1. Introduction

There are a lot of ideas about how to build large futuristic cities on the Moon or Mars without considering the resources and machinery needed for such a task. A more realistic approach was shown in the movie *The Martian*, where a settlement consists of a bunch of tents, which again, is only suitable as a temporary settlement.

Many of those ideas look attractive, but at the end of the day, any big extraterrestrial city must follow a general logic in space, which is: to gain as much as possible with minimum input. Let's explore some ideas about how to construct large extraterrestrial cities according to this logic.

2. 3D printing on other worlds – ideas so far

More innovative ideas consider building with local materials, like 3D printing. These ideas are good, but they somehow fail to take into account the basics of statics of construction.

We've all seen pictures like that. They are attractive, for sure, but this kind of construction requires reinforcement beams and strong walls to hold the air pressure inside the facility. It's very unlikely that the raw materials out there would allow for a high enough load capacity.

https://sservi.nasa.gov/articles/building-a-lunar-base-with-3d-printing/

There is more of the same type of proposed construction. For example, one of five winners of the NASA competition for a 3D printed habitat on Mars, proposed construction from material composed of a mixture of basalt fiber extracted from Martian rock and renewable bioplastic derived from plants.

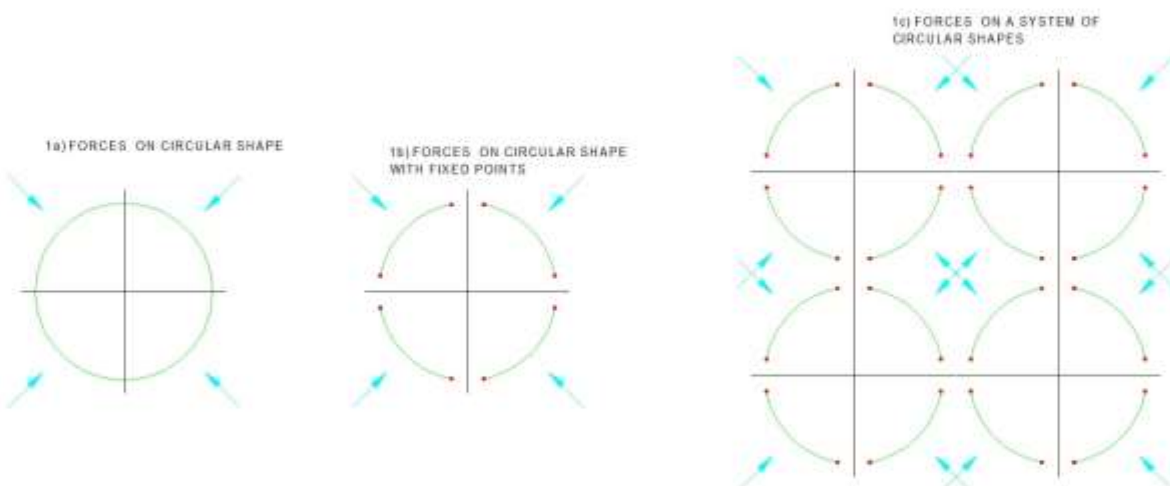
As we can see, all the construction is done on the surface, which is hard to achieve, provides a relatively small usable space for living, and presents challenges of pressurization, radiation, temperature (including diurnal temperature variations peaking at around 100 degrees Celsius), and frequent dust storms on Mars.

The only kind of construction which can avoid most problems with challenging conditions on other planets is underground construction. Let's look at how to efficiently create a big underground construction.

Team Marsha (second place) designed buildings, constructed from a material composed of a mixture of basalt fiber extracted from Martian rock, and renewable bioplastic derived from plants.

3. Circular shapes

It's hard to crack an egg because of its shape. An egg has the best compressive strength of all shapes, when uniformly loaded from the side, as shown in picture 1a. It's a well-known fact, thus arched shapes are often used in construction.

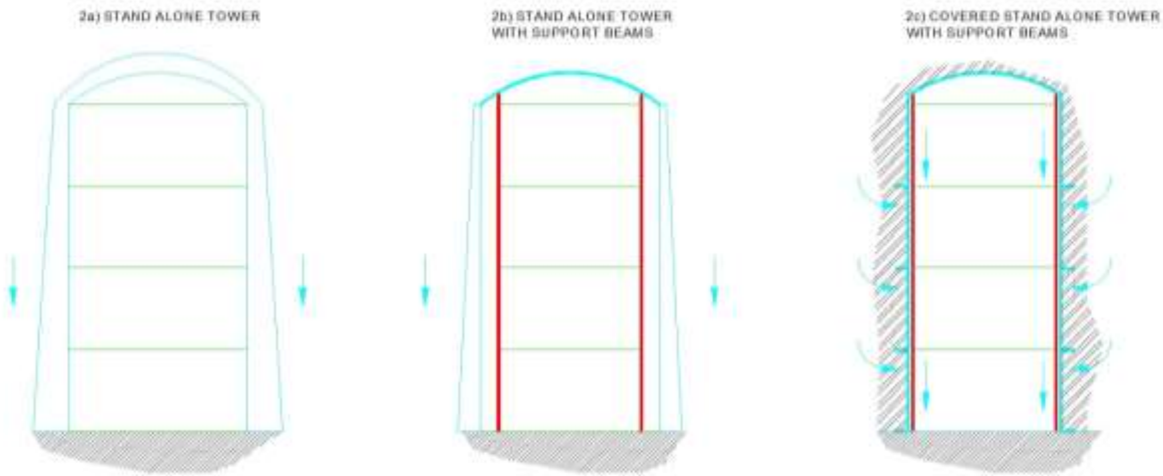


Picture 1: Circular shapes

If we replace the full circles with arches and fixed points at four places, as shown in picture 1b, it doesn't change much. Instead of a circle, separate arches can carry the load. There is no real change again, if we put several circles by each other, as shown in picture 1c.

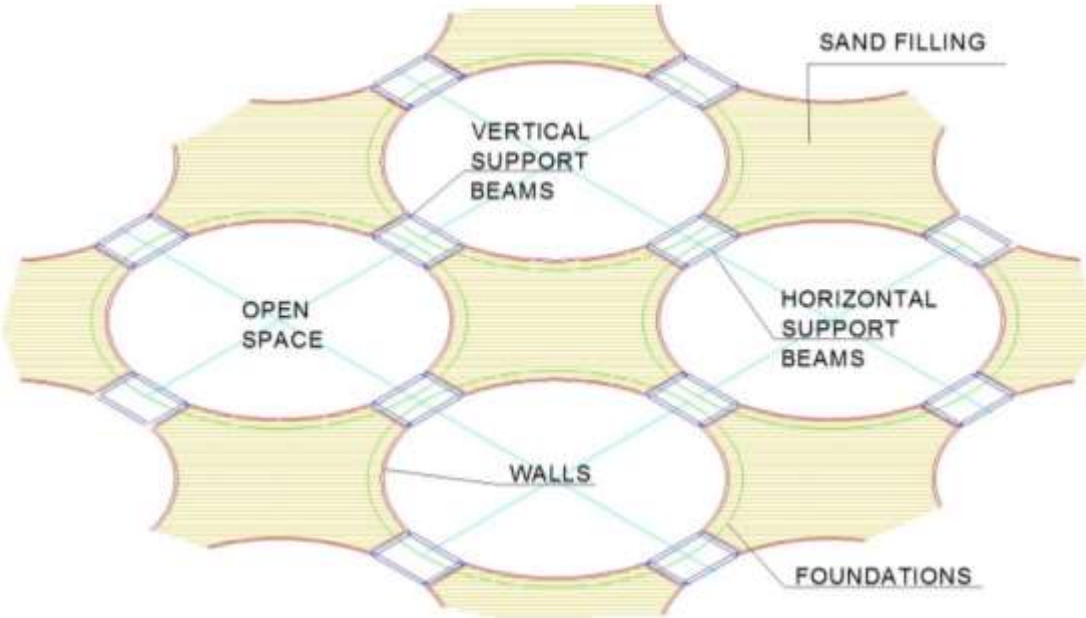
---

4. Towers



Picture 4: Towers

A tower is usually constructed as shown in picture 2a. The walls must be strong and should carry their own weight, the load of the roof, the load of the floors, and what is inside the tower. But if we use some construction tricks, it can be constructed with less material. For example, walls can be thinner if we provide separate vertical beams, which carry the load of the roof and everything inside, as shown in picture 2b. That way, the outer walls carry their own weight only. And finally, if we cover that tower with something, every floor can have a separate foundation, which actually transfers the foundation load to the wall below the foundation by filling it in a horizontal way (picture 2c).



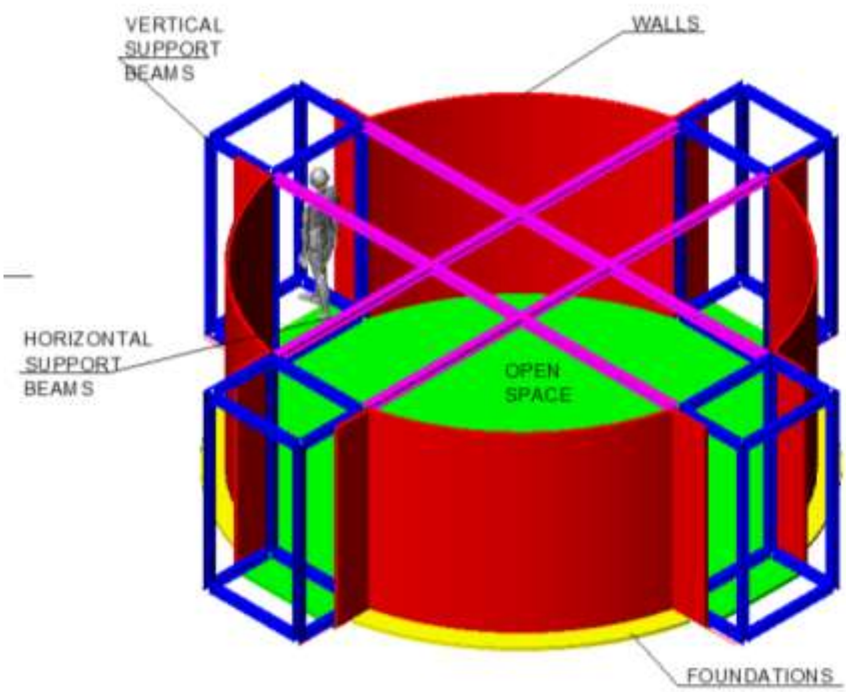
Picture 3: Extraterrestrial city construction-layout

5. Basic construction

Picture 3 shows the layout of one of the possible constructions. There are relatively thick curved walls, built on thin foundations. There are vertical beams, which carry the load of everything inside in a vertical direction, and horizontal beams, which prevent the bending of vertical beams, strengthening the weak points of construction and serving as a foundation for the next floor. Since we learned that circular shapes can carry the load from outside, we need something to provide that load, and that would be some sort of filling in between rooms, for example sand filling, which, similar to water, causes pretty much uniform pressure in horizontal directions at certain depths.

Picture 4 shows a 3d view of a single room with necessary construction elements. It can easily be seen that those elements are simple, generic, and can be manufactured using as small amount of material as possible.

The reinforced beams serve as doors in the neighboring room, and the circular cell in between serves as a room of 20-30 m^2 area and 2.5-3 m height, as shown in picture 4.

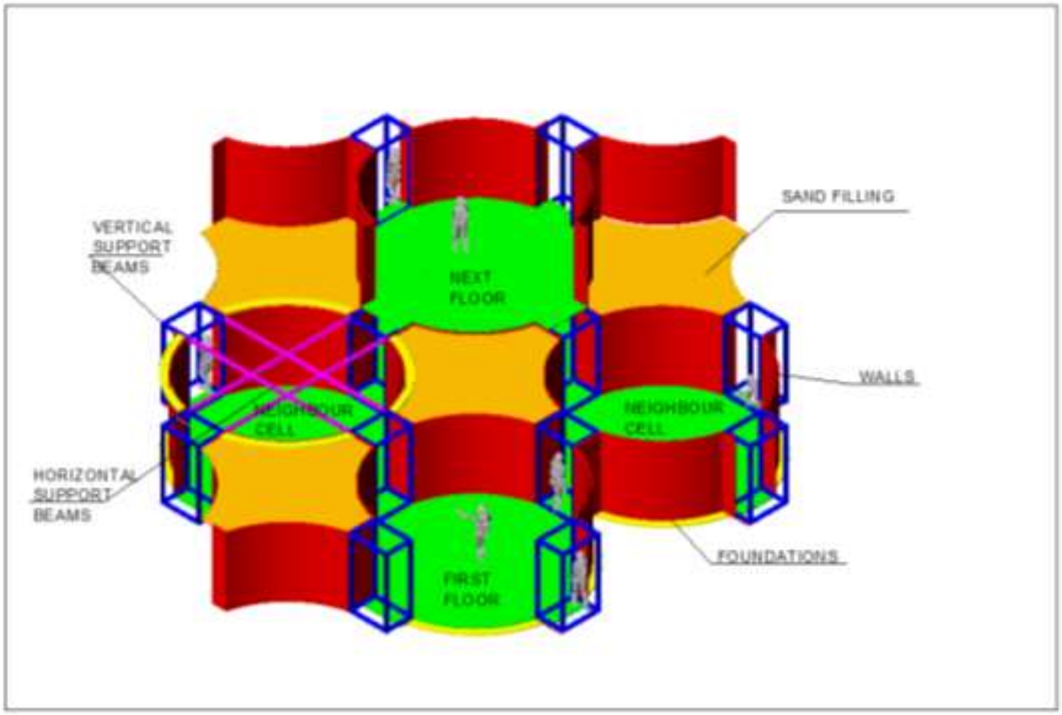


Picture 4: Extraterrestrial city-single cell construction.

6. Extraterrestrial city construction

If we put those cells by one another, and above one another, as shown in picture 5, we get a large modular object, constructed by simple elements designed—and therefore economically dimensioned—to defy expected loads, which is what we need for an extraterrestrial city. We just need enough material to print the walls, beams, and other elements, and a lot of filling material, which would be local sand in this case.

To avoid excavation, there are plenty of canals and craters on Mars to serve for construction, so there is no additional need for digging. The best option would be canyons with sharp vertical boundaries of 10-15 m height on both sides.

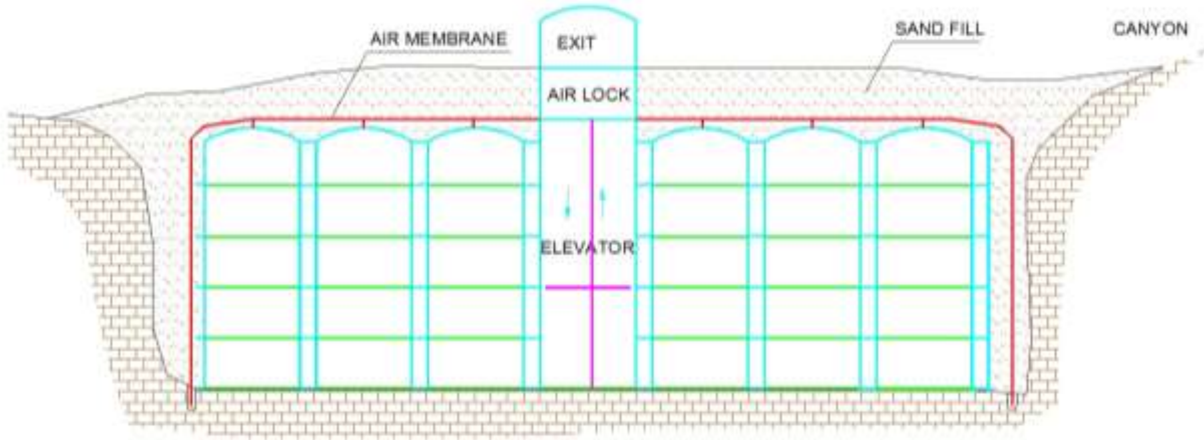


Picture 5: Extraterrestrial city-multy cell construction

We would also need a system to move a lot of sand using local energy sources. One of the sources that is abundant on Mars is wind, typically blowing with speeds between 16 and 32 kilometers per hour. The wind turbines are already so advanced on Earth that they might not require a lot of adjustments to work on Mars. They can also be 3D printed on the spot.

There is only one problem, and it’s the air pressure inside the city. And such a construction can’t handle much inner pressure.

The solution is shown in picture 5. The city is placed in a canyon, as proposed before, but units are air impermeable. There is an air lock membrane around the city, which seals the air inside the city and doesn’t cause inner pressure in cells, because air pressure is the same from both sides of the construction.



Picture 5: Extraterrestrial city-profile

7. Other challenges

While it is true that the gravity on Mars is 62% lower than on Earth and the forces acting on the construction are therefore weaker, large construction can be established, even with significant covers of local materials.

One may say that there is no light inside. Well, while the surface buildings can utilize natural daylight from the Sun with irradiance of around 1000 W/m^2 on the surface, the irradiance on Mars is weaker (590W/m^2), so additional lighting will be necessary in any case. Given that the Mars atmosphere produces around 2000 local dust storms a year and every three years on average envelops the whole planet in a global dust storm which can last up to a month, it is unreasonable to rely solely on natural lighting.

Daylight irradiation on Mars is just over half of the Earth's, and is often obscured by dust storms, therefore some sort of artificial lighting is essential. This can be achieved by various lamps emitting frequencies of the natural sunlight, combined with redirected light from the outside by a series of mirrors. The LED technology for sunlight simulation is already well advanced.

What about the Moon?

Although the Moon poses different challenges than Mars, they have a few features in common. The transport of materials to the Moon is also very costly and therefore the use of local materials is called for, and there are craters that can be used for constructing habitats. Otherwise, the lack of wind renders wind turbines useless, so only mechanical transport can be used, which again must be solved with getting material for 3D printing. On the other hand, the gravity is even weaker on Earth, constituting only a sixth of our planet's, which eases the pressures on the construction itself. As far as cosmic radiation is concerned, the Moon is completely unprotected.

Temperature variations are even greater than on Mars, which is due to the proximity to the Sun, lack of atmosphere, and slower rotational period. When the surface is lit by the Sun (approx. 13 days in a row), the temperature reaches 127 degrees Celsius, while during "night" (another 13 days), they drop to -173 degrees.

Conclusions

The construction proposed here is a relatively big, molehill-like facility, in which it is easy to maintain the temperature and air pressure and can protect from outer influences for an extended time. The advantage of such an approach is minimal material use and large areas of living space for bigger settlements.

Deep underground project
March 2021

https://deeepunderground.com/
https://join.deeepunderground.com/

Related content:

Deep underground concept