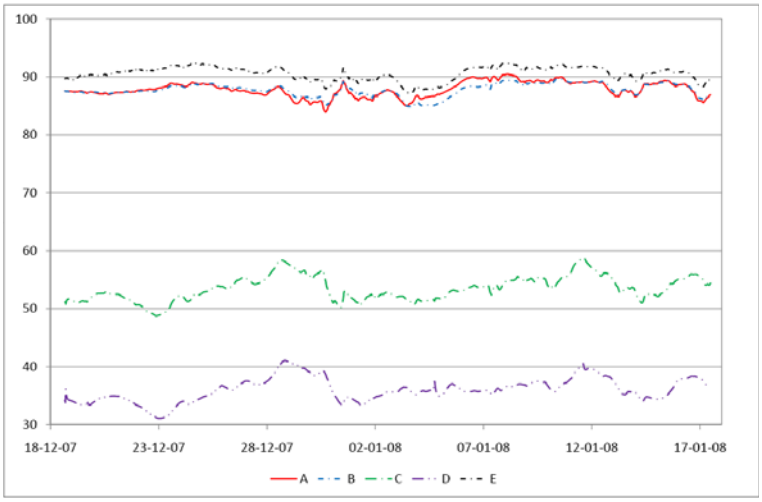

FIG. 10: Measured relative humidity in Element no. 3.

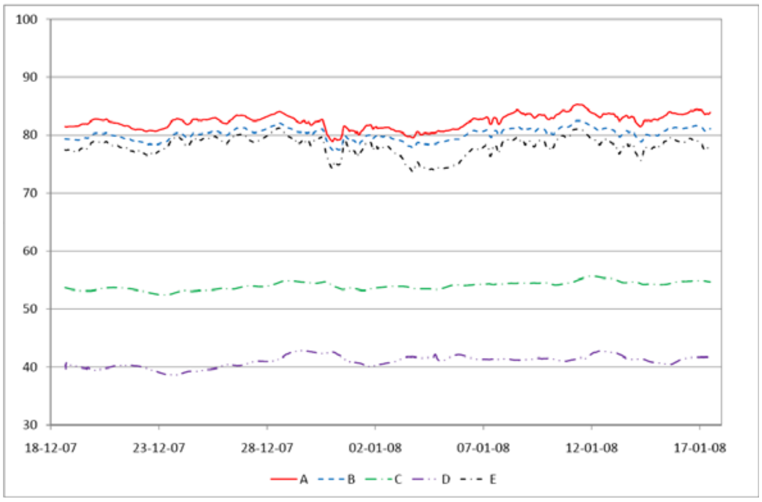

FIG. 11: Measurement of relative humidity in Element no. 4.

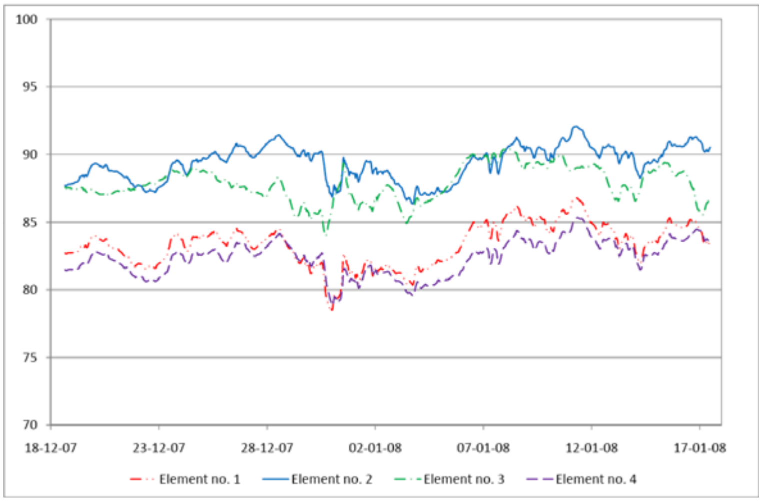

FIG. 12: Measured temperature and relative humidity in point A in all four elements.

As the period of measurement was not long, it is difficult to conclude if the high relative humidity which can be seen in the outer part of the construction will result in damage of the construction. When comparing the measurements, the results for Element no. 1 and no. 4 are similar compared to Element no. 2 and no. 3. However, the relative humidity in the element containing regular sea grass is slightly higher than seen in Element no. 4 containing glass wool. This tendency is also verified in Figure 12, where the relative humidity in point A for all elements is unified in one figure.

Also, it can be seen from Figure 12 that the relative humidity in the outer part of the construction is quite high and the temperature quite low. This means that a sudden drop in temperature of only a few degrees could result in condensation and thereby possible damage to both the regular sea grass and wooden parts in the construction.

7. Conclusion

Through the experiments it is found that regular sea grass is a material with some parameters appropriate for thermal insulation. However, the high hygroscopicity for the regular sea grass, especially at high relative humidity, is of some concern due to the risk of rot in both the material as well as the wood in the construction. This might indicate that the regular sea grass should be further processed before it is used in constructions to avoid corrosion, due to the high salt content or other severe damage on the constructions. It is found, though, that the relative humidity in the outer part of element no. 1 is approximately at the same level as the relative humidity in element no. 4 containing glass wool, which is a commonly used insulation product. The thermal conductivity of regular sea grass is not quite as low as that of conventional insulation materials, but approaches desired values for an insulation product if the density is high.

8. References

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