PROSPECTIVE ROLES OF LUNAR/MARTIAN CONCRETE IN SPACE PROGRAMS. T. D. Lin, Lintek International, Inc.

The recent discoveries of possible life on Mars and a huge ice lake in the lunar south pole region have had great impacts on our thinking toward the Mars exploration and lunar development. The 21st century appears to be an exciting era in which mankind may build bases on the Moon and conduct manned missions to Mars.

Data on the returned lunar materials, Martian soil collected by the Viking landers, and a Martian meteorite (ALH 84001) reveal a wide range of engineering applicability for these extraterrestrial materials. A substantial number of papers presented during recent space symposia and seminars advocate the utilization of space resources for productions of noble and common metals, oxygen and water, Helium-3 for fusion power generation, and construction materials. Construction on the Moon and possibly on Mars will be the logical goals for the next major national space programs.

Solar system resources will undoubtedly offer tremendous commercial opportunities to space entrepreneurs. Space tourism, space industrialization, oxygen and He^3 storage facilities, lunar landing/launching ports, and surface transportation support systems all require major construction involving the use of enormous volumes of building materials. The concept of transporting needed construction materials from Earth is economically impossible due to the high transportation cost ($10,000/kg to the Moon). The only viable alternative is to beneficiate or process local lunar materials with simple operation procedures to make high performance structural elements. One such alternative is to use concrete since virtually all needed materials are readily available on the Moon.

Substantial studies on the production of cement, water, reinforcing bars, and aggregates from lunar materials have been carried out in the last decade, including a lunar concrete cube made with forty grams of actual lunar soil used as aggregate. The measured strength of the tested lunar concrete cube exceeds 700 kgf/cm^2 (10,000 psi), twice the minimum strength required by the ACI Building Codes in designing concrete columns. This is a convincing evidence that supports the validity of the lunar concrete concept.

The hydrogen reduction process has been successfully demonstrated in producing oxygen and water from lunar ilmenite by other researchers. The residue of the process is a combination of iron and titanium oxide that can be extruded to form reinforcing bars or fibers. The availability of ice on the Moon will eliminate the need for water production and further reduce the production cost of concrete on the Moon.

Concrete, the most widely used construction material since the invention of Portland cement in 1824, is a versatile material capable of withstanding solar radiation, lunar temperature extremes, high compressive stresses, and moderate tensile stresses if reinforced with fibers. The engineering properties of concrete have been well documented. The profound concrete technology developed in the last 170 years can be applied to the envisioned planetary construction with slight modification to accommodate the effect of the vacuum on concrete casting.

In 1990–91, an innovative Dry-Mix/Steam-Injection (DMSI) procedure was developed solely for the purpose of casting concrete in space. The procedure is rather simple and straightforward. It involves mixing cement and aggregate in a dry state and exposing the mixture to a 180 C steam in a confined chamber for 18 hours. Surprisingly, concrete thus made develops a strength of 700 kgf/cm^2, two and half times that of companion cubes made with the same mix proportion, using the conventional wet-mix procedure which requires 28 days to develop the desired design strength. The rapid hydration shortens the manufacture time while the high strength development increases the product quality of concrete. The DMSI method will be an added spin-off benefit of space technology to the terrestrial precast concrete industry.

Conceivably, the existing solar energy, robotic, and remote control technologies can be integrated to form a remote-control lunar cement/concrete production system. A remote-control semi-autonomous manipulation system (Skaar, University of Notre Dame) with a human supervisor unit stationed on Earth will minimize the need for a human presence at the lunar sites. The proposed remote-control concrete production system can be designed, assembled, and thoroughly tested here on Earth prior to transporting to and installing on the Moon. Once established, the system can be repeatedly used to produce concrete without astronauts attending the job sites on the Moon.

At the Fifth International Conference on Engineering, Construction, and Operation in Space held in Albuquerque, New Mexico, June 1996, David McKay and Carlton Allen presented a paper, “Concrete - A Practical Construction Material for Mars.” The paper reveals that key materials including water (polar ice) required for the manufacture of concrete are much more readily available on Mars than on the lunar surface. A hardened concrete, however, may be attacked (carbonation) by the Martian atmosphere that consists mainly of carbon dioxide. The carbonation reaction is of a long term process, it may take a few years of direct exposure to carbon dioxide for concrete to disintegrate. A preliminary test program to determine such effect is in progress. Partial test data will be available for discussion during the forthcoming In-Situ Resource Utilization (ISRU) Technical Interchange Meeting.