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Appendix B: Properties and Uses of Concrete

Gene Corley

Properties of Concrete

Concretes that can now be formed have properties which may make them valuable for lunar or space construction. These properties include high compressive strength, good flexural strength (when reinforced), and favorable responses to temperature extremes (even increased strength at low temperatures). These and other properties of concrete are described in T. D. Lin's contribution to this report ("Concrete: Potential Material for Space Station").

Higher quality cements and products may become possible. Among other possibilities is manufacture of "zero-macro-defect" concrete products. When manufactured on Earth, these materials have the potential for developing a tensile strength of 15 000 psi [103 megapascals (MN/m^2)] and a compressive strength of 30 000 psi (207 MN/m^2). Although they are made at relatively low temperatures and pressures, they have properties similar to those of some ceramics.

Other properties of concrete that make its application attractive are good radiation absorption and stability at high temperature. Porosity and permeability may be a problem, necessitating the addition of impermeable coatings in some applications.

Fabrication Techniques

Procedures common on Earth can be used to fabricate structural products. The following techniques are possible:

1. Casting
2. Curing at ordinary temperatures or autoclaving
3. Shotcreting with glass fiber reinforcements

Of the techniques available, autoclaving appears most attractive for "high strength" products. This can be done by placing molded concrete units in a pressure vessel painted black on one side. Curing can be accomplished within a few hours. All free water can be recaptured for reuse. Autoclaving will accelerate the cure and produce concretes that contain less combined water than products cured at low temperatures and have greater volume stability upon drying, which are advantages in the space environment. Slag-type silicate-based hydraulic cements are well suited to autoclaving, because the high temperatures accelerate the hydration reactions.

Shotcreting can be used to construct large monolithic structures. Pressure vessels, structured shapes, floor slabs, and wall panels can be fabricated with the use of glass fiber reinforcements. Molds made of inflated membranes can be used for large enclosures. As in the case of autoclaving, free moisture can be recaptured.

For some applications, such as patching or grouting, where conditions make special curing impossible, a relatively quick-setting cement might be needed. Portland cements are not well suited to such applications, but phosphate cements could be developed to meet such needs. Sulfur cements, which do not require water, have been suggested, but they have poorer properties than hydraulic cements. Special composition cements are a topic worthy of further research.

On the Moon, buildings made of concrete and sheltered by a soil covering can be used as space for living, manufacturing, and storage. The amount of energy used in concrete construction can be low, and the level of worker skill does not need to be high for good results.

As concrete processing technology using appropriate lunar materials develops, concrete may find application in Earth orbit for construction of large structures (see T. D. Lin's paper). Concrete materials such as aggregate, cement, and oxygen from the Moon and hydrogen from Earth can be transported and, in advanced scenarios, at competitive transportation costs. Where large masses of material are desired, concrete has the advantage over unprocessed or sintered material in that it can be cast into compartmented but monolithic structures of high strength, using lightweight forms (e.g., inflated impermeable membranes). Indeed, the versatility of concrete for construction on Earth may be matched in space.

Omit to End

Addendum: Participants

The managers of the 1984 summer study were

David S. McKay, Summer Study Co-Director and Workshop Manager
Lyndon B. Johnson Space Center

Stewart Nozette, Summer Study Co-Director
California Space Institute

James Arnold, Director
of the California Space Institute

Stanley R. Sadin, Summer Study Sponsor
for the Office of Aeronautics and Space Technology
NASA Headquarters

Those who participated in the 10-week summer study as faculty fellows were the following:

James D. Burke	Jet Propulsion Laboratory
James L. Carter	University of Texas, Dallas
David R. Criswell	California Space Institute
Carolyn Dry	Virginia Polytechnic Institute
Rocco Fazzolare	University of Arizona
Tom W. Fogwell	Texas A & M University
Michael J. Gaffey	Rensselaer Polytechnic Institute
Nathan C. Goldman	University of Texas, Austin
Philip R. Harris	California Space Institute
Karl R. Johansson	North Texas State University
Elbert A. King	University of Houston, University Park
Jesa Kreiner	California State University, Fullerton
John S. Lewis	University of Arizona
Robert H. Lewis	Washington University, St. Louis
William Lewis	Clemson University
James Grier Miller	University of California, Los Angeles
Sankar Sastri	New York City Technical College
Michele Small	California Space Institute

Participants in the 1-week workshops included the following:

Constance F. Acton	Bechtel Power Corp.
William N. Agosto	Lunar Industries, Inc.
A. Edward Bence	Exxon Mineral Company
Edward Bock	General Dynamics
David F. Bowersox	Los Alamos National Laboratory
Henry W. Brandhorst, Jr.	NASA Lewis Research Center
David Buden	NASA Headquarters
Edmund J. Conway	NASA Langley Research Center
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Hubert Davis	Eagle Engineering
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Charles H. Eldred	NASA Langley Research Center
Greg Fawkes	Pegasus Software
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Charles E. Glass	University of Arizona
Charles L. Gould	Rockwell International
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Larry A. Haskin	Washington University, St. Louis
Abe Hertzberg	University of Washington
Walter J. Hickel	Yukon Pacific
Christian W. Knudsen	Carbotek, Inc.
Eugene Konecci	University of Texas, Austin
George Kozmetsky	University of Texas, Austin
John Landis	Stone & Webster Engineering Corp.
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John M. Logsdon	George Washington University
Ronald Maehl	RCA Astro-Electronics
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Terry Triffet	University of Arizona
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Scott Webster	Orbital Systems Company
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The following people participated in the summer study as guest speakers and consultants:

Edwin E. "Buzz" Aldrin	Research & Engineering Consultants
Rudi Beichel	Aerojet TechSystems Company
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Joseph A. Carroll	California Space Institute
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Edward A. Gabris	NASA Headquarters
Peter Hammerling	LaJolla Institute
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Nicholas Johnson	Teledyne Brown Engineering
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Joseph P. Loftus	NASA Johnson Space Center
Budd Love	Consultant
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John Meson	Defense Advanced Research Projects Agency
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John C. Niehoff	Science Applications International
Tadahiko Okumura	Shimizu Construction Company
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Harrison H. "Jack" Schmitt	Consultant
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