Bamboo as a novel and sustainable Martian building material

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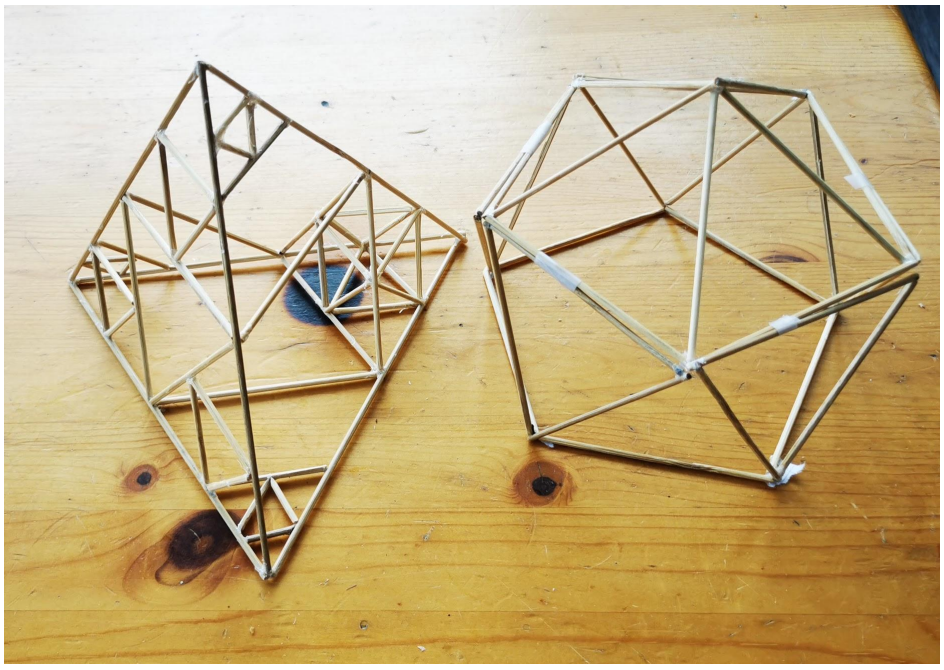
URL of team video: www.youtube.com/etc

Description of the problem and its importance.

Each kilogram brought to Mars from Earth comes with two costs: the direct cost of bringing it, a figure that is hard to give precisely or reliably but it is likely it will be far in excess of current minimum of $2,720/kg to Low Earth Orbit [1], and secondly the fact that space on transportation is necessarily limited means that the inclusion of one cargo is at the exclusion of another. If we want a Martian base to grow and be sustainable, it is essential it can create its own building materials to free up space for the delivery of high-tech goods, and drive down the costs of maintaining a settlement. We must find a way to create building material which is strong, light-weight, and possible to be manufactured in a large scale and sustainable way.

Description of the initial solution.

We propose that young bamboo shoots [2] be transported to Mars and grown in soil created with Martian regolith, waste and nutrients from an aquaponic system. Bamboo can be made to grow quickly, up to 40cm a day [3] and absorb readily-available carbon dioxide as its main building material. Bamboos exist in over 1600 different species and can grow in a range of temperatures from tropical heat to -10*C [4]. Bamboo is as strong as mild steel and glass-reinforced plastics, naturally straight, and lightweight [5]. It can be used to construct large scale structures on Martian bases, both inside pressurised and unpressurised environments.



Scale models of bamboo buildings designs exhibiting high strength to weight ratios: fractal frameworks and geodesic domes respectively.

Evaluation and comparison of the solution.

Bamboo is not the only candidate for rigid building material. We compared bamboo with several other building materials to identify suitable roles for bamboo.

3D Printed structures

3D printing has improved tremendously in price and power in the last decade and would likely be used in some capacity on Mars [6]. 3D printers can be reprogrammed, use several different base materials and produce high-precision parts with great strength. However, 3D printers are expensive, heavy and produce pollution [7]. Until all materials and parts to produce more 3D printers are able to be manufactured on-location, they are incapable of the exponential growth that comes with bamboo grows in bamboo-constructed greenhouses. Some 3D materials can be recycled [8], but must be imported at first.

Steel

Steel can be manufactured from the Martian regolith [9] and has the following properties and has a 66% of the tensile strength of bamboo [10]. We imagine that for the manufacture of high-precision, high-strength and long-lifetime materials, steel will be a sensible and common choice. However, the supply chain to create steel requires the large-scale mining of the Martian regolith, extraction, smelting machinery which will have to be brought, constructed and powered. This requires a significantly higher start up cost than bamboo.

Martian bricks

Baking bricks made from martian earth is an excellent building material: it is readily available and requires little equipment to manufacture - only water and heat - and can be created in blocks of varying sizes.Martian bricks, like on earth are excellent for building basic structures such as reinforce walls, foundations, columns but due to the weak tensile strength associated with clays, ceramics and concretes, it would not be suitable for material under tension.

Ice

Ice is another material which is easy to build with, as liquid water is simple to extract with the application of heat. Ice can be fully recycled and easily transported through pipes, making it an excellent candidate for uses where quick deployment (plugging leaks, temporary covers, amorphous shapes. However, ice has the key weakness that it cannot be used in thermal contact with any material likely to approach 0*C, unless an active cooling system is installed within it

Modifications and improvements proposed to the initial solution.

Bamboo is unlikely to be an all-purpose building material due to its limits in precision, long germination time [3-5 years], however we believe that due its numerous ancillary benefits it has a part to play in the intermediate stage of a settlement: between the scouting phase and the large industrialised settlement phase.

Bamboo presents numerous benefits: the psychological benefit of biophilic interaction, [11] a natural processor of CO_2 into O_2, it can be a source of food (bamboo shoots are eaten across south and southeast asia), and its weight-bearing strengths will be amplified in the low gravity of Mars.

If Martian bricks can supply significant *compressive* strength, and bamboo provides *tensile* strength, we could imagine a case where the two materials are combined much in the way that steel-reinforced concrete is used today. This may become the above-ground Martian building material of choice.

Ideas for further development.

There are several points we would like to be able to investigate before pursuing bamboo as a serious building material:

-Bamboo used in structures on Mars would often be subjected to repeated cooling and heating. We would like to investigate how its mechanical and structural properties change after repeated exposure to this temperature cycle (in a low-pressure environment).

-Bamboo develops an extensive rhizome structure before embarking on its stem growth phase. We would want to investigate how these two phases of growth would be affected by growth in the low gravity of Mars.

-We would like to embark on a large scale classification of bamboo species in light of their suitability as a Martian candidate, and investigate the possibility of editing the genes of species to develop a plant specialised for Mars.

-We would like to employ designers and architects to create modular, strong and efficient structures using bamboo as a building material.

Additional resources.

Here we have some illustrations you may find useful or interesting:

Bamboo shoots, once boiled, are edible and nutritious.

This conceptual illustration envisions ice-filled bamboo shells for the creation of strong and light habitats on Mars. [12]

Team bio.

Alex and Ye are a great team who believe in making the world a better place. Ye is from Hangzhou, China and Alex is from the New Forest, United Kingdom. They are interested in developing sustainable solutions to the cutting-edge of science and technology. They one day hope to run their own design school where past and present, artificial and natural, traditional and experimentation combine.

References

List of references in a specific format:

[1] ID: 20200001093, Jones, Harry W. (NASA Ames Research Center Moffett Field, CA, United States), July 8, 2018, https://ntrs.nasa.gov/citations/20200001093. A report detailing the estimated costs of launching to LEO

[2] https://lewisbamboo.com/pages/bamboo-seeds - explaining why shoots are preferable to seeds.
[3] https://www.guinnessworldrecords.com/world-records/fastest-growing-plant/

[4]Invasion of dwarf bamboo into alpine snow-meadows in northern Japan: pattern of expansion and impact on species diversity Gaku Kudo, Yukihiro Amagai, Buho Hoshino, and Masami Kaneko

[5] Mechanical properties of bamboo, a natural composite S.C.LakkadJ.M.Patel† Department of Aeronautical Engineering, Indian Institute of Technology, Bombay 400076, India

[6] Mars society ,MARS COLONIES (Kindle Locations 976-978). Polaris Books. Kindle Edition.

[7] Characterization of particulate and gaseous pollutants emitted during operation of a desktop 3D printer
Jianwei Gu, Michael Wensing, Erik Uhde, Tunga Salthammer

[8] https://all3dp.com/2/the-3d-printer-filament-recycler-s-guide/ - existing recycling of 3D printing material

[9] Copyright © 2006 Shaun Moss. Published by The Mars Society with permission. STEELMAKING ON MARS Shaun Moss shaunmoss@yahoo.com.au

[10]
https://www.sbcmag.info/news/2020/jan/can-structural-bamboo-replace-steel-construction-soon
[11] Int J Environ Res Public Health. 2009 Sep; 6(9): 2332–2343.
doi: 10.3390/ijerph6092332 Biophilia: Does Visual Contact with Nature Impact on Health and Well-Being?
Bjørn Grinde and Grete Grindal Patil

[12] https://www.dezeen.com/2019/09/03/mars-colony-bamboo-warith-zaki-amir-amzar/