AUTOMATION SYSTEM FOR LUNAR LANDING PAD

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ABSTRACT: Concrete needs long time (28 day) for curing to reach enough strength in construction site. Also, it needs various materials. Thus, most of the construction sites in Extreme Environment select to deliver the prefabricated concrete modules. To construct structures on the Moon one has to select proper materials considering safety, cost, and procurement. Lunar concrete concept is quoted ISRU (In-Situ Resource Utilization). It only needs pressure and heat on lunar soil mixed with polymer. Moreover, the process of production is simple and short. This idea has born as terrestrial concrete request water, cement, and reinforces steel which has limit to manufacture in the Moon or to bring the massive resource from Earth because of the high cost. According to NASA and other space exploration roadmaps they are planning manned lunar exploration and building infrastructures in the Moon. This requires multiple landing of rockets that causes fine dust in the Moon which has harmful effect on human and infrastructures. Therefore, there is a need of lunar landing pad developed by ISRU. In addition as long term human existence and working on the lunar environment is dangerous automation system applied on rover needs to be developed. This paper introduces the lunar landing pad manufactured by the new type waterless concrete for lunar construction and presents automation system prototype for lunar launching pad construction.

Keywords: *Landing Pad, Lunar Concrete, Mechanism, Polymer, Glass Fiber, Lunar Simulant, Moon, Automation*

1. Introduction

Concrete needs long time for curing to reach enough strength in construction site. Also, it needs various materials. Thus, most of the construction sites in Extreme Environment select to deliver the prefabricated concrete modules. To construct structures on the Moon one has to select proper materials considering safety, cost, and procurement. Lunar concrete concept is quoted ISRU (In-Situ Resource Utilization). The ISRU works to establish, evaluate and assess the in situ resources available on the Moon and Mars and the technologies needed to utilize and exploit these resources. [1] According to NASA and other space exploration roadmaps they are planning manned lunar exploration and building infrastructures in the Moon. This requires multiple landing of rockets that causes fine dust in the Moon which has harmful effect on human and infrastructures.

2. Necessity of Research

The surface of the Moon is fully covered with micro dust. The surface, which initially used to be a hard rock, innumerably ran against micrometeorite coming from the space and high-speed from solar wind, turning into a form of powder or dust called micro dust. When someone should walk or ride a vehicle on top of this tiny meteorite, the passing object(body or vehicle) will be covered with a powder or dust.

In addition, the Moon dust may seem like a powder, but its fine particles are very sharp. Therefore, the particles scratch astronaut's protection equipment, causing damages to the spacesuit or going into the astronaut's lung. In addition, the main component of the Moon's dust is silicon, and this causes silicosis in earth. Silicosis is known as a disease which occurs by being exposed to quarry.

During the America's Great Depression, the quarry workers in the West Virginia were exposed to silicon for a few months and most of them ended up dying within the last dozens of years. Silicosis is known as one of the most serious occupational diseases in America. Quartz, the main cause of silicosis is chemically nontoxic. It is even eatable and still causes no harm. However, when quartz is inhaled into a lung in a form of fine dust(less than 100 micros and lunar regolith average sizes are from 30 to 100 micros also [2]), its accumulation in the lung disturbs the circulation of air inhaled, and even coughing cannot get rid of such dust. Moreover, it destroys white blood cells of the immune system, and makes people suffer from suffocations such as pneumonia, a traditional symptom of silicosis. Such events will not occur to astronauts in a way so dramatic, but it is value to do a research to be at least prepared. Therefore, in this research, through automation, a method to construct infrastructure minimizing or even removing the dust harmful to the human body for manned expedition to the Moon is considered. Also when spacecraft arrived in the Moon, there are occurred to lots of dust except in atmosphere, so it could be shot to human or equipment. The trend of precedent researches will be analyzed in the chapter 3, and purpose and scope of research will be described in the chapter 4. An advance test will be described in the chapter 5, and a simplified algorithm and automation will be described in the chapter 6.

3. Literature review

Table 1. Paper on Lunar Concrete

Paper	Author	Content
Concrete lunar base investigation	T. D. Lin et al., 1989 (Constr. Tech. Lab.,)	Analysis of pre-cast pre-stressed concrete design to withstand internal pressure of lunar habitats
Lunar in situ materials-Based habitat technology development effort at NASA/MSFC	Bodiford et al., 2006 (NASA Marshall Flight Center)	In Situ Fabrication & Repair(ISFR) Program at NASA/Marshall Space Flight Center(MSFC) study. Suggests the construction of habitats on the lunar by using waterless concrete
Development and application of lunar “Concrete” for Habitats	Toutanji, 2006 (University of Alabama)	Review the various shapes of structure for constructing habitats on the Moon, and develop the waterless concrete based on JSC - 1
Sulfur Concrete : A Viable Alternative for Lunar Construction	Gracia and Casanova 2006 (NEXUS)	Development of lunar concrete by using ISRU
Analysis of Lunar-Habitat Structure Using Waterless Concrete and Tension Glass Fibers	Meyers and Toutanji 2007 (NASA Marshall Flight Center)	Analysis of lunar habitat which uses lunar concrete that mixed with glass fibers
Mechanical Properties and Durability Performance of “Waterless Concrete”	Toutanji et al., 2008 (University of Alabama)	Develop waterless concrete by using boiling point of sulfur at the Moon’s temperature
Experimental Study of Waterless Concrete for Lunar Construction	Sung Won Koh., 2010 (Hanyang University)	Develop waterless concrete by using polymer and improvement to scale up
Experimental Research for Construction of a Lunar Landing Pad	Gun Hwan Park 2011 (Hanyang University	Apply to landing pad by using waterless concrete

Recently, researches on waterless concrete using polymer have been making an active progress. In particular, a rectangular parallelepiped form was used in the concrete manufacturing test [3]. Especially, Hanyang University has progress of the research about space exploration and Lunar concrete.

4. Purpose & Scope of Research

The purpose of this research is initially to consider the damage to be done by the dust created when a spaceship lands on the Moon, and to manufacture **Lunar Landing Pad** capable of **removing or minimizing the dust** by using unmanned **auto equipment system** located at the landing position. In this test, KOHLS-1(Korea Hanyang Lunar Simulant – 1, Lunar simulant made of volcanic ash from Kyungju) was used, and the ratio of physical particles was considered in the mixing process for manufacturing a stimulant sample. Since fine particles below no.200 take up approximately 50% of all in the Moon, either ball mill or grinder must be used for a sufficient pulverization in the process of manufacturing a stimulant. The test began at Hanyang University in 2010. As for the courses, after scaling up the sample sizes from 10cm * 10cm to scale up along with an addition of glass fiber, a strength test was conducted. Then the scope was set to forming mechanism, developing prototype equipment, and running an operation test. The material idea about Moon is from ISRU. Polymer and glass fiber are light weight because delivering to the Moon is depended on cost. Last advance preparation-3 has considered the dust environment by lunar simulant.

5. Advance Research

Prior to performing this research, based on a 10cm*10cm wide sampling, the scale of width was upgraded to 43cm*34cm. By using information from basic references, glass fiber was added to the landing pad, and the strength test was conducted to find out if such level can is practically applicable in the Moon. Such test is significant since not only the process of man manufacturing the pad can be simplified, but algorithm can be made simultaneously for designing of auto equipment.

5.1 Manufacturing Test(Advance Preparation-1)

Initially as a way of removing the Moon's dust, along with the concept of In-Situ Resource Utilization(ISRU), only one side of a form used for manufacturing concrete was used to perform the test. This is first type of making the lunar landing pad so, before this experiment, nobody had done. By setting mixture of polymer to 10% in contrast to simulant and mass, it was stacked in 10cm * 10cm * 2cm thickness. Then the teflon sheet was attached under the quadrilateral panel to prevent adhesion of the polymer and the panel. The two rod lines went on top of the panel and the heating started. In the process of heating, water bleeding and smoke occurred. The target heating temperature of the center spot was set to above 200℃, and it took 56 minutes to reach such temperature.

Fig 1 First Sample of Landing Pad

During compression, it sunk 1.5mm. With the panel as the center, an oval shape was created on the base side of the landing pad, showing influence of heat conduction. Efficiency of compression/heating authorized on one side wasn't so great compared to heating authorized on the side 4, and compression on the side 2 of a preexisting rectangular parallelepiped..

5.2 Manufacturing Test for Scale Up & Addition of Glass Fiber (Advance Preparation-2)

After the first manufacturing test, to examine the strength performance, the scale up and the glass fiber were attached in a grid shape and added for the manufacturing test.

Fig 2 Scale up & Glass Fiber

The scale was upgraded to 43cm * 34cm size, and weight of the panel was compressed to 18.3kg (When applied in the Moon, such weight performs compression of over 100kg). At this stage, 10% of polymer in contrast to mass was used. Compared to the sampling, including the manufacturing courses, the time for heating and compression was increased by 3.5 times.

5.3 Strength Test (Advance Preparation-3)

Identical to the advance preparation-2, the size was compressed to 43cm * 34cm. At this stage, topsoil less than Sieve #200(0.075mm) in sizes of 10~20cm was filled, and pebble-sized particles made of identical components were stacked under it in height of 10 cm to run the test.

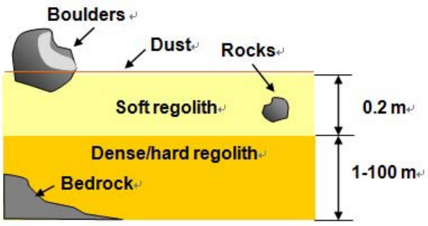

Fig 3 Lunar Soil Composition

Fig 4 Scaled Up Landing Pad

5% of polymer in contrast to mass was used to decrease transportation weight so that it suits the concept of ISRU. As for the glass fiber, a chop strand mat, an interior material, was used without manually attaching the glass fiber, performing standardization by using a ready-made product. As a result of testing the compressive strength after manufacturing, the highest strength was 2.75MPa (16.5MPa, giving consideration to the Moon’s gravity).

6. Automation System for Lunar Concrete Launching Pad Methodology

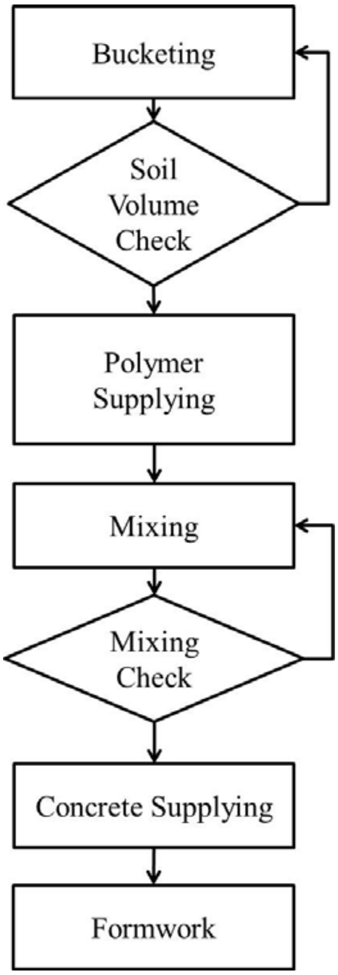

Fig 5 Algorism of Landing Pad

The test courses were simplified into four stages. The four stages are collection→mixture→transportation→form. The reason for having to simplify algorithm is because more movements result in greater influence of the Moon’s dust, meaning that the process of replacement must be convenient and that such process must be simple and accurate. Therefore, the mechanism was minimized.

6.1 Mechanism

TRIZ(Russsianspell :TeoriyaResheniyaIzobretatelskikhZadatch, in English, Theory of Inventive Problem Solving) method was used to actualize the prototype, focusing on functions required for automation, by applying equipment gettable in reality. As the first priority, the damage which may be caused by the dust to a driveshaft was minimized.

Therefore, with the goal to minimize driving, it was manufactured so that the four parts of bucket elevator, mixer, concrete supply and formwork mutually connect to one another for operation.

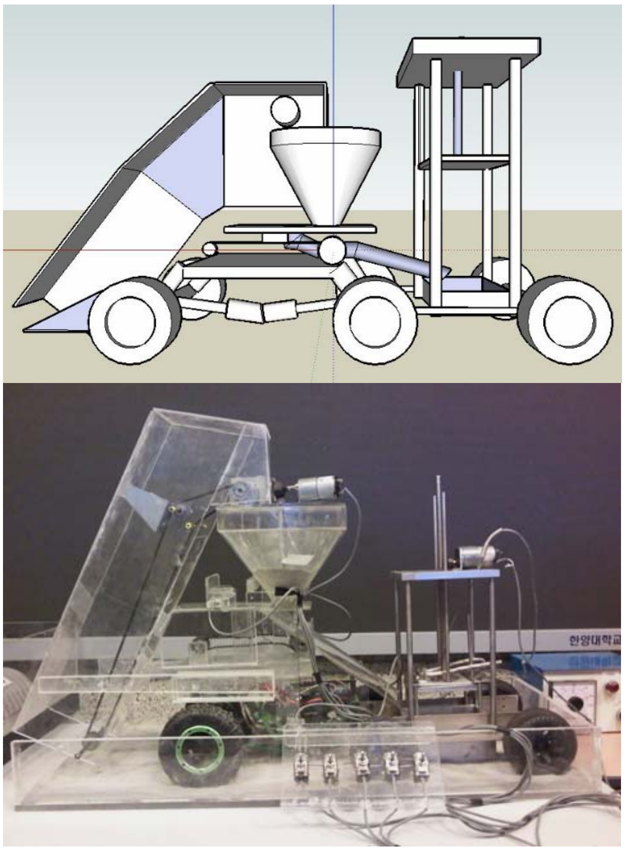

Fig 6 Design & Making Prototype

6.2 Bucket Elevator

The front section of the bucket was designed by using the shovel car's design, and by applying characteristics of the bucket elevator, a method in which the bucket moves to the mixer's entrance through a belt was selected. The manufacturing was done so that the bucket follows the belt upward to naturally pour stimulant into the mixer. However, a problem of dust being flown occurred in the transferring course of the bucket, which draws up the dust, to the mixer. Therefore, a pipe was used to isolate the surrounding of the belt to minimize the dust from being flown.

6.3 Mixer

The concept of hopper was introduced to manufacture the mixer's shape in a triangular pyramid. Through such shaping, it was possible to concentrate the dust in the lower section, and the wing to be installed within was manufactured in a shape so its length decreases as it goes down lower. An inclined structure was needed to use gravity to transfer the mixture from the mixer to the formwork. Therefore, the mixer was installed at the highest level.

6.4 Concrete Supply

A method to transfer the mixture made in the mixer to the formwork was sought. 1) A method of attaching a door in the mixer's lower section for opening/closing, 2) A method of developing a hole instead of a door to use another shape with a hole, 3) A method of having a cap open itself when slanted to allow dust to flow down, 4) Of the methods of connecting a hose to a glass pipe. The 2nd method was selected. The mixer's lower hole is normally closed by a shape which is entirely moved by the timing belt when the motor runs. Then the pipe directing towards the form working meets this hole, allowing a natural transfer of the mixture through this hole to the form working.

By attaching the vibrating motor to the shape for transportation, the transfer of mixture became more convenient.

6.5 Form work

A method allowing compressor to authorize compression and heat when mixture builds up within the form work was used. In particular, the previous lunar concrete manufacturing method developed a rectangular parallelepiped shape by heating the side 4 and compressing the side 2. But such authorization of compression and heat cannot be applied to the landing pad, so heat and compression were simultaneously authorized to the side 1 only.

7. Result of Mechanism

The formwork's width of the first prototype was 10cm * 10cm. It was run in a concept of never disconnecting the landing pad, and was manufactured for one hour. As a result, the connected sections were very weak in connection, and since not enough time for congealment was given to the formwork processing, the shapes were indistinct. In particular, the polymer in the pad section partly wasn't fused, and it took a lot of time to authorize a bit more heat.

Fig 7 Failure of Continued Landing Pad

8. Conclusion

This research, using the unmanned auto system based on the landing pad mechanism, was performed to minimize the Moon's dust to prevent harmful influences to a human body prior to an actual manned expedition to the Moon. Approximately 10Mpa strength was revealed and confirmed in the strength test, but the glass fiber used in this strength test wasn't added to the formwork course. However, along with the development of new technology for an efficient collection of the Moon's resources, it is a research that must be considered before the manned expedition, in order to fortify the foundation for construction of infrastructure. In the future, along with the scale up, a function extracting the glass fiber should be added, the testing time should be increased, and the mechanism should be optimized to fulfill the need of developing a prototype capable of actively manufacturing the landing pad in the Moon.

10. Acknowledge

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