Cement and Concrete

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The most commonly used construction material on Earth is concrete made with Portland cement. Three quarters or more of the mass of concrete is aggregate, usually sand and gravel. Portland cement, made by sintering limestone, iron ore, and clay, has as its principal constituents anhydrous calcium silicates and aluminates whose typical compositions are $3CaO \cdot SiO_2$, $2CaO \cdot SiO_2$, $3CaO \cdot Al_2O_3$, and $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$. The first three are essential to good concrete strength. In addition, cured concrete contains about 5 percent (by weight) water, a result of the hydration reactions that bind the Portland cement component around the aggregate.

The principal constituent of concrete—aggregate—is abundant on the lunar surface. Lunar mare basalt is similar to terrestrial basalt, which has been used to make concrete with high compressive strength.

To produce lunar cement, high-temperature processing will be required (see fig. 11). It may be possible to make calcium-rich silicate and aluminate for cement by solar heating of lunar pyroxene and feldspar, or chemical treatment may be required to enrich the calcium and aluminum in lunar soil. The effects of magnesium and ferrous iron present in the starting materials and products would need to be evaluated. So would the problems of grinding to produce cement, mixing, forming in vacuo and low gravity, and minimizing water loss.

The need for water, a substance not known to exist on the Moon [but oxygen is an element in most lunar compounds and see Carter (1985) for the abundance of hydrogen in the lunar soil],

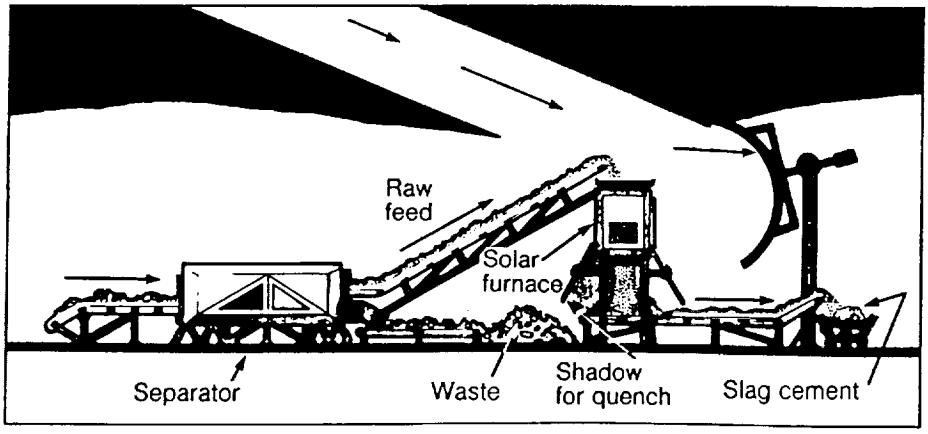

Figure 11

Slag Cement Production Facility

Cement for the concrete might be made by heating lunar anorthitic feldspar to drive off the more volatile components and concentrate its calcium and aluminum oxides. It seems possible to make a usable cement on the lunar surface by relatively simple means. Feedstock separated from lunar soil would be melted in a solar furnace and then quenched in shadow to form a reactive glassy product. When this product is mixed with water and allowed to react and dry, it should make a coherent cement suitable for many structures at a lunar base.

appears to be the most serious deterrent to extensive use of concrete in space. Nevertheless, the convenience of using concrete in space construction has great potential and such use merits close attention. Water may not always be as scarce a commodity as it is now (see fig. 12), and, for some applications, concrete might prove cost-effective even if water had to be furnished. This possibility becomes more realistic if lunar oxygen is made available so that only hydrogen has to be imported. The hydrogen content of cured concrete can be as low as 0.5 percent (by weight).

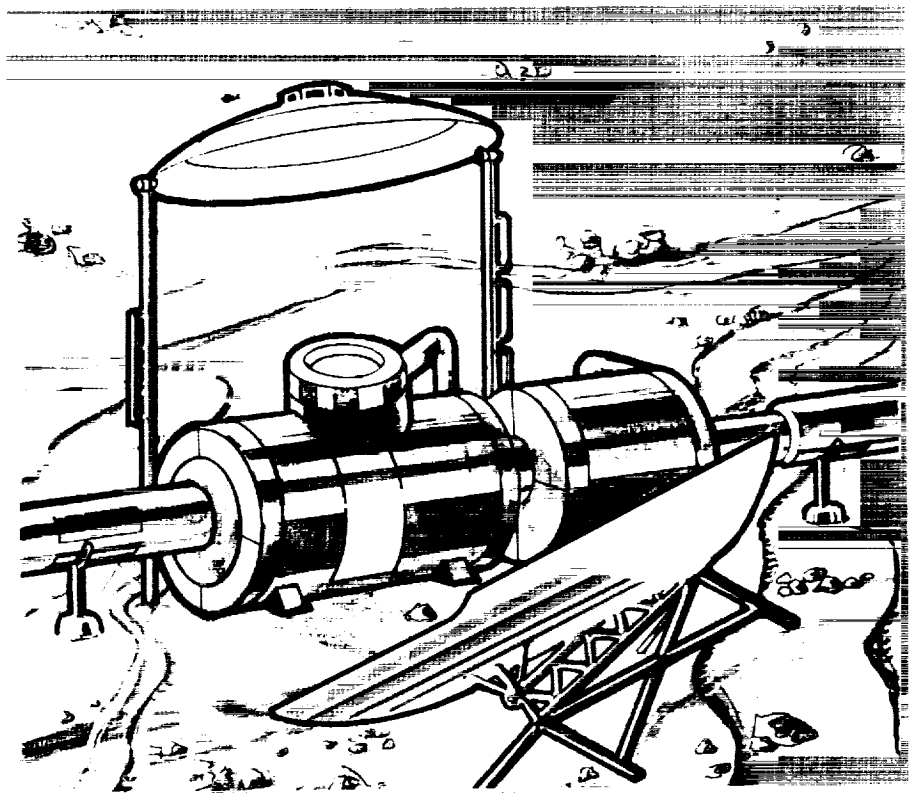

Figure 12

Water on the Moon

Although scarce on the Moon as compared to on Earth, there is enough hydrogen in lunar material to provide about 1 kilogram of water per cubic meter of lunar soil. This water, in turn, could be used to make about 20 kilograms of concrete. The hydrogen could be extracted by solar heating of the finer grained fraction of the lunar regolith, then reacted with ilmenite to form water (and leave an iron-rich residue).

A possible product of interest might be concrete beams reinforced with glass fibers. If imported hydrogen could be used with perfect efficiency, each metric ton could yield 6 kilometers of beams with a cross section of 10 by 10 centimeters. The same amount of hydrogen could yield a wall 10 centimeters thick, 3 meters high, and 24 meters long. Thus, where bulk plus reasonable strength is required or where complex shapes are needed, concrete may be a plausible material to use. See figure 13.

A more complete discussion of concrete's properties and potential uses is found in the second appendix to this part.

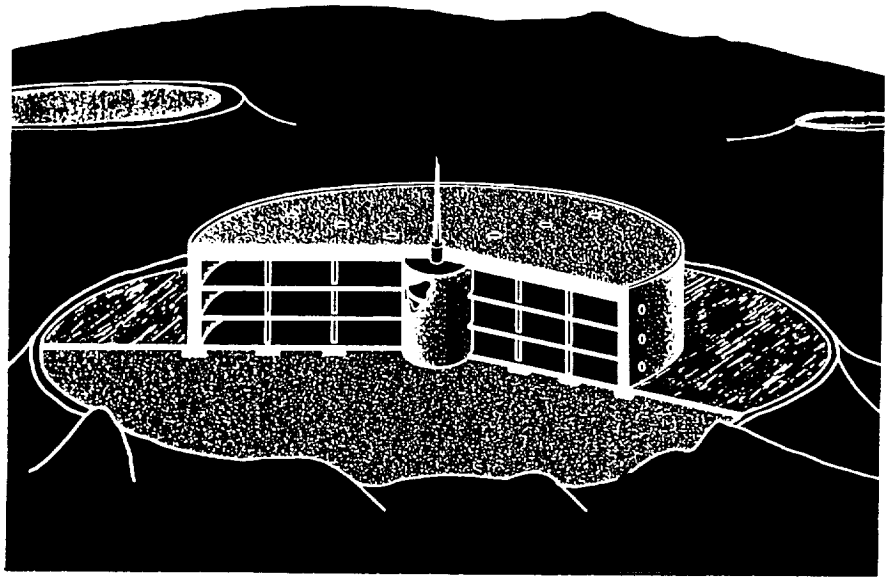

Figure 13

Concrete Structure

Concrete can be made from rocks, sand, cement, and water. The rocks and sand are readily available on the lunar surface. Cement could be made from lunar soil, although considerable processing would be required to produce the right composition. Even the hydrogen for the water might be found in the lunar soil.

The facility shown here, which could house 300 people, would require about 36 metric tons of hydrogen, to be brought from Earth. All other constituents of the concrete would be lunar. If the same 36 metric tons were brought from Earth in the form of space station modules, the assembled structure would provide space for only 8-10 people.