ALGINATE IN ARCHITECTURE
An Experimental Approach to the New Sustainable Building Material[1]

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Abstract: The embodied carbon emissions from building materials and construction are today responsible for 38% of annual global GHG emissions in the current global environment. If we are to reach the European energy plan with net-zero emissions by 2050, now is the time to rethink our construction principles, as well as building elements and materials.

One of the possible steps to achieve this goal is to explore new solutions using regional sources and sustainable raw materials. In our research, we use alginate to see if we can substitute conventional structural elements with others based on this sustainable material, whose potential in architecture is so far unrevealed. Alginate, which is found in brown algae cell walls, is an irreversibly hardening elastic moldable material, i.e. once hardened, its form can neither be changed nor converted back into an original state.

In this paper, we present a series of experiments with different natural additives. By respecting the natural behaviour tendencies of macroalgae, but also by experimenting with chitosan to increase the rigidity and glycerin to increase the elasticity of the alginate, various shapes of elements are obtained, ranging from linear ones, towards membranes and shells. An initial tensile test is made for the linear elements and the results are commented in comparison to similar natural fibres. The created models demonstrate promising outcomes while also opening some new research questions, confirming the potential of this innovative application.

Keywords: macroalgae, alginate, sustainable material, regional resources, building material, architecture

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INTRODUCTION

The UN Environment Programme 2020 Global Status Report for Buildings and Construction – Towards a zero-emission, efficient and resilient buildings and construction sector[2], presents alarming figures. 35% of the world's energy demand and 38% of the world's emissions are caused due to the construction and building sector. If we continue to use the same materials and building principles until 2050, embodied carbon will be responsible for almost 50% of the total construction emissions. Since the energy goal in Europe is to achieve net-zero emissions by 2050[3] rethinking of building materials is the fundamental step on the way to building elements with a low carbon footprint that will make a positive impact on the developments in the building industry.

One of the possible steps to achieve this goal is to explore new solutions using regional sources and sustainable raw materials. In our research, we use macroalgae in the form of alginate, the potential of which in architecture is yet to be revealed.

Behind the term algae hides an eukaryotic plant-like organism. Although algae are mainly found in water and are capable of photosynthesis, they are not defined as plants, but belong to the biological kingdom of chromista[4]. The number of algae species in the world is not yet known, but research estimates that there are between 30,000 and one million[5]. The big challenges in species registration are estimating which organisms are to be defined as algae and distinguishing the single species from each other. From this large number of species, however, only about 160 have so far found industrial applications[6].

Water – both sea and freshwater – is the main habitat of algae, as mentioned above. A couple of species, however, have adapted to other environmental situations, so they can be found in the air (aerophytes), on the ground (terrestrial algae) and in snow. One of the most important aspects of algae is their filtering ability – not only are they able to filter toxic substances from water, but they are also an important part of the hydrocarbon cycle. Due to their swift growth and photosynthesis, they are estimated to be the supplier of about 50% of the world's oxygen demand[7].

MICROALGAE VERSUS MACROALGAE

Differentiation can be made in broad terms between microalgae (Fig. 1, left) and macroalgae (Fig. 1, right). Microalgae can be further subdivided into unicellular organisms, colonies and filaments. Depending on the species, these range in size from a few to several hundred micrometres (µm). They do not have roots, stems or leaves and are specially adapted to an environment with viscous forces. Estimates

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2 United Nations Environment Programme (2020), *2020 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector,* Nairobi, 2020, 4.

3 https://ec.europa.eu/clima/policies/strategies/2050_en

4 T. Cavalier-Smidt: "Kingdom Chromista and its eight phyla: a new synthesis emphasising periplastid protein targeting, cytoskeletal and periplastid evolution, and ancient divergences", *Protoplasma*, V.255, 2018, 297–35.

5 www.Algaebase.com, 37.455 species of algae have been recorded so far.

6 M. Smith and J. Senior: "Alginate. Hydrogels with Tuneable Properties", *Advances in Biochemical Engineering/Biotechnology*, 2021, 161, DOI: 10.1007/10_2020_161.

7 V. Smetacek: *Die Primärproduktion der marinen Plankton-Algen*, Spektrum der Wissenschaft, Heidelberg, 1991, 52.

Fig. 1

indicate that in phytoplankton biomass[8] are annually about 45 – 50 gigatons of carbon dioxide. The biodiversity of microalgae is enormous and it represents a virtually untapped resource. Over 15.000 new compounds derived from algal biomass have been chemically determined. These include carotenoids, antioxidants, fatty acids, enzymes, polymers, peptides, toxins and sterols[9].

Industry is making efforts to make use of the vast potential microalgae represent, as they have also aroused the interest of many architects and artists. The focus of interest is, however, above all on energy generation. Photobioreactors can be integrated into architecture, as demonstrated by the BIQ House in Hamburg[10]. Another example is ecoLogicStudio. An architecture and urban design office that specialises in environmental design, urban self-sufficiency and the integration of nature in architecture[11]. Design examples include the Bionic Chandelier by Julian Melchiorri[12] or the Coral and the indoor micro-algae farm created by the design student Hyunseok[13].

Microalgae can be cultivated on a small laboratory scale, in open or closed[14] systems and in large photobioreactors (Fig. 1, middle).

Fig. 1: left) Microalgae colony; middle) photobioreactors; right) macroalgae.

While microalgae are unicellular, microscopically small organisms, macroalgae are multicellular. Macroalgae, with the binomial scientific name *Macrocystis pyrifera*, is also commonly known as giant kelp and belongs to the brown algae genus. It can grow up to 45 meters in length, with a growth rate of up to 30 cm per day[15]. This type of algae is usually found in large "colonies" – kelp forests. These are characterized, on the one hand, by their density and size. On the other hand, they provide a habitat for an incredible range and quantity of other species. Thus, kelp forests are an important component of both coastal ecosystems and also the world climate.

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8 P. G. Falkowski: *Der unsichtbare Wald im Meer*, Spektrum der Wissenschaften, Heidelberg, 2003, 56–62

9 K.H.M. Cardozo, T. Guaratini, M.P Barros et al: "Metabolites from algae with economical impact", *Comparative Biochemistry and Physiology, Part C: Toxicology & Pharmacology*, Volume 146, Issues 1–2, 2007, 60–78.

10 https://www.buildup.eu/en/practices/cases/biq-house-first-algae-powered-building-world

11 http://www.ecologicstudio.com/v2/index.php

12 https://www.julianmelchiorri.com/Bionic-Chandelier

13 https://hyunseok.xyz/projects/the-coral-home-algae-farming/

14 E. Cohen, A. Koren and S. Arad: "A closed system for outdoor cultivation of microalgae", *Biomass and Bioenergy*, Volume 1, Issue 2, 1991, 83–88.

15 https://www.algaebase.org/search/species/detail/?tc=accept&species_id=w7faaac344fafeb7e

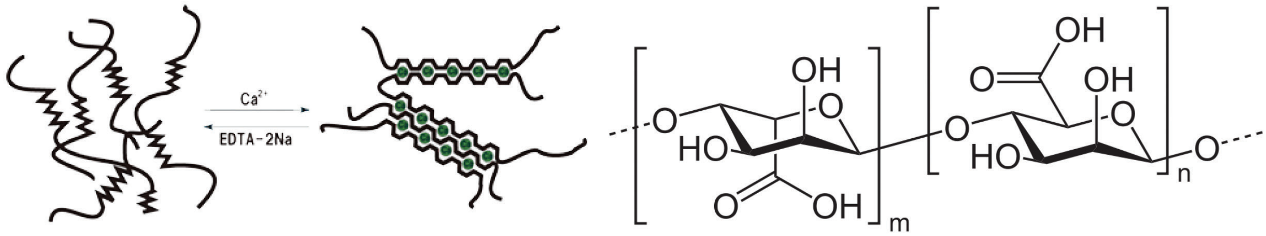

Fig. 2

They are a significant oxygen producer and therefore have an important function as a carbon sinker.

The harvesting of algae today is mostly fully mechanical or automatic. In North America in particular, so-called “kelp harvesters” are used. These can harvest up to 300 tons of algae per day. The giant kelp is cut off a few meters below the water surface and loaded onto the deck by a conveyor belt. Harvesting by hand with sickles or picking up the seaweed that washes up on the beaches is also possible.

ALGINATE

Alginate is a product of alginic acid processing. The salt of alginic acid is generally referred to as alginate, which is a by-product of the extraction of iodine from marine algae by wet process. This is formed by brown algae (*Laminaria*, *Ecklonia*, *Macrocystis*, *Lessonia*, *Ascophylum*, and *Durvillea* – serve for commercial use) and by some bacteria (e.g. *Azotobacter*). In algae, alginate represents the structuring element of the cell walls. The intracellular gel matrix provides both flexibility and strength to the algae. Alginate is mainly used in the food, pharmaceutical and cosmetic industries as a thickening or gelling agent. The collected algae are given a preliminary cleaning to eliminate dirt and impurities and are finally dried. After drying, they are delivered to the alginate producer.

Alginate belongs to the irreversibly hardening elastic moldable materials, i.e. once hardened, the form can neither be changed nor converted back into the original state. While the cellulose ensures that the cell walls have the necessary strength, the alginate, together with water, forms a slimy, gelatinous mass, in which the cellulose components – the fibrils, are embedded. Insoluble alginate gels additionally strengthen the cell wall and ensure that the brown algae can resist mechanical stress, e.g. those caused by the sea.

From a chemical point of view, alginate consists of several, zigzag, negatively charged threads, or chains (Fig.2 left). Positive ions are necessary to bind these individual threads together. The most frequently used “binding agent” is calcium chloride ($CaCl_2$). Since calcium ions are divalent, i.e. they have a double positive charge (Ca^{2+}), they can bind to two alginate chains simultaneously. The alginate chains are bonded together in such a way that a stable system is formed. The initial sodium alginate is transformed into calcium alginate. FIGURE 2

Fig. 2: left) Alginate chains in reaction with Ca^{2+}[16]; right) structure of alginic acid.

STATE OF THE ART

The use of algae, most commonly as a food and healing supplement, has a long tradition in Asian cultures of the Far East. The interest in using algae in various fields

16 https://kimica-algin.com/products/NaAlgin/

has grown in recent years, indicating that there is still a lot of unrevealed potential for their use.

The latest research[17] that combines paper-based packaging material with alginate and chitosan has revealed the multifunctional barrier properties of these two biomaterials together, offering various applications for the packaging industry. Research from 2021[18] proved that Ca-alginate particles and alginate-impregnated hemp fibres have great potential for water filtering and reducing nickel concentrations cost-effectively and efficiently.

The alginate from brown seaweeds has found application in tissue engineering, especially for heart valve scaffolds[19]. This is enabled by 3D deposition of alginate hydrogel, where different techniques (inkjet-based and extrusion-based) can be applied, with an emphasis on printing in suspension baths[20]. Not only films, fibres, or bead shapes can be obtained, but a variety of forms (and sizes) can also be achieved, which provide the physical support necessary for the heart muscle during repair and recovery.

The use of alginate has recently started in the fashion industry, which is one of the most polluting industries of today and responsible for 10% of the world's carbon emissions. Extracted alginate offers a wide range of textile applications, particularly in the field of footwear, accessories, and garments. Yarns, made out of kelp provide a non-toxic compostable alternative to petrochemical textiles[21]. Knitting of yarns assures flexibility and strength of textile. During the fabrication of yarns, the remaining cellulose can be transformed into a stable and light composite material[22], providing a zero-waste production.

No application of alginate in architecture was found in the course of the literature review. The following chapter thus provides an insight into research on using alginate as a building material.

EXPERIMENTS

In this chapter, we present a series of experiments of shaping alginate. By respecting the natural behavioural tendencies of this material, we mixed alginate and additives with the aim of changing the mechanical properties of the base alginate. With natural additives, such as chitosan, it is possible to increase the rigidity of the material, whereby glycerin is used to increase the elasticity and surfactant to increase the porosity of the base material. We created various structural elements, ranging from the linear, to planar and free-form ones. The novelty in our shaping process is the possibility of creating and controlling the geometry without additional formwork.

17 S. Kopacic, et al. "Alginate and Chitosan as a Functional Barrier for Paper-Based Packaging Materials", *Coatings 2018*, 8, 235; doi: 10.3390/coatings8070235.

18 A. Zdujić, et. al. "Comparative Study of Ni (II) Removal from Aqueous Solutions on Ca-Alginate Beads and Alginate-Impregnated Hemp Fibers", *Fibers and Polymers*, 2021, Vol.2, 9–18, DOI 10.1007/s12221-021-9814-6.

19 A. R. Liberski: *Three-dimensional printing of alginate: From seaweeds to heart valve scaffolds*, QScience Connect, 2016, 3, http://dx.doi.org/10.5339/connect.2016.3.

20 A. McCormack et. al: "3D Printing in Suspension Baths:Keeping the Promises of Bioprinting Afloat", *Trends in Biology*, 2020, Vol. 38, No.6, https://doi.org/10.1016/j.tibtech.2019.12.020.

21 https://www.algiknit.com/

22 https://kh-berlin.de/projekt-detail/Project/detail/al-g-transformation-der-braunalge-2-2694

AS-01 (transparent)	AS-02 (green)	AS-03 (yellow)	AS-04 (red)	AS-05 (blue)	AS-06 (purple)	AS-07 (turquoise)	AS-08 (turquoise)
water 83% glycerin 12% alginate 5%	water 77% glycerin 19% alginate 4%	water 83% glycerin 8% oil 4% alginate 5%	water 93% glycerin 5% alginate 2% chitosan <1%	water 93% glycerin 5% alginate 2%	sea water 77% glycerin 19% alginate 4%	water 89% glycerin 4,5% alginate 2% decyl -gl. 4,5%	water 76% glycerin 19% alginate 4% decyl.-gl. 1%

yarn	Ø in mm	max tension in N	tensile stress in N/mm²
AS-02 fresh	3	3	0,42
AS-02 dry	1	6,7	8,5
AS-05 dry	0,5	12	61,14
AS-04 dry	0,5	13	66,24
AS-06 dry	0,9	4,6	7,23

Fig. 3

An initial tensile test is made for the linear elements and the obtained results are compared to the ones of similar natural fibres. (Fig 3, bottom).

Some of the samples from this research and architectural scale models made of algae will be presented at the exhibition named "ALG.A". The exhibition is organized with the Association of Istrian Architects[23] (DAI-SAI) in Pula, Croatia and will be open to the public from 19th June to 3rd July 2021. After this period, the artefacts from the exhibition will be relocated to the Aquarium Pula[24] and become part of the permanent exhibition.

Preparation of the alginate suspensions

Several alginate suspensions were prepared with different additives and mixing ratios (Fig 3, top). Since the alginate suspensions are transparent, food and acrylic colour was added for better differentiation and presentation. However, these additives do not influence the properties of the suspensions.

Fig. 3: top) Alginate suspension (AS) and different additives used in experiments; bottom) results of the initial tensile test by using a dynamometer.

In case of all the suspensions, special care was taken to use only natural and sustainable products and also tap water rather than distilled water. The seawater used for the experiments was collected from the region around Pula. The calcium chloride solution was always prepared at the beginning of each experiment following this procedure: 1) fill out a stand mixer with water; 2) add colour and the liquid components (glycerin or oil) at the lowest speed of the stand mixer; 3) add small quantities of alginate powder while stirring constantly; 4) stir until a homogeneous mass is formed. When preparing the solution, it is important to pay attention to the following aspects: a) alginate powder immediately clumps when in contact with water; b) stirring by hand or with a hand mixer is not sufficient to produce a homogeneous mass; c) if chitosan is added, the suspension must first be reduced to an acidic pH value with the aid of lactic acid; d) finally the surfactant is added to avoid over foaming.

Depending on the experiment, the alginate suspension is dipped into the solution of 10% $CaCl_2$ or sprayed with a spray bottle. In this way, optimal ion exchange takes place with low material input. Since the alginate suspension consists of natural and biological raw materials, it is important to note that this is a biodegradable substance. The suspensions should thus be processed quickly. After a couple of days,

23 www. dai-sai.hr

24 http://www.aquarium.hr/

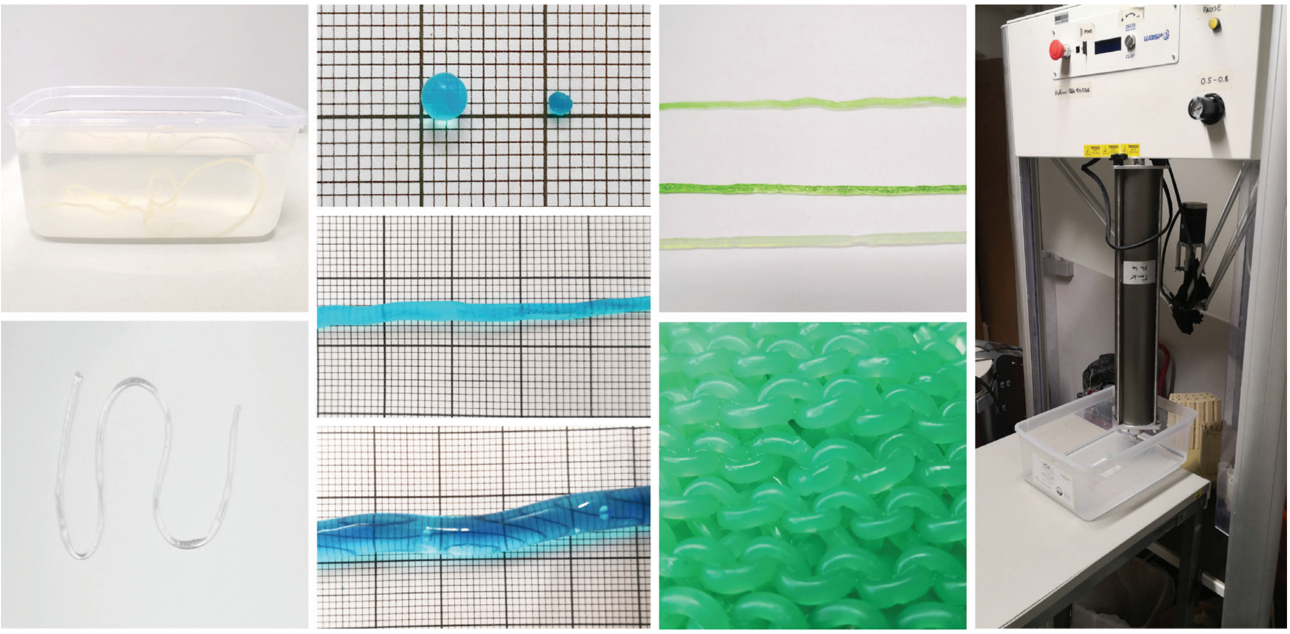

Fig. 4

mould growth may occur. Even after the ion exchange, the calcium alginate is still biodegradable, but becomes less susceptible to atmospheric conditions and thereby less prone to decompose. The solidified alginate was exposed to sunlight for months and did not change flexibility, mechanical properties and is therefore UV resistant.

Linear elements

Linear elements are mainly extruded from a syringe into a $CaCl_2$ bath. This process is known in the textile industry[25] as the wet-spinning process. The chemical reaction of the ion exchange takes place without delay; as soon as the alginate touches the $CaCl_2$ solution, a solid is formed from the liquid mass (Fig. 4, top-left). Such a quick reaction allowed us to use a 3D printer in making very long linear elements. We used a standard WASP clay printer with a 2 mm nozzle (Fig. 4, right). The initial results of the tensile test made by using a dynamometer (Fig. 3, down) show that for a specific suspension, a tensile strength of around 60 MPa can be achieved, which can be compared to the tensile strength of a reed (70-140 MPa)[26] as another natural fibre. It is assumed that the suspensions AS-04 and AS-05 have higher tensile strengths due to their low proportions of glycerine. The alginate could therefore bind the water molecules more strongly and thus produce more tear-resistant properties. In further planned research, aimed at finding out more about the behaviour of alginate yarns under tensile forces, tests providing a displacement-force diagram and values of elongation (at break and yield) will be conducted. The tests will also be made for intertwined alginate yarns, as shown in Fig. 4 middle right, bottom).

Fig. 4: left, top) $CaCl_2$ bath; left, bottom) extruded transparent material (AS-01); left middle column) shrinkage of material AS-05 after 24 hours; middle right, top) dry yarn AS-02; middle right, bottom) knitted structure from AS-02 yarn; right) extrusion of a very long linear element with a standard WASP clay 3D printer's tank and its solidification in $CaCl_2$ bath.

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25 H. J. Koslowski: *Chemiefaser – Lexikon*, Frankfurt am Main, 2009, 127.

26 D. Verma and I. Senal: "Natural fiber-reinforced polymer composites: Feasibility study for sustainable automotive industries", Woodhead Publishing Series in *Composites Science and Engineering*, *Biomass, Biopolymer-Based Materials*, and Bioenergy, 2019, 103–122.

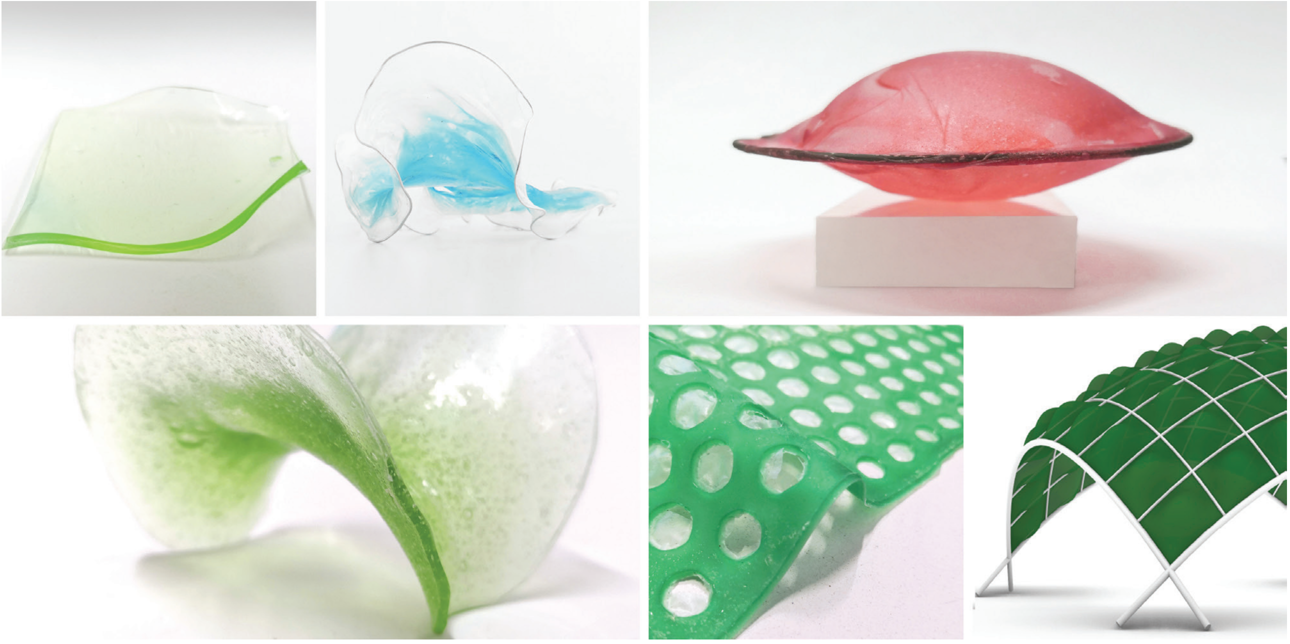

Fig. 5

Planar and volume elements

Due to the viscous consistency of alginate and the possibility for spraying it with $CaCl_2$, it is suitable for the production of flat and solid elements by casting. Compared with linear elements, this method is a more intensive process, as it requires additional material for the moulds. The advantages of this are that mats, thin films, membranes and even air cushions can be created (Fig. 5)

In the production of mats, the moulds or frames help to significantly counteract contraction. Excessively deep moulds are unsuitable, but otherwise, there are almost no limits to the freedom of design using wireframes (Fig 5 top, middle). The difficulty of using wireframes is that tearing can still occur if the alginate does not enclose the wireframe sufficiently. In Fig. 5 some experiments are presented and briefly discussed in the corresponding figure description.

Fig. 5: top, left) Flexible foil with a controlled thickness (AS-02); top, middle) very thin membrane within a flexible wireframe, solidified material was formed into free form double curved shape without cracks (AS-05); top, left) air cushions within a circular wireframe (AS-04); bottom, left) shape like a hyperbolic paraboloid (HP) formed with a flexible wireframe, the form was separated from the frame after drying (AS-02); bottom, middle) cast mats with irregular structure (AS-02); bottom, right) one possible architectural design with air cushions.

On a smooth and even surface, the alginate can glide better during contraction (Fig 6, top) than on a rough surface. A rough surface in turn influences the surface structure of the alginate. Subsequent bending of the alginate wire elements is ideal for creating shapes (Fig. 5, bottom, left) that are otherwise difficult to obtain, such as those of a hyperbolic paraboloid (HP).

Furthermore, the inflated elements are more than interesting, since once cured they retain their shape and do not require a constant air supply. Even though the alginate has no adhesive effect in the conventional sense, it can join two elements together when they are fully coated with the suspension. In Fig. 6, top – two alginate suspensions are shown, AS-04 and AS-05. They are bonded together into a rigid frame and as air cushions. The shapes of these air cushions can also be controlled

Fig. 6

to a large extent, unfortunately, these experiments did not yield any results in the context of an alginate frame for the alginate cushions. In Fig. 6, bottom – we can see some air cushions with the wireframe and some made without any aids.

Fig. 6: top) Bonded rigid and elastic alginate (AS-04/AS-05); bottom) wire framed and free shaped air cushions (AS-05).

ALGINATE AS COMPOSITE ELEMENT

Alginate can be used in combination with other materials, such as textiles, clay or wool. We investigated to what extent alginate changes its properties in a combination with another structure and which materials are suitable for making a composite structure (Fig. 7). Properties of alginate, such as shrinkage, some of which are disturbing factors, can have positive and desirable effects in composite structures. What the alginate itself cannot do, the compound can. By layering with elastic material, alginate can be used as a programmable actuator (Fig. 8). On Fig. 7 and Fig. 8 are some examples of how the alginate interacts with other materials. Experiments are briefly discussed in the corresponding figure description.

Fig. 7: left) Coating of a linear element with clay did not show promising results – due to the smooth structure of the alginate, the binding of the clay to the linear element is difficult (AS-04); middle) coating of a wool knitted structure with alginate AS-04 – wool fibres allows a good bond of the alginate with the wool structure increasing the stability of element; right) the dried part of the "Column" structure prepared for the exhibition in Pula.

Fig. 7

Fig. 8: left) composite of elastic fabric and AS-04 in a hexagonal matrix; middle) backside of fabric-alginate composite (AS-02) – due to rectangular alginate fields the elastic fabric is pulled together while drying; left) front side of fabric-alginate composite – alginate expands on contact with water, textile returns to its original extended form.

DISCUSSION AND CONCLUSION

Algae and alginate are no strangers, they are an integral part of some industries and it is impossible to imagine a life without them. Unfortunately, architecture and the construction industry are lagging far behind. Sustainability is increasingly becoming a topic and part of the architectural discourse. Sustainable, resource-saving materials, however, are a rare and expensive alternative to conventional building materials. But as demand grows, so will supply. Many industries have already recognized this trend reversal and are forging ahead on new paths. The construction industry must also face up to these developments and actively pursue new solutions.

This work is only the beginning of such an approach. It gives a first insight into what alginate is and the remarkable qualities it brings. It being an interesting material is beyond question, as well as its sustainability. The raw material algae has enormous potential and brings many advantages with it. No land area is lost for cultivation, no additional drinking water and fertilizers or pesticides are needed. At the same time, it filters toxins from the sea and also binds more CO_2 from the air than an average forest. Furthermore, its rapid growth, easy harvesting and processing are additional criteria that are powerful arguments for its use in the construction industry.

Fig. 8

In our research, we presented a series of experiments with alginate and different natural additives. By respecting the natural behaviour tendencies of macroalgae, but also by experimenting with chitosan to increase the rigidity and glycerin to increase the elasticity of the alginate, various shapes of elements are obtained, ranging from linear ones, suitable to resist tensile forces, to membranes and shells. Some basic mechanical tests are made, and results are compared to the properties of standard materials. The models obtained show promising results, while also opening some new research questions, confirming the potential of this innovative application. However, it must be remembered that this experimental approach is just the beginning. We are encountering a previously unknown product in architecture. This fact alone means that making predictions is not an easy task. More time and additional research will certainly be needed to develop a marketable product.

FUTURE WORK

Producing an alginate mixture that does not change its state after curing (swells on contact with water) and can therefore be pressurized will be of great importance for future work. A water-repellent coating would also be conceivable here. The elastic properties could then be retained so that outdoor use can be guaranteed. The first acoustic test showed that alginate can be used as an effective absorber and this path we would like to follow in our future research.

ILLUSTRATIONS

1: left) Microalgae colony; middle) photobioreactors; right) macroalgae.
Sources:
left: https://www.mint-engineering.de/de/uber-algen/
middle: https://www.cash.at/news/media/13/--125302.jpeg
right:https://www.sportdiver.com/sites/sportdiver.com/files/styles/opengraph_1_91x1/public/images/2017/06/kelp1_istock-520593426.jpg?itok=bwAn7KyK
Лево) Колонија микроалги; средина) фотобиореактори; десно) макроалге.
2: left) Alginate chains in reaction with Ca2+; right) structure of alginic acid.
Source: https://kimica-algin.com/products/NaAlgin/
Лево) Алгинатни ланци у реакцији са Ца2+; десно) структура алгинске киселине.
3: top) Alginate suspension (AS) and different additives used in experiments; bottom) results of the initial tensile test by using a dynamometer.
Горе) Алгинатна суспензија (АС) и различити адитиви коришћени у експериментима; доле) резултати почетног испитивања затезања помоћу динамометра.
4: left, top) CaCl2 bath; left, bottom) extruded transparent material (AS-01); left middle column) shrinkage of material AS-05 after 24 hours; middle right, top) dry yarn AS-02; middle right, bottom) knitted structure from AS-02 yarn; right) extrusion of a very long linear element with a standard WASP clay 3D printer's tank and its solidification in CaCl2 bath.
лево, горе) CaCl2 купка; лево, доле) екструдирани провидни материјал (AS-01); лева средња колона) скупљање материјала AS-05 после 24 сата; средње десно, горе) суво предиво AS-02; средина десно, доле) плетена структура од предива AS-02; десно) екструзија веома дугачког линеарног елемента са стандардном WASP глином из резервоара 3Д штампача и његово очвршћавање у купки CaCl2.
5: top, left) Flexible foil with a controlled thickness (AS-02); top, middle) very thin membrane within a flexible wireframe, solidified material was formed into free form double curved shape without cracks (AS-05); top, left) air cushions within a circular wireframe (AS-04); bottom, left) shape like a hyperbolic paraboloid (HP) formed with a flexible wireframe, the form was separated from the frame after drying (AS-02); bottom, middle) cast mats with irregular structure (AS-02); bottom, right) one possible architectural design with air cushions.
Горе, лево) Флексибилна фолија контролисане дебљине (AS-02); горе, средина) веома танка мембрана унутар флексибилног жичаног оквира, очврснути материјал је формиран у слободној форми двоструко закривљеног облика без пукотина (AS-05); горе, лево) ваздушни јастуци унутар кружног жичаног оквира (AS-04); доле, лево) облик сличан хиперболичком параболоиду (HP) формиран помоћу флексибилног жичаног оквира, форма је одвојена од рама након сушења (AS-02); доле, средина) ливене простирке неправилне структуре (AS-02); доле десно) један могући архитектонски дизајн са ваздушним јастуцима.

6: top) Bonded rigid and elastic alginate (AS-04/AS-05); bottom) wire framed and free shaped air cushions (AS-05).
Горе) Спојени крути и еластични алгинат (AS-04/AS-05); доле) ваздушни јастуци у жичаном оквиру и слободно обликовани (AS-05).
7: left) Coating of a linear element with clay did not show a promising result – due to the smooth structure of the alginate, the binding of the clay to the linear element is difficult (AS-04); middle) coating of a wool-knitted structure with alginate AS-04 – wool fibers allow a good bond of the alginate with the wool structure increasing the stability of element; right) the dried part of the "Column" structure prepared for the exhibition in Pula.
Лево) Облагање линеарног елемента глином није дало очекивани резултат – због глатке структуре алгината, везивање глине за линеарни елемент је отежано (AS-04); средина) премазивање вунене плетене структуре алгинатом AS-04 – вунена влакна омогућавају добру везу алгината са вуненом структуром повећавајући стабилност елемента; десно) осушени део конструкције „Стуб" припремљене за изложбу у Пули.
8: left) composite of elastic fabric and AS-04 in a hexagonal matrix; middle) backside of fabric-alginate composite (AS-02) – due to rectangular alginate fields the elastic fabric is pulled together while drying; left) front side of fabric-alginate composite – alginate expands on contact with water, textile returns to its original extended form.
Лево) композит еластичне тканине и AS-04 у хексагоналној матрици; средина) полеђина тканине-алгинатног композита (AS-02) – због правоугаоних алгинатних поља еластична тканина се скупља током сушења; лево) предња страна композита тканина-алгинат – алгинат се шири у контакту са водом, текстил се враћа у првобитни издужени облик.

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АЛГИНАТ У АРХИТЕКТУРИ
Експериментални приступ добијања новог одрживог грађевинског материјала

Резиме: Емисија угљен-диоксида из индустрије грађевинских и конструкционих материјала учествује са 38% у укупној емисији угљен-диоксида. У настојању да до 2050. године постигнемо европски енергетски план са нултом емисијом, неопходно је већ сада размотрити постојеће принципе градње, као и технологију производње грађевинских елемената и материјала.
Један од могућих корака за постизање овог циља представља изналажење нових решења коришћењем регионалних извора и обновљивих сировина. У спроведеним истраживањима коришћен је алгинат као могућа замена за конвенционалне структурне елементе, чији је потенцијал у архитектури до сада недовољно истражен. Алгинат, који се налази у ћелијским зидовима смеђих алги, је неповратно очвршћавајући еластични материјал који се може обликовати и који након очвршћавања задржава постојећи облик.
У овом раду представљена је серија експеримената са различитим природним адитивима. Узимајући у обзир природу и својства макроалги, али и експериментишући са хитозаном за повећање ригидности и глицерином за повећање еластичности алгината, добијени су различити облици елемената, од линеарних, до мембрана и шкољки. За линеарне елементе извршено је испитивање отпорности на истезање, а измерене вредности су поређене са вредностима сличних природних влакана. Креирани модели су показали задовољавајуће резултате, који отварају могућност за даља истраживања ове иновативне апликације.

Кључне речи: макроалге, алгинат, одрживи материјал, регионални ресурси, грађевински материјал, архитектура