The Aga Khan Award for Architecture

Sandbag Shelter Prototypes

Various locations worldwide

Architect:

Cal-Earth Institute

Hesperia, United States

Client:

UNDP/UNHCR Tehran, for the refugees of the Persian Gulf war

Tehran, Iran

Date of Completion:

1992

2761.IRA

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Sandbag Shelter Prototypes

Various locations worldwide

Architect
Cal-Earth Institute

Design
Begun in 1992

Completed
Ongoing

Sandbag Shelter Prototypes
Various locations

Description

The global need for housing includes 17 million refugees and displaced persons – victims of natural disasters and wars. Iranian architect Nader Khalili believes that this need can be addressed only by using the potential of earth construction. After extensive research into vernacular earth building methods in Iran, followed by detailed prototyping, he has developed the sandbag or 'superadobe' system. The concept allows people to build their own shelter simply by packing whatever earth they find in their location into sandbags, which are then stacked into dome forms, held together by barbed wire. The shelters are structurally strong – able to resist earthquakes, fires, floods and hurricanes. They are extremely quick, easy and cheap to build. They can be made into permanent structures by rendering them with external plaster and adding any necessary ancillary spaces. They are sustainable in terms of energy, using only sun, shade and gravity. They are adaptable in terms of size, material and configuration, and the system can also be used to build roads and other infrastructure.

These shelters focus on the economic empowerment of people by participation in the creation of their own homes and communities to create sustainable developments that integrate traditional building materials with modern materials and technology, providing comfortable living spaces acceptable to modern safety standards.

Jury Citation

These shelters serve as a prototype for temporary housing using extremely inexpensive means to provide safe homes that can be built quickly and have the high insulation values necessary in arid climates. Their curved form was devised in response to seismic conditions, ingeniously using sand or earth as raw materials, since their flexibility allows the construction of single- and double-curvature compression shells that can withstand lateral seismic forces.

The prototype is a symbiosis of tradition and technology. It employs vernacular forms, integrating load-bearing and tensile structures, but provides a remarkable degree of strength and durability for this type of construction, which is traditionally weak and fragile, through a composite system of sandbags and barbed wire. Created by packing local earth into bags, which are then stacked vertically, the structures are not external systems applied to a territory, but instead grow out of their context, recycling available resources for the provision of housing. The sustainability of this approach is further strengthened because the construction of the sandbag shelters does not require external intervention but can be built by the occupants themselves with minimal training. The system is also highly flexible: the scale of structures and arrangement of clusters can be varied and applied to different ecosystems to produce settlements that are suitable for different numbers of individuals or groups with differing social needs. Due to their strength, the shelters can also be made into permanent housing, transforming the outcome of natural disasters into new opportunities.

Essay

Architect Nader Khalili started his career as a modernist and achieved success building conventional high-rises. But in 1975 he closed his offices in Los Angeles and Tehran and set out alone by motorcycle into the deserts of his native Iran, convinced that the only way the world's poor could ever afford homes was to build with earth and fire. He dedicated his time to researching traditional vernacular mud construction in Iran and began to work on ideas for using earth as a modern building material. As well as developing a concept for a 'Ceramic House' constructed from sun-dried mud and then fired, Khalili also developed 'Superadobe' – a structure made from sandbags secured with barbed wire. The basic construction technique involves filling sandbags with earth and laying them in courses in a circular plan. The circular courses are corbelled near the top to form a dome. Barbed wire is laid between courses to prevent the sandbags from shifting and to provide earthquake resistance. Hence the materials of war – sandbags and barbed wire – are used for peaceful ends, integrating traditional earth architecture with contemporary global safety requirements.

Using this technology, several design prototypes of domes and vaults were built and tested, including emergency shelters for refugees and the homeless, a sustainable small house called 'Eco-Dome', and a conventionally planned four-bedroom home using a three-vault design concept. The system is particularly suitable for providing temporary shelter because it is cheap and allows buildings to be quickly erected by hand by the occupants themselves with a minimum of training.

Khalili found inspiration for the technology and design of the structures in the principles of Iranian architecture and Sufi philosophy: the unity of the elements of earth, water, air and fire; harnessing sustainable energy – sun, shade, gravity; geometry and symmetry; and the unity of tension and compression. Each shelter comprises one major domed space with some ancillary spaces for cooking and sanitary services. The system is extremely flexible. The earthen materials of clay and sand with straw and water that have been used to make traditional sun-dried mudbricks for millennia are not always available, nor do those most in need of a home have the time to make blocks, dry them and store them. By filling bags directly from the land and reinforcing them with barbed wire, almost any earth can be used and the speed of building is much faster. The structures can be temporary or they can be made permanent by adding a layer of mud daub or other finishing. Incremental additions such as ovens and animal shelters can also be made to provide a more permanent status and the accommodation can be tailored to individual needs. The technology can also be used for both buildings and infrastructure such as roads, kerbs, retaining walls and landscaping elements.

The system employs the timeless forms of arches, domes and vaults to create single and double-curvature shell structures that are both strong and aesthetically pleasing. While these load-bearing or compression forms refer to the ancient mudbrick architecture of the Middle East, the use of barbed wire as a tensile element alludes to the portable tensile structures of nomadic cultures. The result is an extremely safe structure. The addition of barbed wire to the compression structures creates earthquake resistance; the aerodynamic form resists hurricanes; the use of sandbags aids flood resistance; and the earth itself provides insulation and fireproofing.

The earth used to fill the sandbags is taken from the site where shelters are required and comprises at least 90 per cent of the filling material, although stabilizers such as cement, lime and asphalt emulsion may be added. The barbed wire is four-point, two-strand, galvanized barbed wire and is recyclable. Materials research has shown that the majority of existing bags made of both natural and synthetic material can be used. The ideal is a synthetic, ultraviolet-resistant, degradable material. In a temporary building, the bags are allowed to degrade and the building returns to earth. For permanent structures, the synthetic bags are plastered over to provide an erosion-resistant layer.

Because the structures use local resources – on-site earth and human hands – they are entirely sustainable. Men and women, old and young, can build since the maximum weight lifted is an earth-filled can to pour into the bags. Barbed wire and sandbags are supplied locally, and the stabilizer is also usually locally sourced. The shelters are also sustainable and efficient in energy terms: the wind and the sun provide passive cooling and heating and the sandbags provide thick walls that resist changes in temperature.

Since 1982, Nader Khalili has developed and tested the Superadobe prototype in California. He has lectured widely on the concept, including presenting his ideas at NASA's first Lunar Habitat Symposium in 1984, where he proposed construction with lunar soil. In 1991 he founded the California Institute of Earth Art and Architecture (Cal-Earth), a non-profit research and educational organization that covers everything from construction on the moon and on Mars to housing design and development for the world's homeless for the United Nations. Cal-Earth has focused on researching, developing and teaching the technologies of Superadobe. The intense desert environment of California, with summer temperatures regularly exceeding 40ºC and harsh winters with snow and freezing temperatures, flash floods, high winds, and the most dangerous seismic zone in the United States, has provided an ideal testing ground.

The prototypes have not only received California building permits but have also met the requirements of the United Nations High Commissioner for Refugees (UNHCR) for emergency housing. Both the UNHCR and the United Nations Development Programme have chosen to apply the system, which they used in 1995 to provide temporary shelters for a flood of refugees coming into Iran from Iraq.

Throughout the period of prototype building and testing, Khalili's educational philosophy has continued to develop. A distance-teaching programme is being tested for the live broadcast of hands-on instruction directly from Cal-Earth. Many individuals have been trained at Cal-Earth to build with these techniques and are carrying this knowledge to those in need in many countries of the world, from Mongolia to Mexico, India to the United States, and Iran, Brazil, Siberia, Chile and South Africa.

Project Data

Architect: Cal-Earth Institute, US: Nader Khalili, concept and design; Iliona Outram, Project Manager.

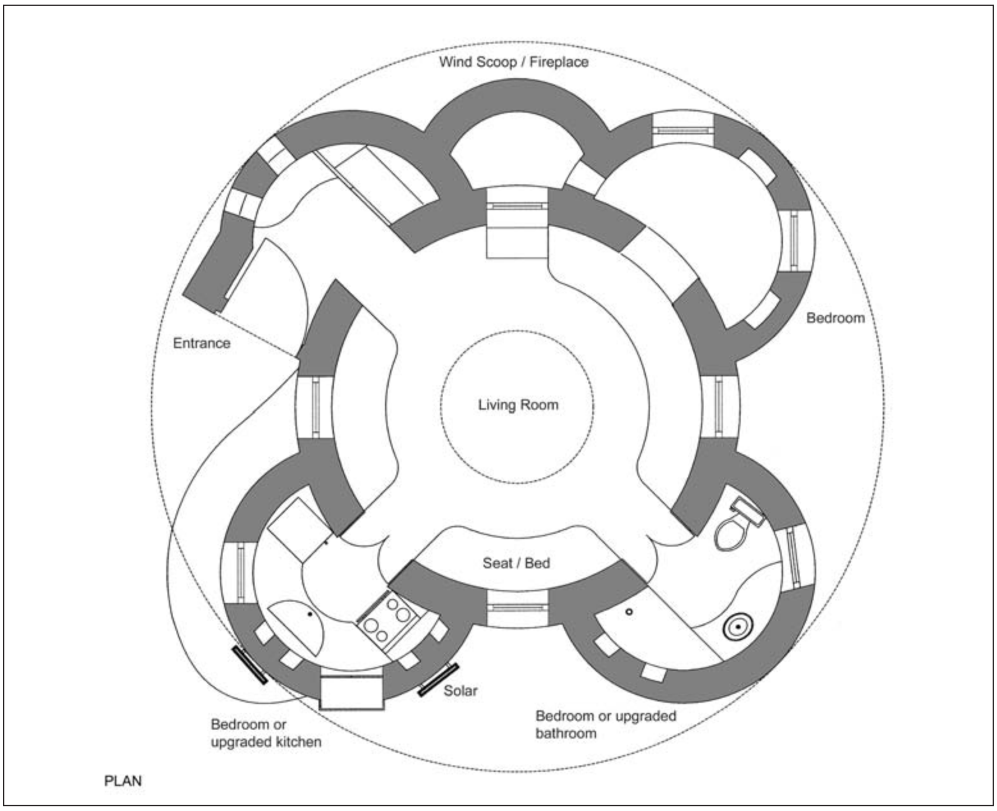
Consultants: P. J. Vittore Ltd, US, and C. W. Howe Associates, US, structural engineers.

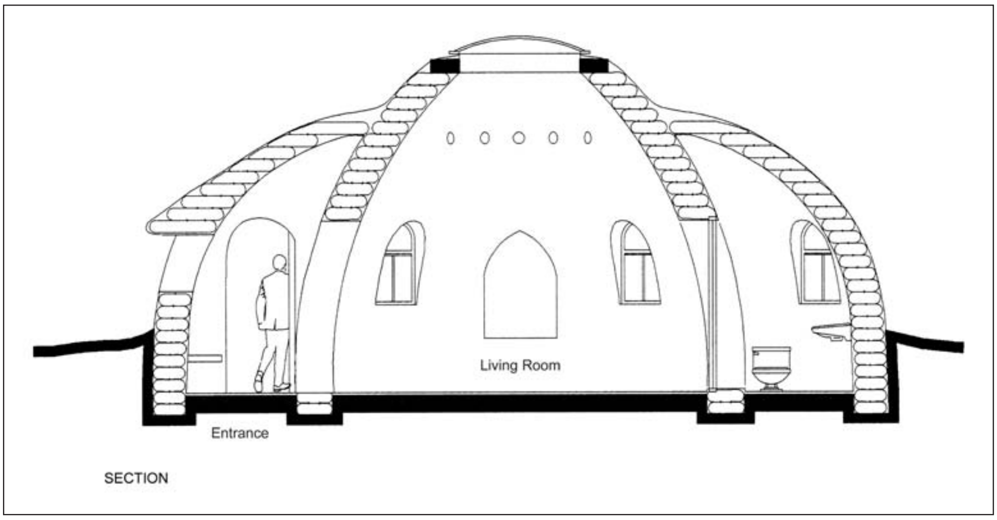
Sponsors and clients: National Endowment for the Arts, US; Southern California Institute of Architecture (Sci Arc), US; the Ted Turner Foundation, US; United Nations Development Programme (UNDP), US and Switzerland; United Nations High Commissioner for Refugees (UNHCR), Iran offices; the Bureau for Alien and Foreign Immigrant Affairs (BAFIA), Iran; Laura Huxley's Our Ultimate Investment Foundation, US; the Rex Foundation, US; Kit Tremaine, US; the Leventis Foundation, Cyprus; the Flora Family Foundation, US.

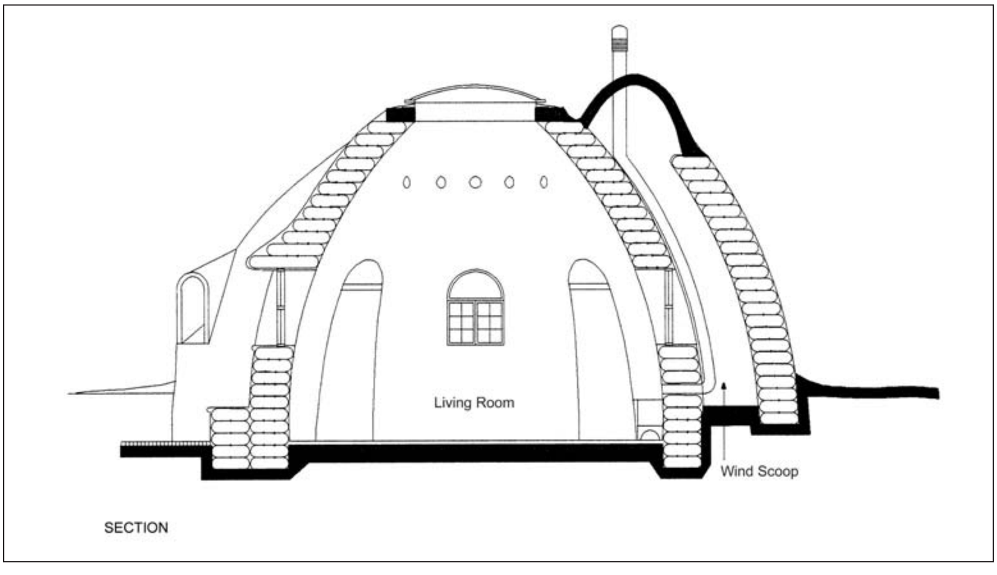
Prototypes built to date by: Hamid Irani and Iraqi refugees at Baninajar Camp, Iran; Eric Hansen, Mexico; Djalal and Shahla Sherafat, Canada; Michelle Queyroy and orphans at the MEG Foundation, India; Dada Krpasundarananda, India, Thailand and Siberia; Mara Cranic, Baja, Mexico; Virginia Sanchis, Brasil; Patricio Calderon, Chile; Jim Guerra and Mexican farmworkers, US; Don Graber, Craig Cranic, Giovanni Panza and Yacqui People of Sarmiento, Mexico.

Timetable: Sandbag Shelters (Superadobe): first development, 1992.

Nader Khalili (b. 1937, Iran) trained as an architect in Iran, Turkey and the United States. From 1970 to 1975, he practised architecture in Iran, and has since dedicated himself to research into building with earth. He has served as a consultant to the United Nations (UNIDO) and a contributor to NASA. Mr. Khalili founded the California Institute of Earth Art and Architecture (Cal-Earth) in Hesperia, US, and teaches architectural research at Sci Arc. He has received awards from organizations such as the California chapter of the American Institute of Architects, for ‘Excellence in Technology’; the United Nations and HUD (US Department of Housing and Urban Development), for ‘Shelter for the Homeless’; and the American Society of Civil Engineers (Aerospace Division), for his work in lunar-base-building technology. He is the author of five published books, including two translations of the work of the thirteenth-century Sufi poet, Jalal-e-Din Mohammad Rumi.


Wind Scoop / Fireplace
Bedroom
Entrance
Living Room
Seat / Bed
Solar
Bedroom or upgraded kitchen
Bedroom or upgraded bathroom
PLAN


Living Room
Entrance
SECTION


Living Room
Wind Scoop
SECTION

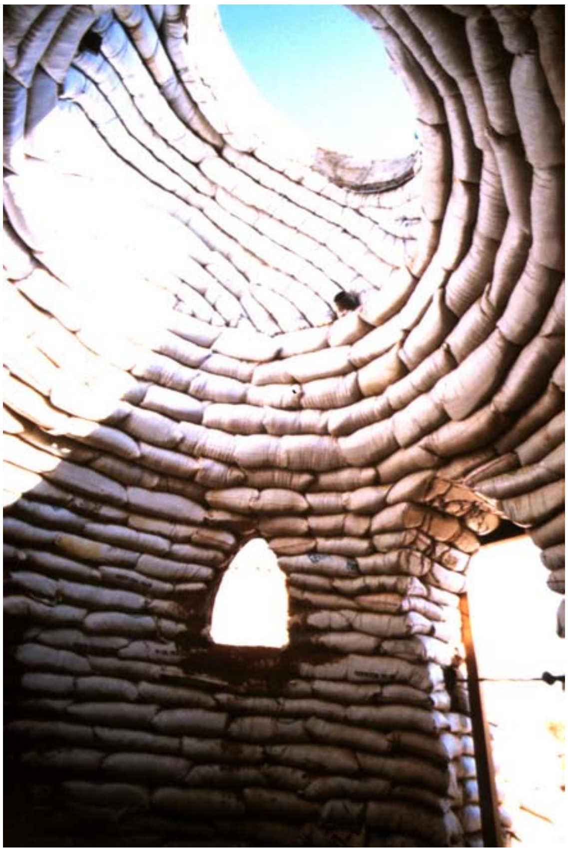
Demonstration of the construction of domes with multiple niches and rooms using the “superadobe” method that meets United Nations standards.

The sandbags can be filled and layed by one person.

Demonstration image.

Demonstration image.

Interior of a prototype dome showing corbelled sandbags, and apses using traditional "leaning arches" technique.



This is an example of a small house (34 sq. m.) with five rooms formed by a dome with four large apses. The temporary shelter can be upgraded into permanent housing, as seen below.

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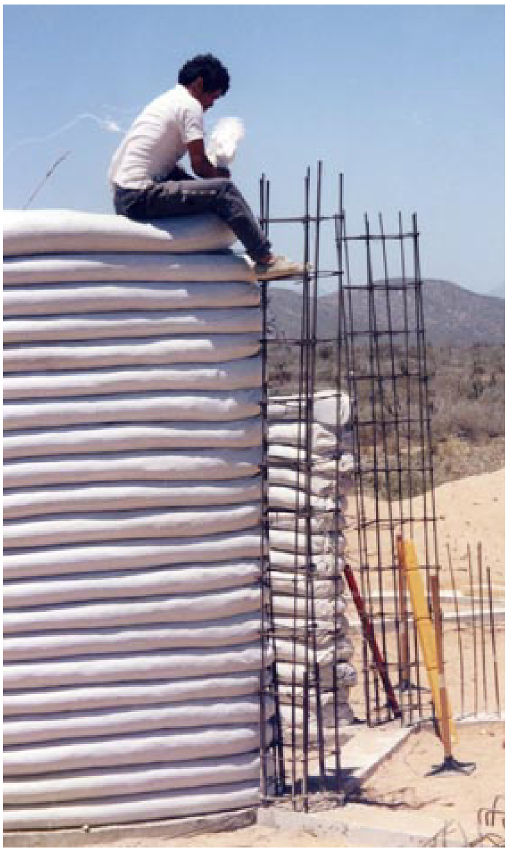
Cal-Earth Institute variations.

Baninajar Refugee Camp in Iran.

A prototype in Mexico.

Another example from Mexico.



A prototype as constructed in Canada.

An example of the prototype in Chile.

Two different examples from India, above and below.

Prototypes built by the Yacqui People of Sacramento, Mexico.

Brazil.

The Aga Khan Award for Architecture

ARCHITECT'S RECORD
2004 AWARD CYCLE

I. IDENTIFICATION

Project Title : Sandbag Shelters
Street Address : Baninajar refugee camp
City : Khuzestan Province
Country : Iran

II. PERSONS RESPONSIBLE :

A. Architect/Planner

Name : Architect Ebrahim Nader Khalili
Mailing address : 10376 Shangri La Avenue
City : Hesperia
Postal code : CA 92345
Country : United States
Telephone : (760) 244-0614
Facsimile : (760) 244-2201
E-mail : calearth@aol.com
Principal Designer. Ebrahim Nader Khalili

B. Client

Name : UNDP/UNHCR Tehran, for the refugees of the Persian Gulf war.
Mailing address : No. 185 Ghaem Magham Farahani
City : Tehran
Postal code :
Country : Iran
Telephone : 8732812-15 or 8732818
Facsimile : 8738864
E-mail :

C. Project Affiliates/Consultants

Please list those involved in the project and indicate their roles and areas of responsibility (e.g. engineers, contractors, economists, master craftsmen, other architects, clients, etc.). Please cite addresses and telephone numbers separately.

Name	Role
Michael Schulenberg, UNDP Tehran	Client, UNDP Resident Representative
Hamid Irani, Architect UNDP Tehran	Project Supervisor, trained by Cal-Earth
P.J. Vittore Ltd., Illinois USA.	Structural Engineering
Refugees of Baninajar Camp	Construction Labor

III. TIMETABLE

(Please specify year and month)

A. Commission: Sept. 1993

B. Design: This is a "typical design", worked on from 1991 to present day. Commencement 1994 Completion 1994

C. Construction: Training of UNDP supervisor, Oct. 1994. Commencement Phase II, May 1995 Completion May 1995

D. Occupancy: Spring/Summer 1995

Remarks: In early 1995, the Building Research Center, Tehran asked to present this technology to the Nepal Conference that year in Low-cost housing technology for central Asian Countries.

IV. AREAS AND SURFACES

(Please specify in square metres)

A. Total size area: The building lot area within Baninajar camp for all 14 domes is about 2,200 sq. metres.

B. Ground floor area: 14 domed units of 22 square meters each unit.

C. Total combined floor area: 308 square meters interior space.
(Including basement(s), ground floor(s) and all upper floors)

Remarks: The floor area of each unit was based on the UN standard refugee tent size for 5 persons.

V. ECONOMICS

(Please specify the amounts in local currency and provide the equivalent in US dollars. Specify the date and the rate of exchange in US dollars at the time.)

	Amount in Local Currency	Amount in US dollars	Exchange rate	Date
A. Total initial budget		$20,000		June 1994
B. Cost of land	n/a			
C. Analysis of actual costs:				
1. Infrastructure	n/a			
2. Labour				
cost per basic shelter	500,000 IRR	$167	3,000 IRR = USD 1	May 1995
cost per upgraded shelter	830,000	277		
3. Materials				
cost per basic shelter	1,865,500 IRR	$621	3,000 IRR = USD 1	May 1995
cost per upgraded shelter	3,095,500	1030		
4. Landscaping	n/a			
5. Professional fees		$2,000 (Cal-Earth only)		
6. Other	Costs of other professional fees are unknown.			
D. Total actual costs (Without land)	Costs per UN report amount to $16, 420			
E. Actual cost (Per square metre)	Estimated UN costs 187,770 IRR (USD 62.5) or less. Construction costs alone for basic shelter USD 35.81 per sq. metre			

Remarks: All cost data is based on UNDP/UNHCR final report of August 1996, pp. 23-24, .see support materials.

VI. PROJECT DESCRIPTION

Pre-Project Phase:

1991-1993: Prototypes of the Sandbag and Barbed Wire technology (Superadobe) were built and tested by architect Nader Khalili at the California Institute of Earth Art and Architecture (Cal-Earth) to United Nations minimum standards.
1993: UNDP (United Nations Development Program) through TOKTEN (Transfer of Technology Through Expatriate Nationals) invited Khalili to his native Iran.

Project Phases:

1994: After demonstrating the technology at Tehran University and Building Research Center on the UN invitation, Khalili was awarded a contract by UNDP Tehran to provide the design and technical training of UN personnel for project "Sandbag Shelters".
1995: UNHCR High Commission for Refugees Tehran collaborate with UNDP to build "Sandbag Shelters" in two phases to assess the feasibility, and cost of constructing Sandbag and Barbed wire refugee homes.
Phase I: Feb. '95 - Two prototype shelters built in the Tehran Building Research Center. Prototype 1, the basic emergency shelter; Prototype 2, the upgraded shelter, to assess the suitability of Sandbag Shelters in emergency situations.
Phase II: May '95 - Fourteen shelters built in Baninajar refugee camp in Khuzestan, Iran. The refugees from Southern Iraq, as the eventual inhabitants, built the shelters supervised by the trained UN personnel, to assess the manpower need, gauge cultural reaction, and habitability. The climate of the region is adverse, with very high temperatures in summer and 2-3 months of heavy rainfall in winter and spring. (see UNDP/ UNHCR final report of 1996)

Post Project Phase:

1995-? The fourteen Sandbag Shelters were inhabited by the refugees at Baninajar camp, we believe for two years, and probably longer.
1993-2003 R & D continues with UNDP input at Cal-Earth Institute. **1)** A second round of seismic tests were successfully passed by the original Sandbag prototypes in California's severe Seismic zone 4, adding earthquake resistance to being fire, flood, and hurricane proof. California building permits were issued under the U.S. Uniform Building Code. Engineering reviewed by local building departments in consultation with ICBO (International Conference of Building Officials). **2)** Long sandbag tubes were developed for mechanization and faster hand construction. **3)** A range of design prototypes in domes and vaults were built and tested. They were also endorsed by UNDP emergency response and UNITAR (United Nations Institute for Training and Research). **4)** Educational system and materials were and are being developed.

VII. MATERIALS, STRUCTURE AND CONSTRUCTION

Cal-Earth is a non-profit institute for research and education into the four elements of earth, water, air and fire, their equilibrium and unity at the service of the arts, environment , and humanity. It is directed by architect Nader Khalili who has been developing simple breakthrough housing technologies for the world's poor, especially in the rural regions of the developing countries, since 1975. Sandbag architecture was presented by him at NASA's 1984 symposium for building on the moon, as "Velcro adobe". Velcro bags, filled with lunar soil, would construct lunar habitat in the forms of domes, vaults, and apses. Later this became known as "Superadobe" sandbag and barbed wire technology, or earth-bag.

Materials:
Sandbags and barbed wire, the materials of war, become the building blocks of peace and help refugees to resist war, as well as natural disasters. Long or short sandbags are filled with on-site earth and arranged in layers or long coils. Between layers, strands of barbed wire act as both mortar and seismic reinforcement. The building is "tailored" and constructed directly from the available earth on-site, without requiring clay, by adding stabilizers like cement, lime, or asphalt emulsion.

Structure:
The forms of arches, domes, vaults, and apses are built with the materials of earth, sandbags and barbed wire to become strong, useful and beautiful structures. Thus the ancient earth architecture of the Middle East using sun-dried clay bricks (adobe) is fused with its portable nomadic culture of fabrics and tensile elements, not just through design and pattern, but through the structure itself. Structural design uses modern engineering concepts like base-isolation and post-tensioning. The thick, load-bearing walls and mainly compressive forces, combined with these strongest forms in nature, allow earthen material of a low compressive strength. The innovation of barbed wire adds the modern tensile element to the traditional earth domes and vaults, creating earthquake resistance despite the earth's low shear strength. The aerodynamic forms resist hurricanes. The innovation of sandbags adds flood resistance, and easy construction. The earth makes them fire-proof.

Construction:
Unskilled persons use simple new construction techniques to build the sandbag shelters. In the spirit of the Islamic architecture of the Middle East, the last 12 years of research builds upon the accumulated human knowledge of four thousand years of earth architecture, adapting to modern needs and skills for the 21st century. Construction techniques such as leaning arches, corbels, squinches, compasses, have evolved with the new flexible material of earth-filled bags into new methods, which allow unskilled men and women to build for themselves, whether as refugees or people in need of a home. The refugees themselves constructed this project in small groups taking five to nine days per dome.

VIII. PROJECT SIGNIFICANCE AND IMPACT

This project should not be judged by the usual architectural standards. Its success does not depend on being permanent, socially prominent, aesthetically special, an important physical landmark or affecting many people's lives personally.

Project "Sandbag Shelter" is significant because it realizes a powerful idea at the service of humanity. Such an idea is carried in the mind and the architecture is repeatable universally.

This humble project is the first UN application of this new technology and demonstrates how it meets all the stringent requirements of UNHCR, the host country, and the refugees.
UNDP/ UNHCR selected this technology and design because of the following characteristics necessary for refugee shelter:

* minimum size
* minimum cost
* maximum speed
* minimum on-site skill
* temporary with the potential for permanence

Because host countries do not allow architecture that is permanent, to encourage refugees to return to their homeland, the project was designed to last up to 2 years. If upgraded, it had the potential to become permanent. The sandbag shelters were lived in for 2 years or more, but there is no data on their current use available to us at this time.

The Baninajar refugee homes validate the following principles of Sandbag Architecture giving them great impact to benefit future refugee camps, and self-help housing worldwide.

Integrating tradition, Islamic religion, local arts and architecture, and contemporary technology into the principles of simple sandbag architecture, is achieved through the following.

1) "Towhid, Vahdat e Anaser". Unity of the universal/natural elements. *"Earth, water, air, and fire are dead to you and me, but alive at God's presence."* The process of "Archemy" architecture and alchemy, and the inspiration of the mystic poetry of Jalalluddin Mohammad Rumi, who wrote in the Persian language: *"If a wise man holds a handful of earth, it will turn to gold."*.

2) Timeless materials (Earth, Water, Air and Fire) and timeless forms in architecture (Arches, Vaults, Domes, and Apses), gives it the dimension to be used both on earth and other planets. As it was proposed to NASA in 1984 for lunar habitat *"Two main materials and methods utilizations of moon dust for shielding or generating structures are in the forms of automated or manually packed soil covering or Velcro adobe, and fused lunar adobe. Soil-packed covering in flexible dry-adhering containers (Velcro adobe), will utilize unprocessed regolith for both structures and shielding. Packed Velcro adobe in flexible containers can be used to construct structures using corbels, dry-packs, and leaning arches. In single-curvature and double-curvature compression shells, the dry-adhering container texture will allow the tightness of consecutive rows, in the case of a vault, or rings in a dome, to hold up the structures in space during construction. Neither type of structure needs centering or form-work. Velcro adobe can also be used in conjunction with other conventional structures, mainly for shielding purposes."* (from Lunar Structures Generated and Shielded with On-Site Materials, Khalili 1989).

3) Timeless aspects of sacred geometry and sustainable energy: sun, shade, gravity, and the scale of the human hand.

4) Houses are constructed by unskilled men and women, old and young, since the maximum weight lifted is an earth-filled coffee can to pour into the bags. They use available on-site earthen material, sandbags and barbed wire, with high insulation value. The design is based on time-tested, Iranian, sustainable desert architecture.

5) The building system focuses on economic empowerment of native people by teaching them how to build their own safe shelter, creating new skills for a construction job, while at the same time incorporating their traditional forms, patterns and colors.

6) The dignity of participation in creating their own shelter rather than the tent handed to them. UN Emergency Response director and team stated to Reuters news agency that,

   "...Superadobe represented a far better option than the tents or plastic sheets and corrugated iron that are used now to provide emergency shelter for refugees from natural disasters and wars. 'The initiative is very suitable because it covers the permanent character of the structure and the dignity aspect of the people who are going to benefit from the shelter – to live in one of these houses is absolutely perfect. To live in a tent is not so dignified in the long run.'....."(from Reuters article Emergency Building Method Fuses Ancient and New Aug. 2001).

7) It grows from the roots of Khalili's own life.

"I grew up in a Muslim society, in Iran. My grandmother used to recite hundreds of mystic poems in Persian that dealt with all these elements of the unlimited universe with unlimited resources, and all those unlimited resources are within you. Later when I went into the high-tech of learning all this knowledge and high rises, there was the natural integration of all these parts. I was very successful in Iran before the revolution but I had quit two years earlier when I went into the desert, so when the revolution broke I was welcome to continue. I stayed for two more years. So it is truly an integration of the East and West. I grew up among the poor. I am one of nine children, and constantly knew need. I never forgot, so now I'm responding." (from Reuters article Emergency Building Method Fuses Ancient and New Aug. 2001).

8) UN authorities and world media comments after studying the emergency shelter prototypes:

1) ***Reuters:*** *UN director of Emergency Response Division: "I don't think there's a risk, it's a proven technology, it's cost effective, you need very little building material, just what nature gives you. So simple it can be learned by everybody"*

2) ***CNN:*** *"They meet all building codes, are energy efficient, weather-tight, and so solid they passed the most gruelling stress tests.."*

3) ***BBC:*** *"The buildings are cool in summer and warm in winter, probably the most environmentally friendly homes you'll ever come across."*

4) ***NASA:*** *(Lunar habitat) Khalili's perspective on Lunar Architecture provides an interesting and thought-provoking contrast to 'orthodox' scenarios"*

5) ***Mayor of Hesperia:*** *"We think this design has the potential of revolutionizing the housing industry" – Hesperia Resorter*

Name (please print) ____________________

Signature ____________________ Date ____________________

Sandbag Shelters

Baninajar Refugee Camp
Ahwaz, Iran

Architects	Ebrahim Nader Khalili Hesperia, CA, United States of America
	Hamid Irani Tehran, Iran
Clients	UNDP/UNHCR Teheran Tehran, Iran
Commission	1993
Design	1994 - 1994
Construction	1995 - 1995
Occupancy	1995
Site	2'200 m2
Ground floor	22 m2
Total Floor	308 m2
Costs	
- Global	16'420 USD
	USD = US Dollar
Programme	Emergency housing for refugees, sponsored by UN agencies and designed by an architect at the Cal-Earth Institute. The arch-shaped adobe houses are seismically safe, impervious to weather conditions, and built using war materials. Sandbags are filled with on-site earth, arranged in layers and lined with strands of barbed wire to act as mortar. Stabilizers like cement, lime and asphalt emulsion are added to the structures, which are "fired", turning the mud into a ceramic-like material. They measure 14 square metres each and, significantly, cost only $4 to construct.

Building Type 875
2004 *Award Cycle* 2761.IRA

SUPERADOBE EMERGENCY HOUSING

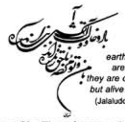
Cal-Earth / Nader Khalili, architect
(CALIFORNIA INSTITUTE OF EARTH ART AND ARCHITECTURE)
Hesperia CA, U.S.A. www.calearth.org

Project: ***SANDBAG SHELTERS***

Baninajar Refugee camp, Khuzestan Province, Iran.

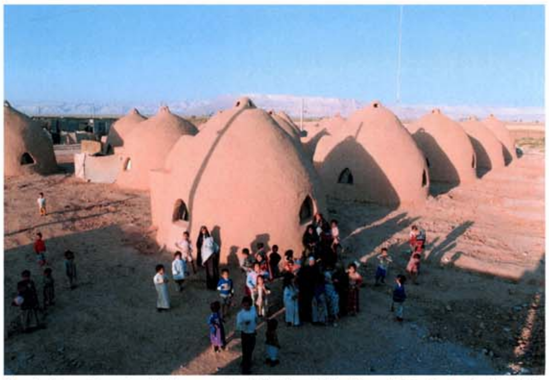
Design and technology by architect Nader Khalili / Cal-Earth Institute
Project by United Nations Development Program and United Nations High Commision for Refugees
Built by the Refugees.

2761.IRA



earth, water, air and fire
are obedient creatures
they are dead to you and me
but alive at God's presence
(Jalaluddin Muhammad - Rumi)

Phase I: Architect teaches students and UNDP representatives the essence of sandbag construction, an arch, at the University of Tehran and Building Research Center.



Phase II: After a prototype domed shelter was completed at the Tehran Building Research Center, fourteen Sandbag Shelters (domes only) were constructed by the refugees themselves in 6-11 days, with UNDP supervision. The refugees immediately moved into the shelters, and some upgrading was completed soon afterwards (plaster finishes, windows and doors).

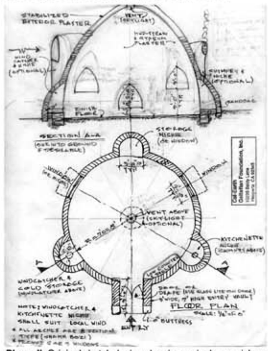
There over 20 million refugees and displaced persons in the world today, victims of natural disasters, wars.

Sandbag Shelter is shown in this project to meet the stringent requirements of UNHCR, the host country, and the refugees. Host countries do not allow permanent architecture, to encourage refugees to return to their homeland. Minimum shelter is specified according to United Nations requirements.

UNDP/ UNHCR selected this technology and design because of the following characteristics:

- minimum size
- minimum cost
- maximum speed
- minimum on-site skill
- temporary with the potential for permanence

Houses are constructed by unskilled men and women, using available on-site earthen material, sandbags and barbed wire, with high insulation value. The design is based on time-tested, Iranian, sustainable desert architecture.



Phase II: Original sketch design showing main dome, niches, door and windows, and bad-gir (windscoop).

2761.IRA

SUPERADOBE EMERGENCY HOUSING

Cal-Earth / Nader Khalili, architect
(CALIFORNIA INSTITUTE OF EARTH ART AND ARCHITECTURE)
Hesperia CA, U.S.A. www.calearth.org

Research and Development: Pre-project and post-project phases

earth turns to gold
in the hands of the wise
(Jalaluddin Muhammad - Rumi)

Sandbag and barbed wire technology, today known as **Superadobe** or earth-bag, uses the materials of war for peaceful ends, integrating traditional Middle Eastern architecture with contemporary global safety requirements. Long or short sandbags are filled with on-site earth and arranged in layers or long coils (compression, low-tech). Strands of barbed wire between them act as both mortar and seismic reinforcement (tension, hi-tech). Stabilizers such as cement, lime, or asphalt emulsion may be added.

Architect Nader Khalili began developing simple breakthrough housing technologies with the freely available material of earth, for the world s poor especially in the rural regions of the developing countries, in 1975. The sandbag concept was first presented by him on NASAs invitation at their Lunar habitat symposium in 1984, as long coiled tubes (velcro-adobe), filled by robotic automation with lunar soil in the forms of domes, vaults, and apses.

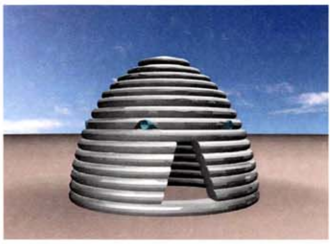
In 1991 he founded **Cal-Earth Institute**, a non-profit research and educational organization, where life-size prototypes are built and tested to U.N. minimum standards, for self-help housing.

The technology and design is inspired by principles in Islamic mysticism and architecture:
1) Towhid, Vahdat e Anaser - the Unity of the universal natural elements of Earth, Water, Air and Fire.
2) Timeless Materials: the universal elements, and Timeless Forms in architecture: the Alpha principle of the Arch, and its derivatives, Vaults, Domes, and Apses.
3) Sustainable energy: sun, shade, gravity, and human hands.
4) Sacred geometry and symmetry of structure, unity of tension and compression..

Pre-project prototypes of 1991-1993 used only damp desert earth, small sandbags, and barbed wire (photo above right). These passed Seismic tests for California s severe Seismic zone 4, making them earthquake resistant, and fire, flood, and hurricane proof. After engineering review by ICBO (International Conference of Building Officials), California building permits were issued by local building departments under the U.S. Uniform Building Code.

Post-project prototypes of 1993-2003 with UNDP input at Cal-Earth, shows the development of:
A) one long fabric tube (before it is cut into standard bags) improves the technology for easier construction, speed, optional mechanization and availability of bags.
B) lifting only one coffee can of earth at a time (not a shovel), and filling the bags directly on the wall (no lifting heavy weights), the whole family indluding women, children and the elderly can participate (photo middle right and below).
C) a simple coiled dome (graphics above left) developed in design with niches for upgraded shelter (middle and below left).
D) educational materials and how-to instructions are provided for self-reliance (example plan below far right).

Other developments using the Superadobe system (see slides and support materials) are 3-vaulted housing typology using more conventional rectangular plans with vaulted roofs.



Simple Emergency Shelter Coiled Dome. This type of 2.5 metre diameter dome can be built in one day to shelter a small family.

Upgraded Shelter Dome with Apses under construction

Upgraded Shelter Coiled Dome with Apses

Moslem woman trains to teach others

Left: Standard sandbags create dome and skylight.

Right: Coils of long bags create a simple dome with a compass.

Comments from world media:

Reuters: UN director of Emergency Response Division: ....you need very little building material, just what nature gives you. So simple it can be learned by everybody
CNN: They meet all building codes, are energy efficient, weather-tight, and so solid they passed the most gruelling stress tests..
BBC: The buildings are cool in summer and warm in winter, probably the most environmentally friendly homes you ll ever come across.
NASA: Khalili's perspective on Lunar Architecture provides an interesting and thought-provoking contrast to orthodox scenarios

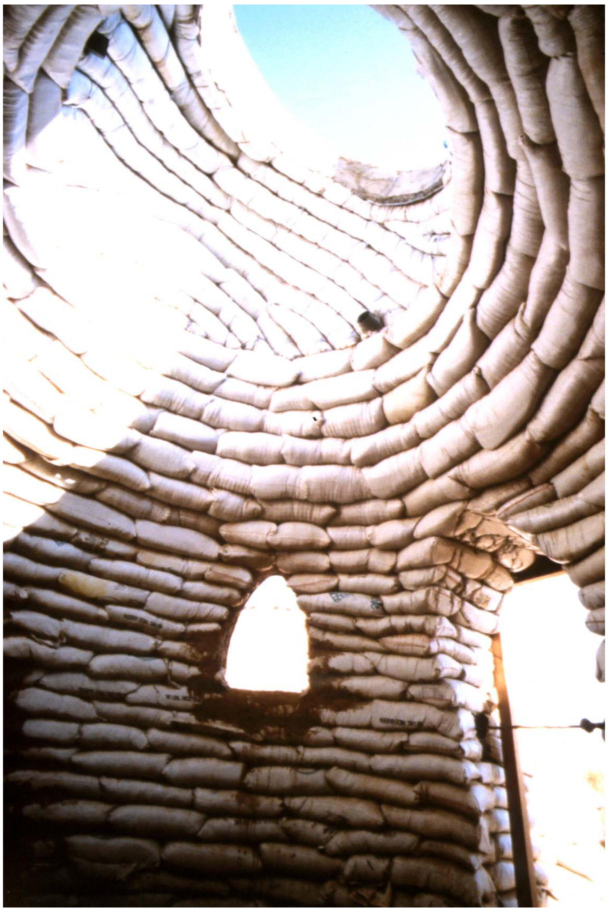
Original tested prototype dome under construction, 1992.

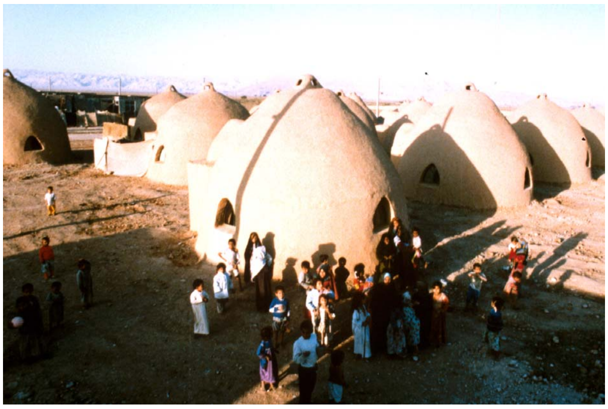
Mother and child fill long sandbag coils with coffee can.

Upgraded Emergency Shelter Plan

Full set of architectural and engineering plans are now permitted within California Building Codes.

Sandbag Shelters, Unidentified, Iran





Sandbag Shelters, Unidentified, Iran

Sandbag Shelters, Unidentified, Iran

Sandbag Shelters, Unidentified, Iran

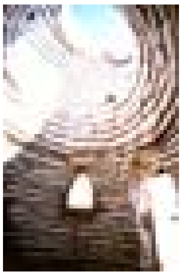
Sandbag Shelters
Unidentified, Iran

Acc No: S221479
VM Title: Sandbag architecture students
Date: 01.01.1993
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221480
VM Title: Early research, sandbag dome shelter
Date: 01.01.1992
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221481
VM Title: First completed sandbag dome prototype
Date: 01.01.1992
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221482
VM Title: Standard 4-point barbed wire
Date: 01.01.1992
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters



Acc No: S221483
VM Title: Interior of prototype dome
Date: 01.01.1993
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221484
VM Title: Men & women learn to build shelter
Date: 01.01.1994
Photographer: Tehran University
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221485
VM Title: 14 domed sandbag shelters, exterior view
Date: 01.01.1995
Photographer: UDNP Tehran
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221486
VM Title: Sandbag shelter window, detail
Date: 01.01.1995
Photographer: UDNP Tehran
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221487
VM Title: Interior view
Date: 01.05.1995
Photographer: UDNP Tehran
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221488
VM Title: Interiors were cool in the summer
Date: 01.01.1995
Photographer: UDNP Tehran
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

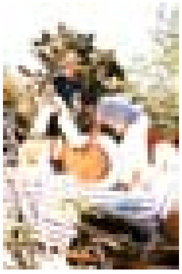
Acc No: S221489
VM Title: Exterior view to street
Date: 01.01.1994
Photographer: UDNP Tehran
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221490
VM Title: Long sandbags are developed
Date: 01.01.1995
Photographer: Cal-Earth
Copyright: N
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Sandbag Shelters
Unidentified, Iran

Acc No: S221491
VM Title: Sreamlined hand-filled techniques
Date: 01.01.2001
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221492
VM Title: Continuous coils speed up construction
Date: 01.01.2000
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

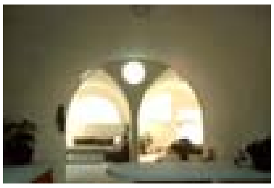


Acc No: S221493
VM Title: Flexibility for larger round windows
Date: 01.01.2000
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221494
VM Title: Small house, 34 sq. m., five rooms
Date: 01.01.2003
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221495
VM Title: Men & women participate in construction
Date: 01.01.2003
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters

Acc No: S221496
VM Title: Clusters of sandbag shelters
Date: 01.01.2000
Photographer: Cal-Earth
Copyright: Y
Technical Infos:
Notes:
CD/Location: - / AK
VM Link: P002761 Sandbag Shelters



Acc No:	S221497
VM Title:	Interior of 3 vaulted house
Date:	01.01.1989
Photographer:	Cal-Earth
Copyright:	Y
Technical Infos:	
Notes:	
CD/Location:	- / AK
VM Link:	P002761 Sandbag Shelters

Sandbag Shelters
Unidentified, Iran

List of Visual Materials

No	VM Num	CD Id	IMG Ord	VM Title	Date	Photographer	Format	Copyright
1	D005957			Upgraded shelter, section II			A4	Y
2	D005958			Upgraded shelter, section I			A4	Y
3	D005959			Upgraded shelter, floor plan			A4	Y
4	D005960						24x36	Y
5	D005961						24x36	Y
6	D005962						24x36	Y
7	D005963						24x36	Y
8	D005964						24x36	Y
9	D005965						24x36	Y
10	D005966						24x36	Y
11	R012587						24x36	Y
12	R012588						24x36	Y
13	R012589						24x36	Y
14	R012590						24x36	Y
15	R012591						24x36	Y
16	R012592						24x36	Y
17	R012593						24x36	Y
18	R012594						24x36	Y
19	R012595						24x36	Y
20	R012596						24x36	Y
21	S221479			Sandbag architecture students	01.01.1993	Cal-Earth	24x36	Y
22	S221480			Early research, sandbag dome shelter	01.01.1992	Cal-Earth	24x36	Y
23	S221481			First completed sandbag dome prototype	01.01.1992	Cal-Earth	24x36	Y
24	S221482			Standard 4-point barbed wire	01.01.1992	Cal-Earth	24x36	Y
25	S221483			Interior of prototype dome	01.01.1993	Cal-Earth	24x36	Y
26	S221484			Men _women learn to build shelter	01.01.1994	Tehran University	24x36	Y
27	S221485			14 domed sandbag shelters, exterior view	01.01.1995	UDNP Tehran	24x36	Y
28	S221486			Sandbag shelter window, detail	01.01.1995	UDNP Tehran	24x36	Y
29	S221487			Interior view	01.05.1995	UDNP Tehran	24x36	Y
30	S221488			Interiors were cool in the summer	01.01.1995	UDNP Tehran	24x36	Y
31	S221489			Exterior view to street	01.01.1994	UDNP Tehran	24x36	Y
32	S221490			Long sandbags are developed	01.01.1995	Cal-Earth	24x36	N
33	S221491			Sreamlined hand-filled techniques	01.01.2001	Cal-Earth	24x36	Y
34	S221492			Continuous coils speed up construction	01.01.2000	Cal-Earth	24x36	Y
35	S221493			Flexibility for larger round windows	01.01.2000	Cal-Earth	24x36	Y
36	S221494			Small house, 34 sq. m., five rooms	01.01.2003	Cal-Earth	24x36	Y
37	S221495			Men _women participate in construction	01.01.2003	Cal-Earth	24x36	Y
38	S221496			Clusters of sandbag shelters	01.01.2000	Cal-Earth	24x36	Y
39	S221497			Interior of 3 vaulted house	01.01.1989	Cal-Earth	24x36	Y
40	S221498						24x36	Y

MATERIALS IDENTIFICATION FORM

Provide a full list of all material being submitted

No.	Description	Remarks
1	Architect's Record 2004 Award Cycle	as required by yourselves
2	Printed Panels	ditto
3	Slides and slide identification form	ditto
4	Daily Press Sept.1992 article on Sandbag Prototypes	Supporting materials 4-18
5	Testing certificate letter Dec. 1995 from Southwest Inspection and testing	
6	I.C.B.O. Publication "Building Standards " of Sept./Oct/ 1998 featuring Superadobe	
7	"Building Standards" Jan./Feb. 2000 featuring Khalili's lunar structures	
8	Reuters article July 2001 on Sandbag Shelters and UNDP assessment.	
9	Reuters Alertnet "Relief Resources" article on Superadobe Emergency Shelter	
10	Reuters, Washington, article on potential application for reconstruction in Senegal, for African Islamic community.	
11	"Safe Haven" Architecture magazine article on Emergency Shelter and Baninajar camp project.	
12	Article and award from ASCE (American Society of Civil Engineers) for "Lunar Structures Generated and Shielded with On-Site Materials"	
13	UNDP/UNHCR "Sandbag Shelters" final Report, Aug. 1996 and cover letter	
14	Building and Housing Research Center, Ministry of Housing and Urban Development, Iran fax./letter.	
15	Los Angeles Times – article "Down to Earth"	
16	Daily Press – article "United Nations Officials Tour Cal-Earth"	
17	Biography of Nader Khalili	
18	Upgraded Shelter Architectural Drawings (niches were not built in the Baninajar Project), prototype at Cal-Earth was built with help from the Flora family Foundation.	

SLIDE IDENTIFICATION FORM

Slide numbers should correspond to the same numbers printed on the « Identification Labels for Slides » which must be placed on each slide. For each slide listed below, specify the name of the photographer and the date of photography. In the space designated « Caption », provide a description of the slide in English or in French. Also specify any copyright restrictions in the space designed « Copyright ». You may substitute this form with your own as long as the required information is included.

No.	Description	Remarks
1	Sandbag Arch. Students at Cal-Earth Institute learn hands-on the essence of building with earth.	Slides 1-5 are early R & D at Cal-Earth (pre-project phase)
2	Early research in building a sandbag dome emergency shelter using the corbelled method.	From 1991-1994.
3	The first completed sandbag dome prototype, later tested for seismic resistance. Of standard sandbags, earth and barbed wire.	Structural testing from 1993 on.
4	Standard 4-point barbed wire is placed between bag rows as seismic and tensile reinforcement.	
5	Interior of prototype dome showing corbelled sandbags, and apse using traditional "leaning arches" technique.	Structural testing in 1995.
6	Men and women learn to build a Sandbag Arch at Tehran University with Khalili during the TOKTEN program visit.	Slides 6-11 are in Iran during the project phases I and II.
7	Project Phase II. Baninajar camp 14 domed Sandbag Shelters exterior view, 1995. Note sun/shade zones for cooling.	
8	Baninajar camp typical Sandbag Shelter window detail and exterior earth plaster.	
9	Typical interior view. Refugees began to move in before finishing of interiors, Spring/Summer 1995.	
10	Interiors were cool in the summer for refugee families, and warm in winter, through the domed design and earth materials.	
11	Exterior view to street. The original design apses and "bad-gir" were not built, but could be added later with courtyard walls.	
12	Based on the Baninajar project timing, long sandbags are developed for faster and more flexible construction.	Slides 12-18 show improved R&D at Cal-Earth.
13	Streamlined hand-filled building techniques add gravity feed of earth by using a foot, compressing long lengths on a tube.	From 1995-2003
14	Continuous coils speed up dome construction, and short pipe sections integrate easily to simplify and beautify windows.	
15	Flexibility for larger round or arched windows with the long bag coils.	
16	A small house (34 sq. m.) of five rooms (a dome with four large apses) can upgrade emergency shelter into long-term home.	
17	Men and women participate in building the home, empowered by learning a single trade for the entire construction.	
18	Clusters of Sandbag Shelters can allow refugees to reconstruct their own social and cultural environments.	

19	Interior of 3-vaulted house. Khalili's design typology of offset vaults uses Superadobe construction to build conventional rectangular rooms which are repeated as needed for small or large shelters/homes.	Slide 19. Additional prototypes.

S221479

S221480

S221481

S221482

S221483

S221484

S221485

S221486

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20 MAI 2003

Cal-Earth – CALIFORNIA INSTITUTE OF EARTH ART AND ARCHITECTURE

May 11, 2003

Mr. Farrokh Derakhshani
Director, Award Procedures
Aga Khan Award for Architecture
7th Floor
1-3 Avenue de la Paix
1202 Geneva, Switzerland

Dear Mr. Derakhshani,

re: "Superadobe Emergency Housing" (2761.IRA)

Please find enclosed the materials for the Cal-Earth/architect Nader Khalili submission for the Aga Khan Award cycle of 2004. Thank you for extending the deadline for submission to May 15th. We had wanted to send you also the new article on Emergency Shelter showing this work, in the New York Times magasine which comes out May 18th, but did not want to overshoot our deadline even further! We hope to send it on later for your record.

We wish the Aga Khan Foundation every success with it's unique work in architecture.

Sincerely,

Iliona Outram

Iliona Outram
Administrator

SOUTHWEST
Inspection & Testing

Continuous Inspection & Materials Testing

10826 South Norwalk Blvd., Santa Fe Springs, CA 90670
(310) 941-2990 • (714) 526-8441
FAX (310) 946-0026

December 27, 1995

Mr. Thomas K. Harp
Building Official/Planning Director
City of Hesperia
15776 Main Street
Hesperia, California 92345

Re: Observation and monitoring of load testing for Cal-Earth Domes and Vaulted Structures.

Dear Mr. Harp:

On December 12 and 13, 1995 Mr. Jim Honaker of Southwest Inspection and Testing observed and monitored the load testing of sandbag domes, masonry domes and sandbag vaults structures, located at the Cal-Earth research site in Hesperia, California. The testing procedures incorporated were submitted by P.J. Vittore, Ltd. and were approved by the City of Hesperia Department of Building and Safety and The International Conference of Building Officials (ICBO). Dynamic load testing was performed on the sandbag dome, masonry dome and sandbag vaulted structures, on the center wall and outside wall. Static load testing was performed on the sandbag vaulted structures. Testing was performed by Mr. Phil Vittore of P.J. Vittore, Ltd. and various trained personnel from Cal-Earth.

This letter is to certify that the testing was done in accordance with the procedures submitted by P.J. Vittore, Ltd. and the results were accurately recorded and attached hereto. All tests have exceeded the ICBO and City of Hesperia requirements. Our observation was done as a third party inspection, with no financial or any other interest in the products tested. If you should have any questions, please do not hesitate to call.

Sincerely,

Jim Honaker
Deputy Inspector

Reviewed By,

Steven L. Godbey
President

JH/SLG:jm

CC: Nader Khalili, Cal-Earth

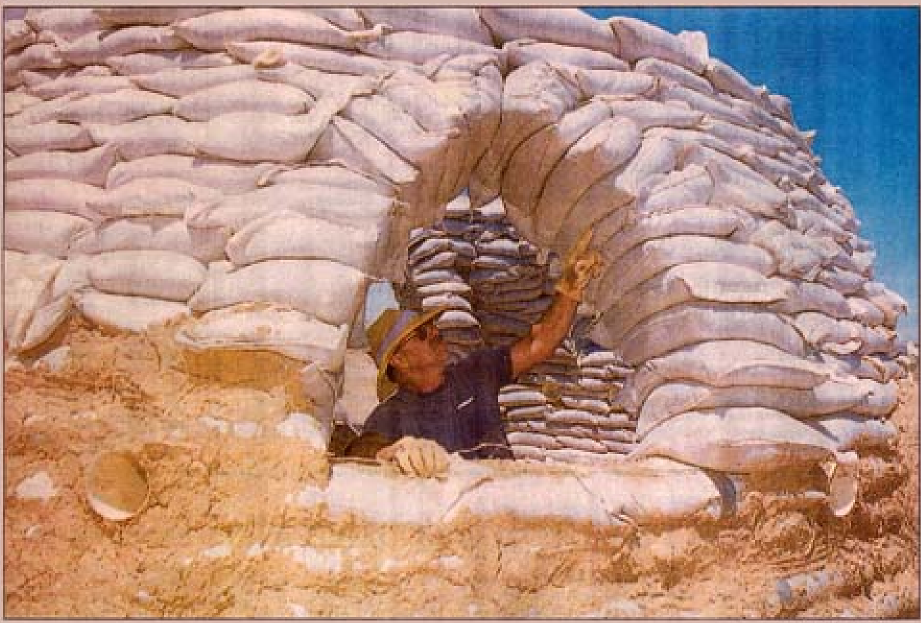
Khalili/ Cal-Earth
10376 Shangri La Ave.
Hesperia CA 92345

DAILY PR

5 sections, 46 pages

Good Morning, Victor Valley. It's Thursday, Sept. 3, 1992

▶ARCHITECTURE



Jeffrey L. Ford / *Daily Press*

Apprentice James Manzi points out the barbed wire used to hold sandbags together for the experimental domed shelter at CalEarth in Hesperia

Making bricks without clay

CalEarth in Hesperia builds refugee shelters of sandbags, barbed wire

By Ruth Mullen
Daily Press

They shall beat their swords into plowshares, and their spears into pruninghooks: nation shall not lift up sword against nation, neither shall they learn war any more.
— Isaiah 2:4

Architect Nader Khalili has taken these ancient words of wisdom and turned them to a modern — and fundamentally practical — end.

Sandbags and barbed wire, often the materials of war, have become the building blocks of peace at the California Earth Art and Architecture Institute, or CalEarth, in Hesperia.

Refugees, domestic homeless

Khalili hopes victims of war, natural disasters and poverty may someday find refuge in a house made with little more than the sweat of their brows and the ground beneath their feet.

"Eight hundred million people in the world are either homeless or live in shelters way below acceptable standards," Khalili said in a recent interview. "There are people who have no hope of ever having any type of housing unless they use what is under their feet."

'Eight hundred million people in the world are either homeless or live in shelters way below acceptable standards. There are people who have no hope of ever having any type of housing unless they use what is under their feet.'
— Nader Khalili

Sandbag domes are just one of many experimental structures Khalili and his apprentices have crafted from earth and recycled materials. The 55-year-old native of Iran founded CalEarth in a converted farmhouse in March as an extension of the prestigious Southern California Institute of Architecture in Santa Monica (Sci-Arc), where Khalili is a professor.

His lofty mission: to teach others to create communities with earth, combining modern technology with timeless building techniques to provide housing for the world.

But not everyone is sold on Khalili's vision.

Hesperia building and safety officials have commended CalEarth for its innovative research — but they caution that the structures are strictly prototypes and are not yet permitted for human habitation.

"It's something for us to consider down the road — using alternative building methods and materials," said John Regner, senior plans examiner. "What they're trying to do has a lot of merit.

"(But) the structures must meet sound engineering practices and principles. We're anxious for them to submit their engineering specifications and calculations to us."

Lunar soil

Khalili has worked with researchers from the National Aeronautics and Space Administration. NASA praised his idea of building low-cost, ceramic housing using lunar soil that can withstand tempera-

Please see SANDBAGS, A10▶

▶ **SANDBAGS** / *From A1*

tures ranging from 250 degrees in the sun to minus 200 degrees in the shade.

That principle extends to Earth, where Khalili has developed a method of sandbag construction using cheap, native, abundant materials strong enough to withstand the worst conditions. A United Nations consultant, Khalili said he is researching the structure as a means of emergency shelter for war refugees and victims of natural disasters.

"The cold, heat and wind have to penetrate 16 to 18 inches of sandbags," he said. "The sandbags not only insulate, but they are also good bomb shelters — shrapnel does not penetrate the mortar, and the sand absorbs the shock."

Sand is the only building material available to the masses in many desert regions, Khalili said. "There is no clay to make bricks in the Sahara Desert," he said. "There is nothing but sand."

Khalili estimates that one cargo plane can drop enough sandbags to build 200 dome houses and that five planes can carry materials for 1,000. Sand, sacks, barbed wire and shovels are sufficient to build a dome strong enough to weather driving winds, scorching sun and bitter nights anywhere on the planet, he said.

"We can transfer the military use of sandbags and barbed wire into housing and community development in places that have never been possible," he said. "Flat-footed soldiers are perfect for stomping on sandbags."

Paul Cohen traveled from Johannesburg to study earth architecture with Khalili in hopes of addressing the growing numbers of urban poor living in shantytowns of sheet metal and door frames on the fringes of South Africa's largest cities.

"This is an opportunity to look at how we can take and appreciate ancient architecture and add in aspects of our own technology," Cohen said.

With the help of a compass, the sandbags are arranged in a circle and gradually built up into a three-dimensional sphere. Forms are used to erect arching windows and a doorway. The barbed wire and gravity act as a kind of mortar, binding the bags and compressing into solid, cementlike blocks. The entire dome is then covered with a metal net banding and plastered inside and out with an adobe mixture of mud, clay and straw. Khalili estimates that four adults working full time can complete a structure in two weeks.

"When we are finished with this, you won't even know it's a sandbag house," Khalili said.

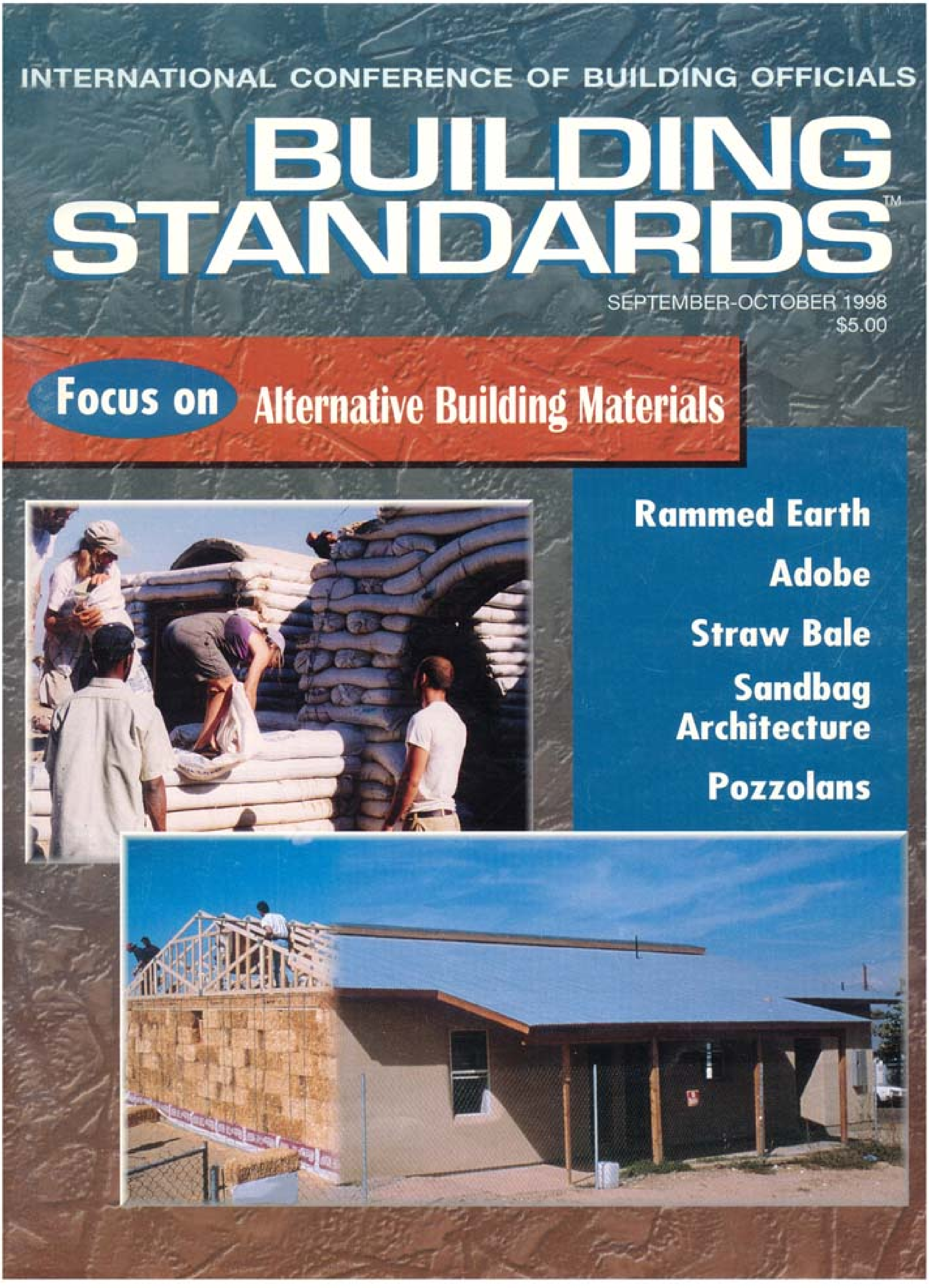
The dome is fundamental to Khalili's architectural style, its ancient simplicity "a symbol of strength and a beacon for the future," he says. The circular base and curved sides absorbs an earthquake's jolts, spreading the shock equally throughout the structure. Likewise, the aerodynamics of the dome can withstand 100 mph winds such as those that recently destroyed thousands of homes in southern Florida, Khalili said.

In a traditional pitched-roof wooden house, the wind hooks onto overhangs, tears off the roof and collapses the walls, he said. In a dome, the weight and curve of the structure deflect the wind and soften its impact.

"The wind wraps around the building instead of lifting it up," he said. "The dome has a natural geometry and density that works with the elements."

For more information, call 956-7533 or write CalEarth, P.O. Box 145, Claremont, CA 91711.

Sandbag Shelters, Unidentified, Iran



Sandbag Shelters, Unidentified, Iran

Sandbag Shelters, Unidentified, Iran

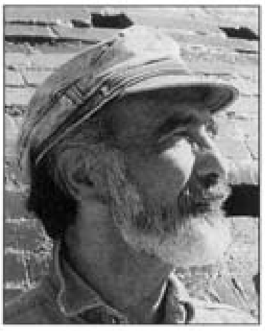
Earth Architecture and Ceramics

The Sandbag/Superadobe/Superblock Construction System

by Nader Khalili
Cal-Earth Institute
Hesperia, California

and

Phill Vittore
Structural Engineering Consultant
Arlington Heights, Illinois



***Nader Khalili**, an Iranian-born California architect and author, is the designer and innovator of the Geltaftan Earth-and-Fire System known as "ceramic houses" as well as the Superadobe building technologies. He received his education in Iran, Turkey and the United States, and has been a licensed architect in California since 1970. In 1975, he closed his successful practice in the United States and Iran designing high-rise buildings and journeyed by motorcycle for five years through the Iranian deserts, where he worked closely with local villagers to develop his earth architecture prototypes. His impressions have been collected in his book* Racing Alone.

Mr. Khalili serves as a consultant to the United Nations and is a contributor to NASA on construction technologies for the moon and Mars. He is the founder and director of the Cal-Earth Institute, Geltaftan Foundation—dedicated to research and development in earth and space architecture technologies for the moon and Mars.

The views expressed here are those of the authors and do not necessarily reflect the opinion or agreement of the International Conference of Building Officials.

Approximately one third of the people of the world live in houses built with earth, and tens of thousands of towns and villages have been raised practically from the ground they are standing on. Today, world consciousness about the use of natural resources and the new perception of building codes as the steward not only of individuals' safety, but of the planet's equilibrium, are leading us into the new millennium of sustainable living.

In 1984, NASA's first symposium on lunar bases and space activities of the 21st century enthusiastically received the presentations dealing with the utilization of onsite natural resources to construct future lunar and martian habitations. The integration of the ancient technologies of building with earth into planetary construction techniques was presented with the following passage:

> The accumulated human knowledge of the universal elements can be integrated with space-age technology to serve human needs on Earth; its timeless materials and timeless principles can also help achieve humanity's quest beyond this planet. Two such areas of knowledge are in earth architecture and ceramics, which could be the basis for a breakthrough in scales, forms and functions. . . .

The Sandbag/Superadobe/Superblock technology presented here (ceramic structures are also part of generic earth architecture systems) is the spinoff from several consecutive presentations to the space and planetary scientific community since that first symposium in 1984. These concepts have been the subject

Sandbag Shelters, Unidentified, Iran

of an intense research and prototype construction program since 1991. The research and development, engineering, and testing have been carried out at the Cal-Earth Institute under the scrutiny of the Hesperia Building and Safety Department, in consultation with ICBO. Building permits for the stock plans of "Earth One" housing models as well as the Hesperia Lake Museum and Nature Center have been issued, and the Sandbag/Superadobe/Superblock building technology is recognized as a construction system.

A New Approach to Sandbags

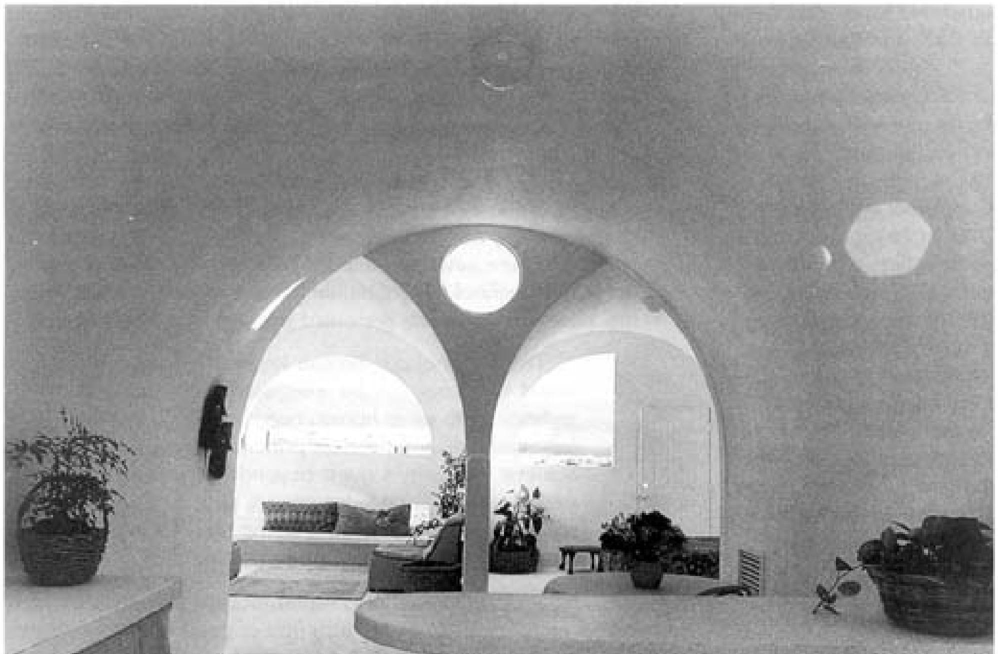
Common sandbags and connecting barbed wire, as well as mile-long bags, are referred to here as Sandbag, Superadobe and/or Superblock construction. For centuries, sandbags have been used as elements in building temporary dikes and protective walls in combat zones, as well as in numerous lesser applications. After the structure has served its temporary purpose, the sandbags normally are removed, emptied and discarded.

The Sandbag/Superadobe/Superblock building system builds on three fundamental aspects of historical sandbag modules, resulting in a permanent system of construction:

1. The most serious drawback in the past concerning sandbags as a structural element is that a stack of bags has no tensile capabilities, which has kept structures very low in height. Also, curved, arched or domed structures were impossible without some friction and tensile resistance available.

Superadobe uses four-point barbed wire (or a similar element) between sandbag layers, allowing one to develop the tensile and shear capabilities that have not been previously achievable. The barbed wire element increases the friction factor between the bags and creates tensile resistance in a wall or structural element. It is an important aspect of Superadobe to provide for the transfer of shear stresses from one sandbag to another by using the barbed wire as an interface between the bags, overcoming problems of low shear capability in the earthen fill. The increased capacity of the sandbags, achieved by using barbed wire, creates the capability of designing higher walls and curved surfaces, such as bearing walls, arches, domes and vaults.

Wall of Superadobe construction—earth-filled sandbags and barbed wire. Coils/courses can be filled by hand or by pump at speeds of 10 to 15 feet per minute, depending on bag width.



A model house similar to this one built of Superadobe was constructed and tested as a prototype in Hesperia, California.

2. Previously, sandbags were not considered part of a permanent structure due to the use of loose fill material, usually sand, which can be loaded easily and discarded when the temporary structure is no longer needed.

Superadobe fabric tube or individual sandbags are packed with different mixes of fluent, particulate material. These include earthen, cementitious, organic, manufactured and recycled materials that form into a permanent block.

Sandbag Shelters, Unidentified, Iran

3. Historically, the potential deterioration of the bag and the subsequent effect on the structure has precluded permanent structures. Superadobe construction shields the sandbag walls from the elements with protective overlay materials. Additionally, the fill material becomes self-supporting once it has been formed into a block by the tubing. When the fill material is sufficiently resistant by itself, the shielding of durable exteriors is not necessary.

The Sandbag/Superadobe/Superblock system, which has developed out of these fundamental changes during intensive research in the last seven years, is used in conventional structures for foundations (poured within the tubing form), for load-bearing and partition walls in conjunction with conventional roofing systems that bear on a bond beam, also generated by the Superadobe tube itself. Emphasis in this article, however, is given to curved structures, such as domes and vaults, since others are addressing the conventional post-and-beam and rectilinear bearing wall structural systems for earthen construction.

Non-post-and-beam Structural System

Superadobe techniques enable the construction of monolithic structural systems built entirely from earth in curved forms. The sandbag, because of its flexibility, allows the construction of curved surfaces. When using single- and double-curvature compression shells—arch, vault, dome, apse—the majority of conventional roofing systems can be eliminated. In the case of wood construction, this can save up to 95 percent of timber, allowing not only for forest products to be more wisely utilized but also resulting in fire-safe buildings. By working with the principle of gravity, these features can be built without special formwork.

The success of the tested prototypes for California's seismic codes and the resulting permits derive from the following principles:

1. Single- and double-curvature compression shells transfer their stresses along the surface of the structure and not from element to element like column- and beam-type buildings. When a single element in a beam and column construction is overloaded to failure, the loss of that element will create a cascading effect on adjacent elements, causing failure of all elements in the vicinity. In many cases, this will cause the entire structure to collapse, as was witnessed in earthquakes in Northridge, California, and Kobe, Japan. Such a structure is only as strong as its weakest element. In a dome, and to a lesser degree a vault, excessive loads on their surface will first cause a puncture failure. This results in the excessive load being shed with only localized damage; the remaining stresses in the vicinity of the failure are transmitted around the failed area, and other loads continue to be held by the structure without any problem.

Double-curvature compression shell, or dome, of Superadobe construction showing rebar guides for the dome shape (removed later) and a simple plank scaffold. Gravity is the generator of the form.

Trainee builders work with hand-filled Superadobe. Long sandbags are filled with earth from the site and tamped in place on the wall. Between courses are set two strands of four-point barbed wire.

2. Dead-load and live-load stresses are transferred to the supporting ground, spreading uniformly along the perimeter of a dome or bearing wall. In a beam and column structure, the loads are concentrated and transferred to the ground via a footing under each column. This situation creates the two basic structural problems of differential settlement and frost heaving. These can cause severe localized stresses within the upper structure, resulting in cracking and other failures. For this reason, most foundations are extended to below the frost line to minimize such problems. In a monolithic bearing wall, dome or vault, differential settlement and frost heaving do not pose severe problems. The base of a dome or bearing wall distributes the load of the structure over a much larger area, and local soft spots in the supporting soil will not create a local problem, as local depressions may be easily spanned. The effect of frost can be rendered negligible with correct design when a dome is free to float on the ground.

3. One of the most significant advantages of a domed or vaulted bearing wall structure is its performance in earthquakes. It is difficult to design conventional structures to withstand earthquake stresses. Their basic shape creates a severe problem, as the building weight is either uniformly spread from roof to foundation or, even worse, weights are often larger in the upper floors. With this propensity for overturning, the deeply planted footings and foundations rip apart at the very base of the structure during an earthquake, causing failures rather than preventing them. Modern earthquake design that incorporates foundation isolation does have shifting capabilities, but it is expensive.

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Sandbag/Superadobe/Superblock: A Code Official Perspective

When architect Nader Khalili first proposed constructing buildings made of earth-filled sandbags, stacked in domes, the building department was skeptical, to say the least. In fact, if we hadn't been trained to be courteous, we would have laughed out loud. How could anyone believe that you could take native desert soil, stuff it into plastic bags and pile them up 15 feet (4572 mm) or more high? Why, if they didn't fall down from their own weight, the first minor earthquake would cause a total collapse, killing everyone inside. How could a responsible building official possibly condone such building code heresy?

Well, Nader Khalili is a very persistent man. Over time, he convinced us that he was going to prove our skepticism wrong, that earth-filled sandbags (now called Superadobe) could be built to meet the rigorous standards of the 1991 *Uniform Building Code*™ (UBC). It all started with Sections 105 and 107, allowing building officials to consider the use of any material or method of construction ". . . provided any alternate has been approved by the building official" and to require testing to recognized test standards as determined by the building official. Although we had applied these sections numerous times, we had never used them to such an extent on a building so foreign to our codes. To say the least, it was a challenge.

Here's a brief description of what we did. Since we are not licensed engineers, and we don't have one on our staff, we contacted ICBO Plan Review Services to see if they would perform the plan review for our city. ICBO welcomed the challenge, but indicated the same skepticism we shared, since Hesperia, California, is within Seismic Zone 4 and local examples of this type of construction are nonexistent.

After some initial discussions regarding standards, Mr. Khalili submitted plans in November 1992, with the understanding that a testing program would be designed as part of the plan review process. In January 1993, ICBO returned the plans with nine general comments, including a provision to provide a rational analysis pursuant to 1991 UBC Section 2303(b).

At about this time, we were introduced to Mr. Khalili's structural engineer, Phill Vittore. Mr. Vittore, with his partner Morrall Harrington, had designed numerous large thin-shell dome structures in the Midwest and was properly represented by a California licensed structural engineer. Mr. Vittore responded to ICBO's initial comments, and a negotiation began that resulted in the design of a static load test program that was agreed to by this department after our discussions with ICBO staff.

The static load test was designed to add 200 percent of the UBC loading of 20 pounds per square foot (psf) (97 kg/m^2) live and 20 psf (97 kg/m^2) wind load. The first test used an 80 psf (390 kg/m^2) loading of additional sandbags over one third of the exterior surface and, after monitoring, over one half of the exterior surface. During the entire test period, deflection was monitored to verify if ultimate loading was approached. Two domes, one of sandbags and one of unreinforced brick, were tested. Special inspection by a local engineering firm was approved and test results showed "that there was no movement of any surface of either dome structure as a result of the loading described in the test procedure." The domes had passed their first test.

After reviewing the test results, ICBO's Plan Review Services staff felt that the use of the domes should be limited to 15-foot (4572 mm) domes of Group M, Division 1 or Group B, Division 2 occupancies until sufficient monitoring had been completed. Mr. Khalili was principally interested in Group R Occupancies, although he was also proposing the construction of a museum and nature center, a building that would house a Group A Occupancy in a 50-foot (15 240 mm) diameter dome. Because of his desire to build larger structures and house occupancies other than Group M, Division 1 and Group B, Division 2 occupancies, Mr. Khalili notified the city that he would not accept the size and occupancy limitations and would propose new testing to approve the use of larger structures.

After extensive negotiations, which lasted more than a year and included a face-to-face meeting at ICBO headquarters, we agreed to a dynamic test procedure. The procedure involved applied and relaxed loads over a short period of time, with a series of tests with increasing loads until Seismic Zone 4 limits were exceeded. After several months of fine tuning and discussion of "passing grades," the tests and desired results were agreed to. Tests involved three buildings, including the brick dome, the sandbag dome and a sandbag vault structure with 5-foot-high (1524 mm) vertical walls and a barrel vault above. The tests were conducted and monitored by an ICBO-recognized testing laboratory in December 1995, and the required test limits were greatly exceeded. Testing continued beyond agreed limits until testing apparatus began to fail. No deflection or failure was noted, however, on any of the tested buildings.

With these results, the plans went back to ICBO, and after final plan check comments were satisfied, ICBO recommended the plans for approval in February 1996. Our skepticism had long since vanished, as we had seen this style of building meet and exceed the testing of rational analysis as required by our code. Mr. Khalili had succeeded in gaining acceptance by the City of Hesperia for a building made of sandbags filled with earth. It is a testament to Mr. Khalili's perseverance and to the flexibility of the UBC.

—Tom Harp
Building Officer/Planning Director
City of Hesperia, California

—John Regner
Senior Plans Examiner
City of Hesperia, California

Sandbag Shelters, Unidentified, Iran

(continued from page 27)

A dome or bearing wall built on a floating foundation, the base isolated by a layer of gravel or sand, provides the ideal earthquake-resistant structure. The continuous or ring foundation can slide across the moving ground, while the upper structure, which diminishes exponentially in mass toward the apex, performs as a unified monolithic piece, eliminating local failure higher up the building.

Structural tests performed during intensive prototype research in Hesperia addressed both live-load and dead-load, static as well as dynamic loading forces. The structural engineering and testing procedures were conducted by Phill Vittore of P.J. Vittore, Ltd. The successful results were documented by an ICBO-approved testing laboratory, Southwest Inspection and Testing.

What follows is the chronology of testing, which includes static and dynamic load tests of the prototype Sandbag/Superadobe/Superblock and masonry structures.

CODE TESTING CHRONOLOGY

Tested models:

1. Two domes constructed with standard sandbags and barbed wire, filled with pure desert sand/earth excavated in situ. *The sand/earth used in the first dome was dry, while for the second dome it was dampened with water before filling the bags.*

2. A vaulted structure consisting of three adjoining vaults constructed with pure desert sand/earth excavated in situ. *The walls were built with standard sandbags and barbed wire, as well as long tubular bags (Superadobe/Superblock) filled with dampened sand/earth. The roof material for the 4-inch (102 mm) slab was the same sand/earth stabilized with 7 to 10 percent portland cement.*

3. A 4-inch-thick (102 mm) perforated dome constructed with standard fired clay bricks and cement mortar with no reinforcing.

June 1992. Two earthquakes centered in Big Bear and Landers, California, measuring 6.9 and 7.4 (respectively) on the Richter scale, affected the Hesperia site of the Cal-Earth Institute, with the completed brick masonry dome and the Sandbag/Superadobe/Superblock dome under construction.

October 1992. Plans and engineering for two completed prototype domes in Superadobe and masonry were submitted to, and reviewed by, the Hesperia Building and Safety Department in consultation with ICBO.

September 24–27, 1993. Live-load tests to simulate seismic, snow and wind loads. Static eccentric loading of both domed structures to 200 percent of code requirements. Monitored by independent engineers from the Inland Engineering Corporation. No deflections were observed.

February 18, 1994. *Uniform Building Code*™ (UBC) Group M, Division 1 and Group B, Division 2 structures were allowed in Hesperia as part of a prototype program.

October 27, 1994. Plans and calculations for the Hesperia Museum and Nature Center, to be constructed using earth and ceramic architecture technology (Superblock/Superadobe and masonry/ceramics), were submitted to, and reviewed by, the Hesperia Building and Safety Department in consultation with ICBO.

December 12–13, 1995. Simulated dynamic and static load tests were performed on all structural prototypes relevant to the project to establish their safety for all UBC occupancy categories. Tests were performed on Superblock/Superadobe dome type (double-curvature compression shell), vault type (single-curvature compression shell) and masonry dome type. Testing monitored by Southwest Inspection and Testing.

December 27, 1995. Report by Southwest Inspection and Testing to ICBO and the Hesperia Building and Safety Department concludes that all tests have exceeded ICBO and City of Hesperia requirements.

March 7, 1996. Construction permit was issued by the Hesperia Building and Safety Department for the Hesperia Museum and Nature Center.

January 8, 1998. "Earth Architecture—Environmentally Friendly Housing Types: Superadobe Model House Plan Permits for 3- and 4-bedroom Models" was issued by the Hesperia Building and Safety Department as stock plans for the Earth One house and variations on the plans and designs.

Over this period, climatic stress to the prototype structures was monitored in the harsh high-desert climate zone, including flash floods, heavy driving rain, dry heat up to 115°F (46°C), freezing and snow, and high winds.

Universal Applications

Modern computer software now allows for structural design analysis on an individual basis. The computer will also permit the utilization of the Sandbag/Superadobe/Superblock systems in space and planetary construction based on performance programs, such as finite element analysis. The construction of infrastructures, structures and shielding elements, such as for thermal, radiation and/or impact shielding on the moon and Mars, would otherwise imply costly transportation of building materials into outer space. The utilization of *in-situ*, minimally processed materials, is crucial to space exploration.

Flood control; erosion control; stabilization of waters' edges, hillside slopes and embankments; and retaining walls, landscapes, and infrastructures are applications in which the Sandbag/Superadobe/Superblock system has shown great potential.

Individuals are enabled once again to build their own homes without the use of heavy equipment, with materials native to the country of use. All the skills required are simple and can be acquired by anyone who wishes to learn them. The Sandbag/Superadobe/Superblock system can use existing contractors' machinery, such as concrete and gunnite pumps, to mechanize the packing of the fill material into the bag forms.

Sandbag/Superadobe/Superblock has been used internationally by the United Nations for emergency housing prototypes and is currently in limited use on several continents and under construction in several states in the United States. Further permits are being sought with other building and safety jurisdictions in California and the Southwest. If integrated into the 2000 *International Building Code*™, it will serve internationally for many building types, including that of emergency housing construction, and be used extensively within the United States for standard housing. ■

Sandbag Shelters, Unidentified, Iran

Pozzolans Unpuzzled

As Mineral Admixtures, Fly Ash and Other Waste Products Add Strength and Durability to Concrete

by Bruce King, P.E.
Civil Engineer
Sausalito, California

Portland cement is the glue that holds rock and sand together as concrete, and it does so very well, but comes with a high environmental price tag. Cement is produced by firing limestone and clay minerals at very high temperatures, emitting a ton of carbon dioxide (greenhouse) gas for every ton of cement produced; by some accounts, cement production worldwide accounts for 8 percent of the total carbon dioxide emissions from human activity. (The production of lime is similar, but uses about one third the energy.) Ordinary portland cement concrete is also relatively permeable, leaving it subject to degradation of many types. The solution to both of these problems is emerging in the increased usage of pozzolans—supplemental mineral admixtures that react with portland cement hydration products to produce additional binder.

The use of pozzolans began many decades ago, but has seen a pronounced surge in the 1990s. This has been caused not so much by environmental considerations, as by the growing recognition that the intelligent use of certain pozzolans can greatly increase both the strength and durability (longevity) of concrete structures. Typically, the siliceous pozzolan reacts with otherwise unused cement hydration products (weak calcium hydroxide becomes strong calcium silicate hydrate). Though some pozzolans are manufactured specifically to augment concrete mixes in various ways, and others are mined directly from the earth (the name "pozzolan" derives from early uses of a cementitious volcanic ash mined near Pozzolano, Italy), the most commonly used ones are waste products from industry. Restrictions on pozzolan usage are described in Section 1904 of the 1994 and 1997 editions of the *Uniform Building Code*™.

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Four such pozzolans (from waste materials) now in use are fly ash, silica fume, slag and rice hull ash.

Fly Ash

Fly ash (also known as coal ash or fuel ash) is the residue collected from the smokestacks of coal-fired power plants, and is therefore abundantly available worldwide. Class F fly ash needs portland cement with which to react (a true pozzolan), whereas some Class C fly ashes are in themselves cementitious and have been combined with lime or even calcium carbonate soils to produce moderately strong concretes.

Historically thought by many engineers to be mere "filler" without added value, fly ash usage has been restrained by building codes to 25 or 35 percent of total cementitious material in a concrete mix. Also, many engineers, out of ignorance, are still wary of using any fly ash, but that attitude is rapidly changing. Coastal communities and states are finding that large-scale fly ash usage decreases the porosity of concrete, thereby making it last far longer in saltwater environments (the same is true of northern states where roads are salted in winter). Research in Canada, the United States and Europe is producing mixes that are 60-percent fly ash and 40-percent cement, attaining long-term strengths in excess of their all-cement counterparts. With fly ash so abundantly available (at about half the cost of cement), code restrictions on its use being lifted and our understanding of its desirable properties growing, market conditions alone will impel increasing usage.

Silica Fume

Silica fume (or condensed silica fume) is a waste product of the silicon metal industry. A super-fine powder of almost pure amorphous silica, it reacts very well with hydrating portland cement, resulting in dramatic increases in both strength and durability. Though difficult (and expensive) to handle, transport

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Unprocessed regolith—lunar soil—can be used to construct superadobe/superblock structures and infrastructures. It can also be melted, using solar rays, to form ceramic structures.

Lunar and Terrestrial Sustainable Building Technology in the New Millennium

An Interview with Architect Nader Khalili

by Madhu Thangavelu

Due to growing interest in sustainable building, University of Southern California faculty member Madhu Thangavelu recently met with Nader Khalili to discuss Khalili's role, as an architect and inventor, in the development of innovative materials and methods of construction.

Madhu Thangavelu: After having specialized in the design of high rises in the 1970s, you turned your attention to the research and development of ceramics and superadobe/superblock building technologies based on indigenous Middle-Eastern building traditions. What prompted you to propose the use of these technologies for lunar and planetary construction to NASA?

Nader Khalili: When I left my high-rise architectural design practice, I set out on a five-year journey through the Persian deserts to explore the potential of clay as a building material that could be used to house the Earth's masses—there were then 800 million people in the world without adequate shelter; that number is now 1.2 billion. In those deserts, there are no resources except earth. Trees are too precious to cut, and constructing walls provides more shade and consumes less water. During those five years, I integrated my knowledge of high-rise and prefabricated building technologies with thousands of years of accumulated human knowledge about earth architecture and ceramics. This synthesis of high-rise and traditional earth building methods resulted in the new technologies of ceramic and superadobe/superblock construction.

I faced some new challenges in 1984 when I was among those invited to the first NASA-sponsored symposium, "Lunar Bases and Space Activities of the 21st Century," held at the National Academy of Sciences in Washington, D.C., to propose new technologies for possible use in the construction of lunar bases, but the fundamental problems were very similar. There are even fewer resources on the moon than in our deserts, and the climate is much harsher. There was not known to be any water then, and there is no atmosphere; therefore, there is no oxygen to fuel the fire needed to manufacture ceramics. The moon's surface temperature range varies from 261°F (127°C) to -279°F (-173°C), and the potential effects of solar particle radiation and meteorite impact had to be considered. Yet on the moon—as on earth and, indeed, throughout the solar system—timeless materials and principles exist. An understanding of the concept of the unity of the elements makes the use of these materials and principles in the integration of tradition and technology with the laws of nature possible at many levels of microcosm and macrocosm.

My paper "Magma, Ceramic and Fused Adobe Structures Generated In Situ," described the timeless architectural forms of the arch, the vault and the dome; their structural principles; and the possibility of constructing them by transforming lunar dust/regolith into liquid magma using solar fire to cast the buildings. It also introduced the concept of a building material I then called "Velcro adobe," which is now referred to as superadobe/superblock, which was referred to in the *Journal of Aerospace Engineering* with these words:

> *Two main materials and methods utilizations of moon dust for shielding or generating structures are in the forms of automated or manually packed soil covering, or Velcro adobe, and fused lunar adobe. Soil packing covering in flexible dry-adhering containers (Velcro adobe) will utilize unprocessed regolith for both structures and shielding. Packed Velcro adobe in flexible containers can be used to construct structures using corbels, dry-packs*

Sandbag Shelters, Unidentified, Iran

and leaning arches. In single- and double-curvature compression shells, the dry-adhering containers' texture will allow the tightness of consecutive rows, in the case of a vault, or rings in a dome, to hold up the structures in space during construction. Neither type of structure needs centering or form-work. Velcro adobe can be used in conjunction with other, more conventional, structures, mainly for shielding purposes.

My vision was seconded by the editor of the NASA-published monograph of that symposium, who wrote:

> *The first humans to live and work on the moon will be supported by an advanced technology. Yet the basic incompatibility of human physiology with the environment will limit flexibility of response to challenges of everyday existence. Our tools will be very sophisticated, but our actual resources will be limited initially. In many ways, the development of a lunar economic and social infrastructure will require the kind of adaptability and innovation seen in successful enterprises in the Third World. For this reason, Khalili's perspective on lunar architecture provides an interesting and thought-provoking contrast to "orthodox" scenarios.*

An hour after that presentation, I was invited to Los Alamos National Laboratory as a scientist (they had no category for architect) to present my ideas and interact with the scientists for several days, which I did in 1985.

Thangavelu: The idea that we will use extremely advanced space technologies to arrive at the moon and then immediately resort to indigenous materials and age-old ways of building up infrastructure is both fascinating and humbling. What are your thoughts on space exploration and the lessons and impact of this activity on humanity?

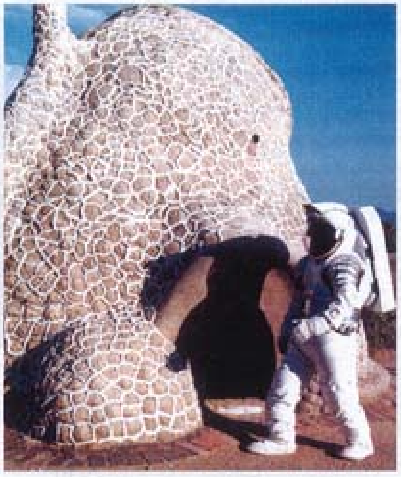
Khalili: My thoughts are best expressed in my original paper, in which I wrote:

> *All heavenly bodies are like human bodies: marvels of creation in the highest forms of technology, yet filled with poetry and spirituality. Everything we need to build is in us, and in the place. We must sail into the cosmos not only with zero-defect spaceships, but in ones filled with inspiration, not merely carrying a databank, but also carrying a sense of unity integrating us with our past and future aspirations. It is good to remember that what we may ultimately reach in space may be the space within.*

Thangavelu: What was the tangible result of these presentations and research?

Khalili: Subsequent to my visit to Los Alamos, at a presentation in a Princeton Space Studies Institute/NASA symposium, I was invited by McDonnell Douglas Space Systems to become part of a research team. They offered me the use

Hesperia Museum and Nature Center utilizes 91 percent in-situ materials to construct stabilized superadobe/superblock coils, with both pumping and manual systems.



The "Mars One" prototype employed in-situ unstabilized earthen material for construction and testing. Its reptile texture is the result of terrestrial demonstration of a random pattern finish.

Cal-Earth Institute's "Earth One" prototype structure was constructed and tested using unstabilized superadobe/superblock walls. Cal-Earth prototypes are also used as grounds for space suit maneuvering and documentary research.

Superadobe/superblock coils under construction, demonstrating pumping method.

Sandbag Shelters, Unidentified, Iran

of their large solar energy concentrator in Southern California in order to develop and test magma structures using lunar regolith simulant, and we conducted several tests. As detailed in my paper, the solar energy easily melted and fused the regolith to the extent where we could create magma structures, ceramics, fused adobe and even magma fibers for potential reinforcing. I spent a few years pursuing Los Alamos, McDonnell Douglas and NASA with proposals and feasibility studies. In one meeting of top McDonnell Douglas management, when they were gearing up for a multimillion dollar proposal to NASA, I voiced my opinion that we could construct a life-sized lunar base in Death Valley for a fraction of the proposed cost of the feasibility study. Of course, this didn't go over well.

I finally decided to start Cal-Earth Institute in California's Mojave Desert to demonstrate these technologies independent of the aerospace industry and NASA. Our main focus at Cal-Earth was to construct full-scale prototypes and put them to the test in a harsh environment and seismically active zone to validate our work. It was time to leave behind the feasibility studies and actually put our buildings through the grueling stress tests of local and national codes via the local Hesperia Building Department and ICBO review. Fortunately, along the way we found open-minded individuals who, while not accepting of any compromise, have been brave enough to assist us in taking steps to benefit the future of the nation and of the world.

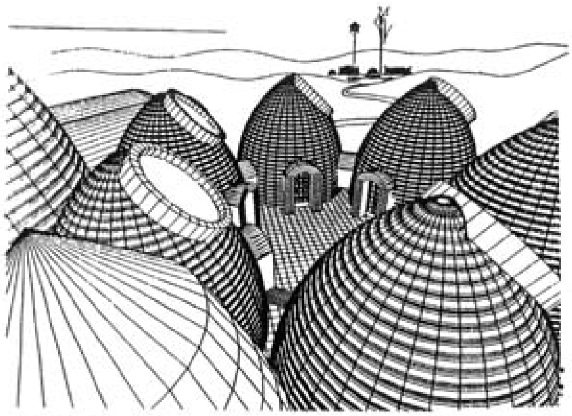


Figure 1 – Hesperia Museum and Nature Center courtyard clustered with skylights angled for high solar gain. Lunar and Planetary Institute, Houston, technical report #98-01, 1998.

We built and tested prototype shell structures of superadobe/superblock using unprocessed desert sand. We used the same timeless principles and materials in harmony with nature, but now applied rational engineering analysis. We worked as a team with P.J. Vittore, Ltd., which has extensive experience in large-span, thin-shell structural engineering (see the September/October issue of *Building Standards*™ for a jointly written article).

Thangavelu: What came out of the Cal-Earth prototypes?

Khalili: The Cal-Earth prototypes generated support from a wide range of individuals and organizations, world media attention, some projects and good community relationships, while operating on a shoestring budget thanks to the efforts of highly dedicated professionals and volunteers.

As the research and testing program developed, so did our working relationship with the Hesperia Building Department, the City of Hesperia, and the local community. In the September/October issue of *Building Standards*, Hesperia's building official, Tom Harp, wrote, "When architect Nader Khalili first proposed constructing buildings made of earth-filled sandbags, stacked in domes, the building department was skeptical to say the least." However, after the years of structural analysis and prototype testing, he reported, "Our skepticism had long since vanished, as we had seen this type of building meet and exceed the testing of rational analysis as required by our code."

The Hesperia Recreation and Park District (HRPD) commissioned us to design the Hesperia Museum and Nature Center, not only as a project but also to demonstrate the environmental and educational benefits of these technologies. It is now under construction. Later, the HRPD and the city offered a 20-acre site to NASA for its Lunar Habitat program.

The Earth One typology was developed for superadobe/superblock housing, of which a standard three-bedroom, two-car garage model home was permitted and is currently under construction for the mainstream marketplace.

Other benefit projects are in different phases of construction around the world. Still functioning excellently are flood and erosion control systems prototypes at Hesperia Lake, where the lake's edge is lined by using the pumped superblock system, in which coils are pumped at a rate of 15 feet (4572 mm) per minute.

Thangavelu: Has there been more interest terrestrially?

Khalili: There is so much need, globally, for these technologies and for the many other ideas that are locked away under different patents by big organizations. We have dedicated our patent to those in need of assistance, as the result of disasters. The United Nations (UN) has now partnered their branch United Nations Institute for Training and Research with us, and together we are developing a program for training in response to natural disasters, emergencies and for reconstruction efforts. The United Nations Industrial Development Organization and United Nations High Commissioner for Refugees built 14 prototypes in the Persian Gulf area after Operation Desert Storm. A few statistics from the World Disaster Report of the International Federation of the Red Cross will tell you just how great the need is for such programs. For example, more major natural disasters occurred in 1998 than in any other year on record; forty of the 50 fastest-growing cities are located in the highest earthquake zones; environmental refugees account for 58 percent of refugees worldwide; and the UN estimates that 80 percent of the world's population will live in developing countries by 2025. The costs in the U.S. alone between 1991 and 1997 of flooding, tornados and hurricanes was over $100 billion.

Thangavelu: What would be the advantage of expanding the use of this technology in the U.S.?

Khalili: The advantages are numerous, but first, let me ask you: Is it reasonable for a technologically advanced nation

Sandbag Shelters, Unidentified, Iran

like the U.S. to rebuild disaster regions with the same disaster-prone types of structures? Is it logical to invest billions of dollars of materials and energy in another doomed community by rebuilding the same structures on the flimsy foundation of what has already been torn to shreds by a hurricane, reduced to rubble by an earthquake or turned to ashes by fire? We must never forget that it is not the hurricane, earthquake or fire that causes the disaster, it is mainly the man-made structures and infrastructures.

It is high time we utilize those timeless structural principles that work in harmony with the laws of aerodynamics, fire resistance, compression, gravity and monolithic response. The spin-off technologies from designing for the moon and Mars have proven able to weather extreme environments and natural disasters. The materials are fireproof and the aerodynamic forms naturally ride through hurricanes and tornados and resist earthquakes. Simple sandbags have been used to resist flooding for centuries, and now the technology exists for using on-site material not only for building homes and public buildings, but also for flood and erosion control. The U.S. could lead the way in developing and implementing these sustainable technologies that address the urgent needs of this new millennium.

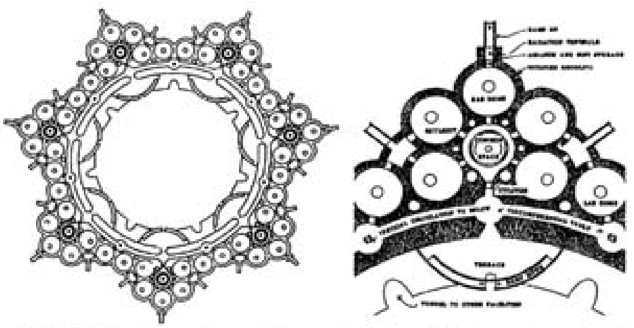


Figure 2 – Lunar base design using domed clusters at a crater's edge for passive utilization of sun/shade zone. From a 1989 Journal of Aerospace Engineering paper by Khalili.

Thangavelu: What measure should we take to foster these technologies?

Khalili: First, the *International Building Code™* should take into account the projected 80 percent of the world's population who will be living in developing countries in the next 25 years and will be unable to afford highly manufactured building materials or timber. Any international code that omits technologies appropriate for these regions will be inapplicable internationally. Perhaps a totally different type of code, such as the performance code, will open the avenue to relevant building technologies, which can in turn create future business and technological improvement opportunities for the U.S.

If existing codes do not allow for entry of new ideas, then some basic rethinking should go into code structures. Do we really want to look back on this millennium and say: "How stubbornly our engineers and officials fought for untenable precepts embodied in inherently unstable structures, and how blindly we followed because our lives were swept up on a wave of panic, financial gain, insurance, tradition and resistance to change?"

Watching the former Soviet Union fragment, we can be thankful that the U.S. still retains the flexibility to grow and adapt to today's needs and still has institutions that can nurture freedom and the pioneering spirit into relevant and useful new products and methods.

Thangavelu: What would be the impact of this new technology on building manufacturers' products, the job market and the mainstream?

Khalili: The computer industry was at first feared because it might eliminate great numbers of clerical jobs; however, once invested in, it created a giant industry. Likewise, the earth, ceramic, straw bale and alternative building industry in general has the potential of opening totally new business horizons and job opportunities. It will allow us, in the best American tradition of moving forward with new ideas, to create flourishing businesses with wiser resource management both nationally and globally.

America's economic base is increasingly shifting from products to services and information, and the offspring of these technologies will produce environmentally friendly wealth.

Thangavelu: What potential opportunities do these technologies offer?

Khalili: The new millennium is offering great opportunities for creative solutions to pressing demands for sustainable building materials, technologies, design and regulatory practices. The accelerating increase in global population and natural and man-made disasters are wake-up calls to a wiser utilization of renewable resources. Development of advanced technologies, with an integrated focus on human and global needs, can be the main source of these creative solutions. It may take a long time to go through the system; meanwhile we can depend on the good old American entrepreneur to take a look at Cal-Earth's web site (*www.calearth.org*), take the next plane to Hesperia, California, and recognize the potential for turning the disasters of the last millennium into the fortunes of the new one. ■

Nader Khalili, California architect and author, is the innovator of the Geltaftan Earth-and-Fire System known as "ceramic houses," and is founder and director of the Cal-Earth Institute in Hesperia, California.

Madhu Thangavelu is an adjunct faculty member of the University of Southern California School of Architecture and Department of Aerospace Engineering in the School of Engineering. Thangavelu is also the co-author of the recently published book The Moon: Resources, Future Development and Colonization *(John Wiley and Sons) and is the vice-chairman for education of the Los Angeles section of the American Institute of Aeronautics and Astronautics. Thangavelu was first captivated by Khalili's ideas at the inaugural session of the International Space University, held at the Massachusetts Institute of Technology in 1988, and has been following and assisting in the activities of Cal-Earth Institute since.*

PUBLICATIONS REFERRED TO

"Magma, Ceramic, and Fused Adobe Structures Generated In-Situ," paper by Nader Khalili; presented at the first NASA sponsored symposium in 1984; published in the monograph *Lunar Bases and Space Activities of the 21st Century*; edited by W.W. Mendell; Lunar and Planetary Institute; 1985.

"Lunar Structures Generated and Shielded with On-Site Material," paper by Nader Khalili (awarded by the American Society of Civil Engineers - Aerospace Division); *Journal of Aerospace Engineering*; July 1989.

Sandbag Shelters, Unidentified, Iran

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Spotlight

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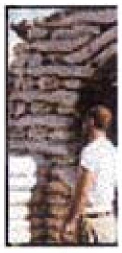
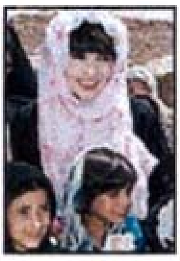
Humedica: our target is to help 100,000 a year
German-based AlertNet member Humedica provides medical supplies supports children's homes and day care in India, Sri Lanka, Brazil and Kosovo, and keeps a database of health professionals prepared to fly help after disasters. Ruth Gidley spoke to its co-founder Wolfgang Gr

30 Jul 2001
Orissa relief in full swing as PM announces aid
AlertNet members and other NGOs, as well as government agencies, stepped up the relief effort in Indian's flood-ravaged state of Orissa this week, after Indian Prime Minister Vajpayee announced $92.3 million in aid for the stricken region at the weekend. UPDATED

23 Jul 2001
Orissa floods photo gallery

30 Jul 2001
Sandbag homes may be shelter breakthrough
U.N. officials plan to test a building method using sandbags they say could revolutionise the way emergency housing is provided after natural disasters. **Anton Ferreira** talked to the officials who were impressed, as well as to the inventor of the system, Iranian-born architect Nader Khalili.





28 Jul 2001
UN envoy says Afghan women and children desperate
Japanese television celebrity Tetsuko Kuroyanagi A goodwill envoy of the United Nations Children's Fund (UNICEF) said on Saturday children and wo in war-torn Afghanistan were living in desperate conditions, but hope mus be lost.

28 Jul 2001
Angolan war puts refugees back on the road

Sandbag Shelters, Unidentified, Iran

25 Jul 2001 14:35

Sandbag homes may be disaster relief breakthrough

By Anton Ferreira

UNITED NATIONS, July 25 (Reuters) - Senior U.N. officials plan to test a building method using sandbags and barbed wire they say could revolutionize the way emergency housing is provided after natural disasters like floods, earthquakes and hurricanes.

The officials told Reuters on Tuesday the method, known as "Superadobe" and developed in Hesperia, California, by Iranian-born architect Nader Khalili, could provide durable, cheap shelter very quickly after calamities like the Gujarat earthquake earlier this year in India.

"I thought it was amazing. It is a hidden treasure," said Omar Bakhet, director of the Emergency Response Division at the U.N. Development Program.

Bakhet and his program adviser Lorenzo Jimenez de Luis visited Khalili's California research site last weekend and said they immediately realized the potential of his building method.

"The technology is fascinating," Bakhet said. "It's a technique one can learn in a few days."

The Superadobe method involves filling empty sacks with earth dug from the building site and piling them in layers with strands of barbed wire acting like Velcro to provide added stability.

The simplest design is a circular room tapering toward the top to form a dome that sheds snow or rain. Several examples of the beehive-like structures have been built in Hesperia and elsewhere, and they have passed seismic testing required under California's strict earthquake-zone building codes.

Building with Superadobe requires no special skills, and rooms can be added.

Khalili has spent most of his career designing affordable housing for the homeless, but until now his work has had little attention from disaster relief professionals.

"I don't think there's any risk, it's a proven technology," said Bakhet. "It's cost effective, you need very little building material, just what nature gives you."

Bakhet and Jimenez de Luis said the only problem they foresaw was persuading governments to try the new technology.

"If these structures had the shape of a conventional house, it would be much easier," said Jimenez de Luis. "A government is going to be reluctant to accept a hemispherical thing."

He said Superadobe represented a far better option than the tents or plastic sheets and corrugated iron that are used now to provide emergency shelter for refugees from natural disasters or wars.

ABSOLUTELY PERFECT

"The (Khalili) initiative is very suitable because it covers the permanent character of the structure and the dignity aspect of the people who are going to benefit from the shelter - to live in one of these houses is absolutely perfect. To live in a tent is not so dignified in the long run."

Jimenez de Luis said Superadobe structures would also be better able to withstand future earthquakes or floods. This was important in regions like Central America or the subcontinent that experienced recurrent disasters.

"The (concept) is extraordinarily positive and definitely worth testing," he said. "It's just a matter of trying it once or twice for this thing to fly solo."

The U.N. officials said they were determined to launch a pilot project, possibly in Gujarat where some 1 million homes are needed, if the backing of local authorities could be obtained.

"Here you have a technology that's so simple, so effective and can be used by everybody, you are cutting the time for addressing housing needs by I don't know how many percent," Bakhet said.

"But like all new approaches, how many people would be readily prepared to embrace it? We are all afraid of anything new... So this where the challenge is."

Khalili said in a telephone interview from Hesperia that he dreamed of building an entire city in India.

"I showed them the plans I have for houses, clusters from 1,000 to 5,000 to 10,000, all the way to a million-person town that will be totally sustainable...

"Imagine, if they gave me 1,000 soldiers and a couple of hundred students, I could build a whole town for them... If you can cut through the bureaucracy, I have the design," he said.

Relief Resources

10 Sep 2001

Emergency building method fuses ancient and new

Nader Khalili has developed a method of coiling biodegradable sandbags, held together with barbed wire to make strong, beautiful buildings. The Iranian-born architect leads the non-profit California Institute of Earth Art and Architecture (CalEarth) based in the southern California desert. He told Ruth Gidley about the technique and philosophy behind "superadobe", which he believes is an ideal solution for housing people displaced by natural disasters and conflicts.

Bags filled with earth are moulded to the shape of the building.
Photo: CalEarth

AN: What is the origin of the designs you use?

NK: The basic forms are timeless -- arches, vaults and domes. You don't need timber or steel to create the roof. These shell structures are both ancient and futuristic at the same time. They are also the strongest form in the universe. When they want to build nuclear power stations, they are all in this form. The space shuttles, the space colonies, are always seen as these forms because they are most resistant to natural forces. They are the strongest against hurricanes, earthquake, floods and all known disasters.

AN: What materials does your method involve, apart from sandbags and barbed wire?

NK: Material at the site itself will usually suffice. We could use some stabiliser too -- depending on the amount of rainfall in the place -- either a small percentage of cement, or what is available most places of the world is lime powder and earth or even sand. The bags are on rolls one mile long. One roll weighs 200 pounds and can make 10 shelters. Then you need four rolls of four-point barbed wire, and each roll of barbed wire is a quarter mile long. These bags are damp soil, not concrete. It's almost dry. You use only six percent of water. So you can build a ring and stop for the day and go and come back the next day.

AN: What kind of manpower is needed for construction?

NK: With a thousand soldiers and a hundred students, you can begin to build mass structures by hand. If it is done by machine then you will need standard concrete pumps and mixers to do it quickly. By hand, it takes almost a foot a minute to build these things. Once it's done by machine, it could be done at 50 feet a minute.

AN: Do you need an architect to be present?

NK: That's why the students are there. You train them to be the supervisors, so that each one of them could handle 10 people. He or she would be the foreman and then, of course, one supervising architect or engineer or one who is trained as a trainee's trainer. They are one of the least dangerous forms because, if you keep the rings every time within an inch or so, you will never fail. If it is on a larger scale, you definitely need supervising engineers who will make sure the walls are straight and so on, but the tolerance for mistakes is high.

AN: Could a community build its own shelter?

AN: I think that the main strength of this work is that the community could become self-reliant. This work could be learned by ordinary men and women, children, old and young. The scale of construction fits almost anybody. The maximum you lift is five pounds (2.3 kg), which is a coffee can of earth. So you would never lift a bag. It's all laid in place just like coils of spaghetti or toothpaste.

AN: What is the advantage of sandbags over materials such as plastic sheeting, corrugated iron or tents?

NK: The basic material is earth, and it is available everywhere. Between 800 million and 1.2 billion people in the world are either homeless or live in a state way below any acceptable level of habitation. There is no manufactured material in the world that could supply such an amount. I understand that there are 40 million refugees either inside their own country or outside. These people have their dignity and their own lives and this would allow them to participate. Then when their relief group left, they would not be sitting and waiting for more to come, so you already create this cottage industry to sustain.

AN: How do the structures stand up to extreme temperatures?

NK: There is a range of 15-to-20-degree Fahrenheit difference between outside and inside in heat in the summer because these walls are thermal mass.

AN: How permanent are these buildings? This could be an issue where land rights are sensitive.

NK: I think one of the major problems is that most countries don't want a permanent refugee presence. This is an ideal system, because if you don't protect it on the outside with stucco plastering, it will last six months to two years, depending on the amount of rain, then it will go back to the earth. If you want it to last five, 10 years, then you plaster outside, because the bags themselves disintegrate in the sun unless you protect them. If you plaster with two layers, that's 15 to 30 years of shelter. They're both temporary and permanent.

AN: What kind of response have you had from international disaster response organisations?

Sandbag Shelters, Unidentified, Iran

NK: We have gone through the severest tests already. The U.N. Development Programme has come to test these buildings and to learn to build them. The greatest barrier that I see is probably breaking through bureaucracies. The decision has to come from the top people.

AN: What other kinds of building have you worked on?

NK: My speciality for 25 years was skyscrapers. Then I bought a motorcycle and went to the desert for five years in Iran to see what was the solution for the poor in the world and learn from what already existed there. Then I was invited by NASA to present my ideas for building on the moon and Mars. Some of these designs, like the superadobe, came about because that environment is the harshest known to humanity. Nothing exists, not even air or water.

AN: Would you be prepared for anybody to use this technique?

NK: I have patented this, so that big companies wouldn't patent it and then nobody would have access to it. If it's done for the poor in a disaster, it's all for free. The mission of my life for the last 25 years has been to provide shelter for people who cannot afford it. But you need to protect this so they can do that, because many systems of building have been started for the poor, but along the way they become too commercial to be able to get to them.

AN: Architecture seems to be a political vocation for you.

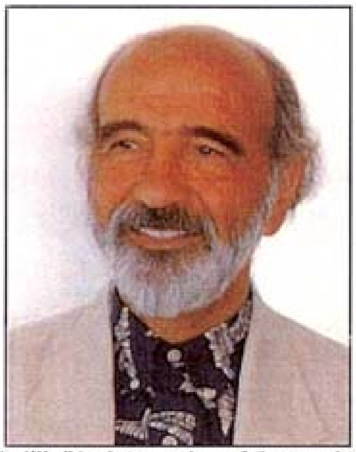
NK: The whole thing is inspired by a philosophy. I am inspired by the mystic poet Rumi. He wrote all his books in Persian in the 13th century. He talks about earth, water, air and fire, the elements. There is a unity that exists among these elements that if one or two or more are missing, they exist in the other elements. That was the concept I went to NASA with. I didn't tell them that, but I wasn't afraid that there was no water on the moon, since there was soil there. In that soil, I knew that everything existed -- the fire was in the sun and the unity of these elements exists everywhere in the universe.

AN: Did you grow up with this philosophy, or did you discover it as an adult?

NK: I grew up in a Muslim society, in Iran. My grandmother used to recite hundreds of mystic poems in Persian that dealt with all these elements of the unlimited universe with unlimited resources, and all those unlimited resources are within you. Later when I went into the high-tech of learning all this knowledge and high rises, there was the natural integration of all these parts.

AN: How soon after the revolution did you leave Iran?

NK: I was very successful in Iran before the revolution but I had quit two years earlier when I went to the desert, so when the revolution broke I was welcome to continue. I stayed for two more years. So it is truly an integration of the East and West. I grew up among the poor. I am one of nine children, and constantly knew need. I never forgot, so now I'm responding.



Nader Khalili: "An integration of East and West."

Website: **http://www.calearth.org**

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China Struggles to Solve Worker Puzzle

Tue Mar 12,12:38 PM ET - (Reuters)
LUOYANG, China (Reuters) - When Guo Yiling joined the big state-owned First Tractor Works some two decades ago, she was one of many trumpeted by China as a model socialist worker to be rewarded with cradle-to-grave welfare.

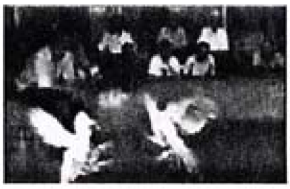
British Asians Shut Up Shop for Better Life
Tue Mar 12,12:35 PM ET - (Reuters)
LEICESTER, England (Reuters) - In 30 years, they have become as British as fish and chips and double-decker buses.

Model 'Eco-City' Could Soon Rise in Senegal
Tue Mar 12,12:34 PM ET - (Reuters)
WASHINGTON (Reuters) - The West African nation of Senegal could soon be the site of a bold experiment in solving the housing problems of the world's poor -- a model town built of sand that harnesses the sun and wind for energy.

Social Malaise Underpins Egypt's Sectarian Woes
Tue Mar 12,12:41 PM ET - (Reuters)
CAIRO (Reuters) - Egyptian Muslims and Christians in the Nile valley around Minya, where sectarian clashes erupted last month over the loud clangs of a church bell, say they live together like brothers.

Payback Time for Overworked Nannies

Mon Mar 11,12:13 PM ET - (Reuters)
LOS ANGELES (Reuters) - Ask any working mother and she'll likely have a nanny horror story -- the trusted caregiver who turned out to be sleeping, stealing or having sex on the job.



Cockfighting Craze Lives on in Colombian Villages
Mon Mar 11,12:16 PM ET - (Reuters)
ARACATACA, Colombia (Reuters) - The two roosters stare defiantly at each other,

http://story.news.yahoo.com/news?tmpl=index&cid=811 3/13/02

Sandbag Shelters, Unidentified, Iran

Model 'Eco-City' Could Soon Rise in Senegal

Tue Mar 12, 12:34 PM ET

By Anton Ferreira

WASHINGTON (Reuters) - The West African nation of Senegal could soon be the site of a bold experiment in solving the housing problems of the world's poor -- a model town built of sand that harnesses the sun and wind for energy.

Senegalese President Abdoulaye Wade told Reuters he wants to build the town of about 20,000 houses using a construction method developed by Iranian-American architect Nader Khalili known as "Superadobe."

In its simplest form, it consists of building circular, beehive-shaped houses with sand-filled tubes placed one on top of the other with strands of barbed wire between the layers to provide a Velcro-like grip.

The walls gradually curve inward at the top to form a self-supporting, domed roof that needs no timber for support -- an important factor in countries afflicted by deforestation. The tubes in which the sand is packed are usually made of woven polyester, but hessian bags can also be used.

Wade, in an interview from Dakar last week, said he heard of Khalili's work when Senegal was looking for ways to help thousands of people made homeless by severe flooding in the northern provinces earlier this year.

"I called him, I invited him to Senegal to talk with him. ... So I will provide him with land, he will choose the place, maybe in Dakar, maybe in a suburb of Dakar, and I am ready to experiment with this system," the president said.

"I am interested in building a new city with this method."

Wade, a champion of African development, said better housing was a pressing issue for Senegal, particularly after the floods in January.

SENEGAL SEEKS LOW-COST SOLUTION

"My problem was how to build, at low cost, houses for the people. ... The fundamental idea was, it should be possible to build a house better than our traditional house, that can be modernized, at a very low cost."

He said one of the attractions of the Khalili system was that it was so simple, people could build their own homes, providing their own labor, and the building materials were close at hand.

"In terms of architecture, I think this type of building will be well adapted to the climate," Wade said, saying the thickness of the walls -- about two feet (60 cm) -- would help insulate residents against heat and cold.

"This type of construction is adaptable to our traditional construction, the African hut," he said.

Wade said Senegal would approach international donors like the World Bank (news - web sites) or the European Union (news - web sites) for help in funding the project.

The project so far is little more than an idea, so no estimates can be placed on what it would cost. The infrastructure of roads, water and sewage would be the most expensive component, but Khalili believes the houses themselves would cost about 50 percent less than houses of a similar standard built by any other method.

For Khalili, who visited Senegal last month with his partner and fellow architect Iliona Outram and his brother Nasser Khalili, an infrastructure specialist, building a model city in Senegal would be a giant step toward attaining a long-standing dream.

"As far as I'm concerned, truly the whole treasure is sitting right there: the land is there, the water is there, the people are extremely nice, very peaceful and cooperative," he said.

"It's a very important project, really it can be a breakthrough."

Khalili and Outram teach the Superadobe system at their Calearth Institute in Hesperia, California (www.calearth.org), and are using the method to build a museum for the city.

Because they are in an earthquake (news - web sites) zone, the buildings have been subjected to stringent state building code tests -- which they passed with flying colors.

Their strength and stability derives largely from their domed construction, much like the shape of a chicken egg allows the thin shell to withstand relatively high forces.

Because a Superadobe house has no conventional roof, there's nothing to be ripped off in a hurricane; the solidity of the structure means it will remain standing in a flood.

Many people who have trained at Calearth have gone on to build their own Superadobe homes, in the United States and abroad, but Khalili has no idea how many.

"Now and then people send us photographs of what they have built," he said.

A SUSTAINABLE TOWN

Despite great interest expressed in its work by development professionals at the United Nations (news - web sites) and elsewhere, Calearth has yet to be given the opportunity to put its ideas for low-cost, secure, comfortable shelter into practice on a large scale. The Senegal project would be the first of its kind.

Khalili said Calearth had trained several apprentices who would be eager to go to Senegal to help local people get started.

"The way I see it, the sun that exists in Senegal is perfect to do solar energy for a sustainable town and of course you could use natural energy like wind for cooling as well, and they use the earth to build just about all the structures," he said.

"The technology to create a sustainable town exists today fully."

Khalili's Superadobe homes borrow heavily from traditional Middle Eastern architecture, incorporating for example wind funnels extending above roof level that catch breezes and bring cooling air down into the living area.

Khalili said he and his team had visited the flood-ravaged north during their trip and had been moved by the plight of the victims.

"The solution seems so close at hand: just some knowledge of how to dig what is under their feet, how to add some bags and barbed wire and tie it all together, how a sensible design can save them from the next flood, storm or natural disaster," he said.

SAFE HAVEN

DISASTERS AND WAR HAVE LEFT MILLIONS HOMELESS AROUND THE WORLD.
CAN ARCHITECTS HELP?

Excerpts from the article BY CATHY LANG HO
WWW.ARCHITECTUREMAG.COM NOVEMBER 2002

Displaced by natural, economic, or political catastrophes, the number of people "of concern" to the United Nations High Commission for Refugees (UNHCR) is about 20 million-one in every 300 in the world. Hundreds of thousands of Afghans and Iraqis are now on the move, fleeing conflict. Floods in India and Senegal in the past year have left countless homeless. Bosnian refugees are still trying to return to their homes despite the devastation. Millions more "internally displaced persons" in Colombia, Indonesia, and elsewhere have extended the conception of refugees beyond the expatriated to include those displaced within their own countries. In the wake of disasters both natural and man-made, the provision of emergency shelter, in addition to food and water, is the most pressing challenge for local governments, international agencies, and humanitarian aid organizations.

As expected some of the best concepts for emergency housing take advantage of cheap, easily transported, or local materials.

NADER KHALILI (HESPERIA, CALIFORNIA):
SUPERADOBE EMERGENCY SHELTER

Refugee Housing in Khuzestan (Persian Gulf) built by the refugees with the U.N. to Khalili's design

Nader Khalili conceived of the "superadobe" as a system for the construction of lunar colonies for NASA in 1984. But the system was destined for more earthly pursuits. In 1991, Khalili's California Institute of Earth Art and Architecture tested the architect's dirt-dome prototypes and eventually passed seismic tests to meet California's stringent building codes. cheap, sustainable, easy to build, and structurally sound, his domes are constructed mainly of on-site materials: Standard polypropylene sandbags, 14 to 18 inches in diameter and up to a mile in length, are filled with dirt, sand, or clay, wound in circular or

spiraling forms, and held in place with barbed wire in between each layer. One house, up to 16 feet wide, can be built in a day by a family of four. It can last decades if cement is added to the soil mix or if the exterior is plastered, as is the case with a community in Southern Iran.

Nader Khalili, an Iranian-born architect and longtime faculty member at SCI-Arc, has developed a technology he calls "superadobe," using on-site earth as its prime building material. Extra long sandbags, 14 to 18 inches in diameter, are filled with local dirt, sand, or clay and wound into spiraling forms. Barbed wire is placed between each layer, acting as mortar, and the result is a self-supporting, reinforced adobe system. Cement can be added to the dirt mix, or dome exteriors can be plastered for added longevity. "The structures make the materials of war–sandbags and barbed wire–into materials of peace," notes Khalili, who founded the California Institute of Earth Art and Architecture (known as Cal-Earth) in 1991 to focus on housing for the world's poor. Last year, Omar Bakhet and Lorenzo Jiminez de Luis, then both of the Emergency Response Division of the UN Development Program (UNDP), visited Cal-Earth and slept in the domes. Finding the shelter buildable, stable, and dignified, they recommended "superadobe" as a potential housing solution for Middle East refugees. On the request of the UNDP and UNHCR, Khalili taught his building method to a UN architect, who subsequently trained refugees in the region to build their own homes. To date, a dozen have been constructed in Southern Iran.

The use of local materials has added logic: Structures attuned to cultural context can help repair some of the psychological trauma of losing one's home. "Even refugees want to live in something that is familiar to them as a house," says Jiminez de Luis.

Increasingly, governments and relief agencies are acknowledging that emergency shelters must sometimes serve as the basis for long-term community building and economic development. Because emergency shelers are often used for several years, some architects are exploring how a transitional shelter can evolve into a permanent one, and how refugee camps can become the foundation for new towns or hamlets.

Lack of funds and bureaucratic inaction on the part of governments and some aid agencies, not to mention the as yet unparalleled speed with which it can be dispatched, remain the main reasons why the blue tarp has prevailed in Timor, Africas's Great Lakes region, the Balkans, and other disaster-struck pockets of the world.

"The immediate response to disaster is to provide temporary shelter," says Jiminez de Luis, newly named deputy representative of the UNDP in Honduras. "But the mandate of the UNDP is more oriented toward transition, which requires longer-term projects, and is harder to raise funds for." Emergency money, however, is more readily available, so he encourages emergency responses that adopt an "integrated development model, with initial investments made in lasting houses and income-generating activities around these houses."

In many ways, UN agencies and other relief nonprofits find their hands are tied, because local governments decide how and what kind of emergency shelter gets built. "We can carry out our own research, and make recommendations and introductions," says Jimenez de Luis, "but we cannot go into a sovereign country and make local governments do anything."

CATHY LANG HO IS A NEW YORK-BASED ARCHITECTURE WRITER. SHE IS THE AUTHOR OF HOUSE: AMERICAN HOUSES FOR THE NEXT CENTURY (UNIVERSE, 2001).

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"Lunar Structures Generated & Shielded with On-Site Materials"

by

E. NADER KHALILI

has been selected by the Aerospace Division as an

Outstanding Paper

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Sandbag Shelters, Unidentified, Iran

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Sandbag Shelters, Unidentified, Iran

Lunar Structures Generated and Shielded with On-Site Materials

By E. Nader Khalili[1]

Abstract: Lunar base structures can be constructed in situ and/or shielded using unprocessed or minimally processed lunar resources with technologies utilized in harsh terrestrial regions for the past four millennia. Single- and double-curvature compression shell structures constructed using the techniques of building without centering can be applied on the lunar surface, where the low gravity and resultant small angle of repose allow for greater spans than under terrestrial condition. Suggested construction materials range from meteorites and lunar rocks to lunar adobe created from unprocessed regolith. Magma structures can be generated and cast based on natural formation, such as lava tubes and voids, using focus sunlight, microwave, plasma, and nuclear energy. Ceramic modules can be "thrown" on a centrifugally gyrating platform. These techniques integrate high-tech and low-tech construction methods of Western, Eastern, and Native American cultures, allowing for direct interaction with nature while working to economical and technical advantage by using primarily local lunar resources and human skills.

Introduction

Unprocessed or minimally processed lunar resources can be utilized for construction and/or shielding of lunar-base structures. Both life-supporting and non-life-supporting structures can be generated in situ using lunar resources by applying technologies that have been invented, constructed, perfected, and time-tested in harsh terrestrial regions for the past four millennia. Suitable human domiciles have been created using single- and double-curvature compression-shell structures—arches, vaults, domes, apses—constructed using the techniques of building without centering: corbels, drypacks, leaning arches, pendentives, and squinches.

These techniques can be applied on the lunar surface, with its low gravity and resultant small angle of repose, and can result in greater spans than possible under terrestrial conditions. Construction materials can range from meteorites and lunar rocks to lunar adobe created from unprocessed regolith.

Magma structures can be generated and cast, based on the natural formations created by magma flow, such as lava tubes and voids, using heat-obtaining means such as focused sunlight, microwave, plasma, and nuclear energy.

Ceramic modules can be molded by utilizing a centrifugally gyrating platform—a giant potter's wheel—with high-flange rims for dynamic casting of ceramic structures.

The methods herein are based on integrating high-tech and low-tech methods of Western, Eastern, and Native American cultures. This integration will not only be to economical/technical advantage, but also will create a direct interaction with nature. This will, in turn, contribute to solving the problem of the basic incompatibility of human physiology with the lunar environment

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by bringing about higher flexibility of responses to the challenges of everyday existence (Mendel 1985).

Archemy

Archemy is a fusion of architecture and alchemy, integrating the timeless principles of earth architecture and ceramics through application of the accumulated human knowledge of the unity of the four universal elements to create structures and environments. Knowledge and practice of archemy can contribute to development of economical and self-sufficient construction methods for radiation/thermal/impact shielding as well as to the creation of structures for space, lunar, and martian bases. Applications of archemy on celestial bodies can be achieved through utilizing local resources such as meteorites, rocks, regolith, ceramics, and magma in structural as well as shielding systems. Automated and/or manual methods of building can be applied without centering (corbels, dry-packs, leaning arches, pendentives, and squinches).

Rock Structures

On-site meteorites and lunar rocks in their unprocessed condition can be used for construction. Such rocks in anhydrous, hard-vacuum conditions with high rock-fracture strength (Blacic 1984) can generate non-life-supporting shelters. The method of construction with nongeometrical, meteoroid, and lunar rocks is similar to free-form terrestrial rock structures constructed with double-curvature compression, full-dome geometry. The soft-pack regolith mortar bedding and dry-pack small rock units can be used both in corbeling and in tight-ring Persian- and Roman-style domes. A viable method of construction with slate-flat rocks is straight, tight-fit pattern walls, such as the Native American rock walls of the American Southwest, those on the Greek island of Delos and in the Sanandaj region of Iran. These same methods can be applied to construct curved roofs in corbeled and leaning-arch systems, which are more feasible in low lunar gravity than on earth.

As such structures cannot easily be adapted to automated systems, the method's feasibility depends on human skill and on man-material interaction. This system would be appropriate for setting up an initial outpost shelter and/or permanent non-life-supporting structures on lunar bases. Life-supporting rock structures can use, in addition to the preceding, fused mortar bedding as well as airtight tensile fiber.

Lunar Adobe Structures

Two main materials-and-methods utilizations of moon dust for shielding or generating structures are in the forms of automated or manually packed soil covering or Velcro adobe, and fused lunar adobe (Khalili 1985).

Soil-packed covering in flexible dry-adhering containers (Velcro adobe), will utilize unprocessed regolith for both structures and shielding. Packed Velcro adobe in flexible containers can be used to construct structures using corbels, dry-packs, and leaning arches. In single-curvature and double-curvature compression shells, the dry-adhering container texture will allow the tightness of consecutive rows, in the case of a vault, or rings in a dome, to

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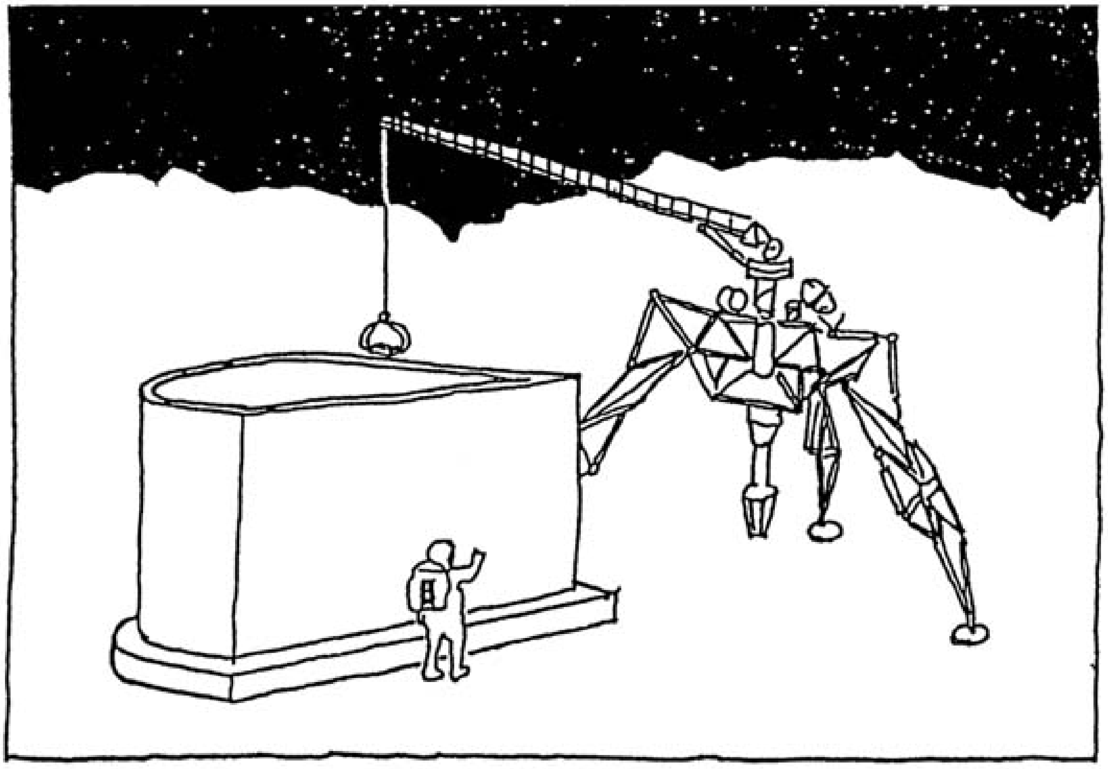

FIG. 1. Transportable Fused Monolithic Vertical Vault Constructed Using Georgia Institute of Technology SKITTER Concept

hold up the structures in space during construction. Neither type of structure needs centering or form-work. Velcro adobe also can be used in conjunction with other conventional structures, mainly for shielding purposes.

Fused lunar adobe can be produced from unprocessed lunar soil or from the by-products of industrial mining operations. Direct block fusion can be achieved by focused sun, microwave, plasma, or other heat generating sources. It is anticipated that vacuum conditions and the essentially zero-moisture content of lunar soils should significantly reduce thermal diffusivity (Rowley and Neudecker 1985). Fused lunar-adobe blocks can be used to construct both structures and shielding shells without centering by applying the earth architecture techniques developed over the course of millennia in limited-resource terrestrial environments (Khalili 1986).

Utilizing an automated system of constructing a vertical, single-curvature structure, lunar adobes can complete the structure, and a postfusion process can produce a monolithic fused vault, which will be lowered to horizontal position at its final location (Fig. 1). Both fused lunar adobe and Velcro adobe can be used for such methods, except that in the case of the latter a corbeled space must cover the vertical structure, while in the former method the total fusion will allow relocation of the structure.

Magma Structures Cast In Situ

Unprocessed lunar soil melted to the crawling consistency of magma-lava with a viscosity generated from basalt at melting point (900 to 1,200 degrees C) will be suitable in malleability for casting both single- and double-curvature shells. Ceramic and fine-grained glass (Heiken 1976; Vaniman and Heiken 1985) and other lunar fluxes can be added to the main unprocessed

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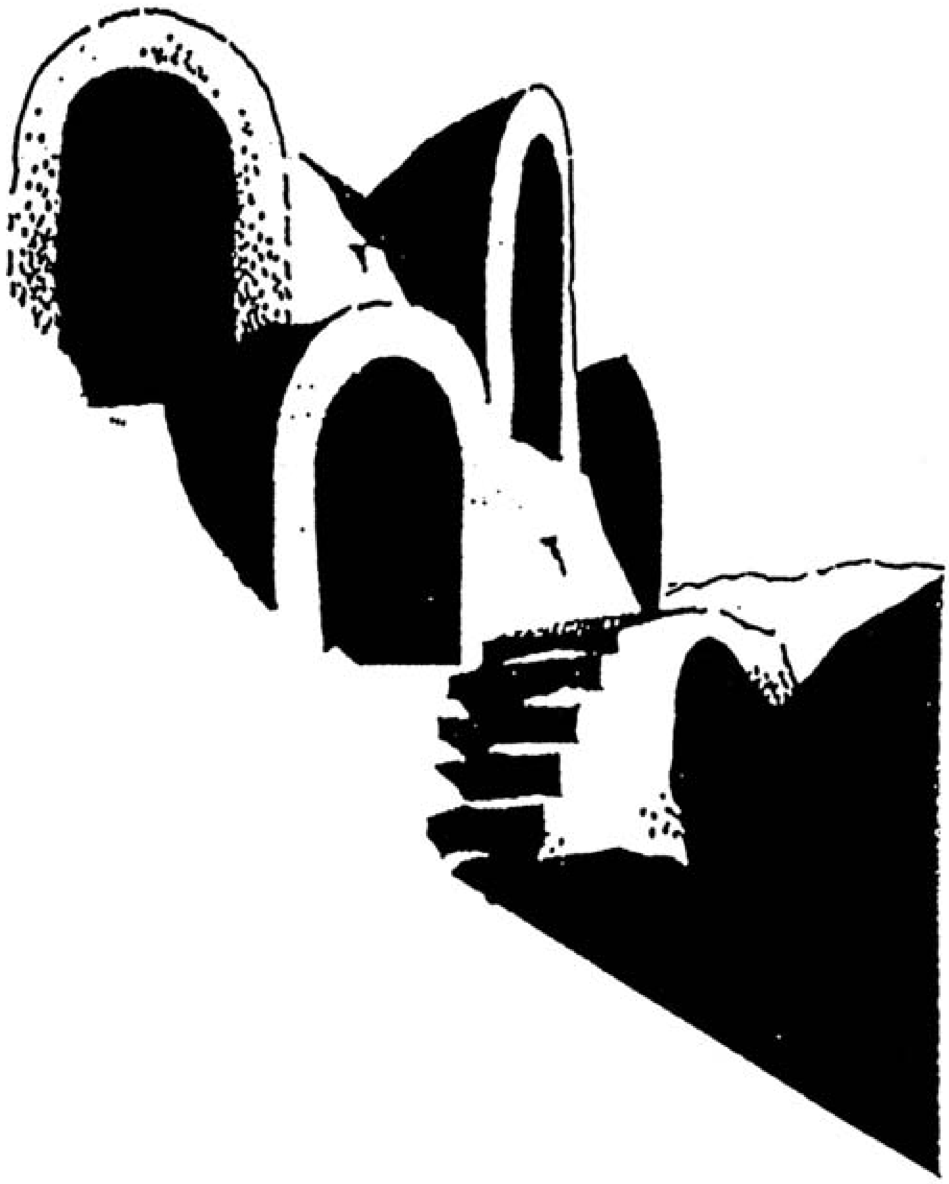

FIG. 2. Natural Lunar Contours Sculpted Using Magma Flows to Create Shielded Light Scoops and Radiation Vestibules

regolith composite to lower the melting temperature to that of glass composite.

Structures can be cast in situ with generated magma either by utilizing existing lunar contours in proximity to the complex, or by forming mounds of lunar soil to desired interior spaces. In this case, more free-form structures could be sculpted (Fig. 2), breaking the barriers of the purely geometrical spaces created by arches, vaults, domes, apses, and cubes. These forms could approach hyperbolic, paraboloid shell structures without reinforcing tensile members. These semicompression structures could withstand low-gravity forces if they are fused monolithically and formed in shorter spans, and when their structural membranes are working in conjunction with other geometrical forms.

Either way, the upper layers of the mounds and the apex, consisting of unprocessed lunar resources, can generate magma flow with focused sunlight (Criswell 1976), microwave (Meek et al. 1985), nuclear, or other energy sources. As the molten composite flows with the low-gravity crawl, the lava crust can form structural members in meridian and hoop generators, or spi-

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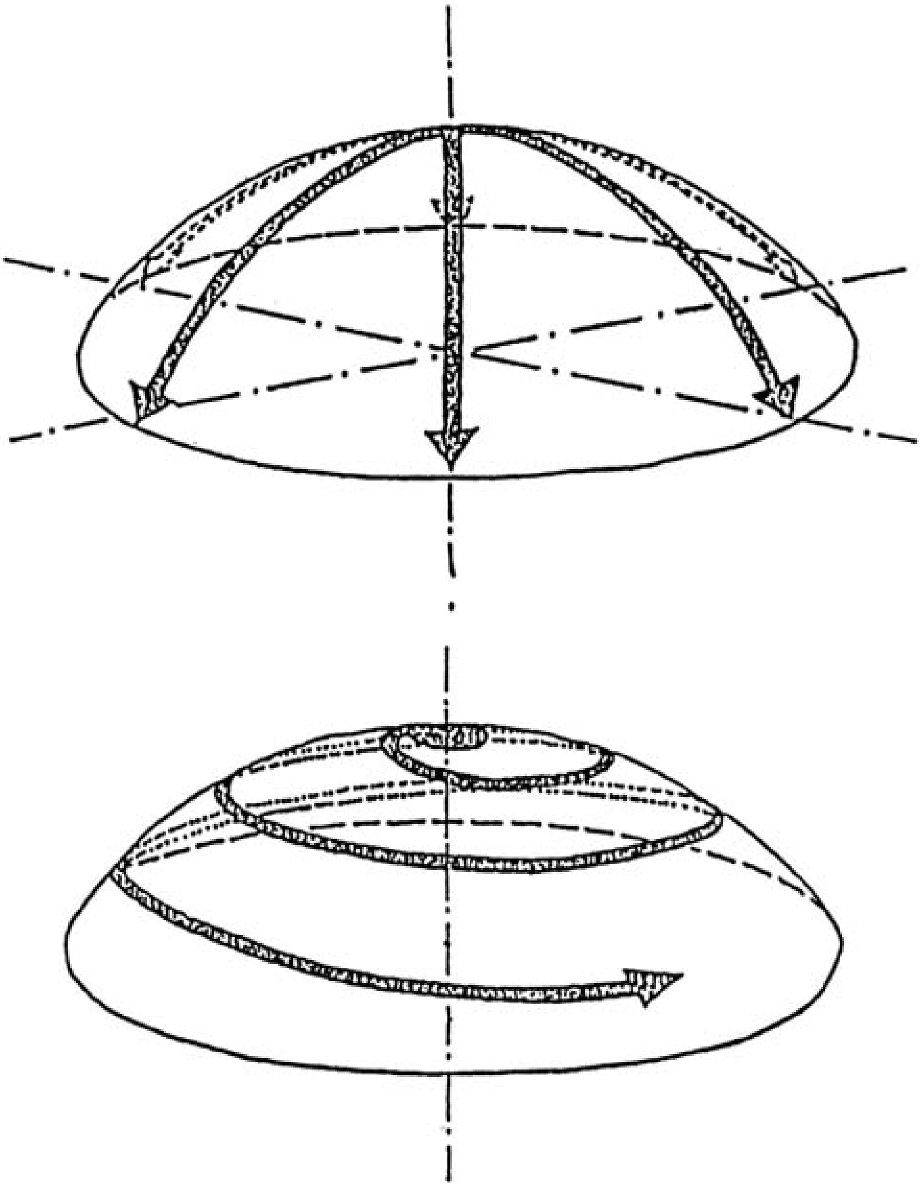

FIG. 3. Magma Creates Double-Curvature Shell Structures as It Flows along Meridians or in Spiral Troughs, with Regolith Mound Form to be Excavated after Completion and Packed over Structure for Shielding

ral, circular, and multipattern rib formations in troughs on the mound (Fig. 3). The spaces between the rib-member structures can be fused by sintering the soil to a lesser depth than that of the members. The monolithic magma structures will eliminate the need for ribbed forms in the case of small to medium spans without the use of tensile reinforcing.

After the structural crust is formed, the underlying mound can then be excavated and packed over the monolithic shell for radiation/thermal/impact shielding (Carrier and Mitchell 1976). The method of formation of mounds can be replaced by the balloon-form spraying system (Vittore 1987) for both domes and vaults, when the application of such form-works is determined feasible in the low-gravity vacuum of the lunar surface. The spraying system will be a shortcut in mechanical separation of lunar dust, and can be achieved by bulk use of soil at its powder stage, involving preheating and Guniting the material onto the structure at the point of fusion.

The high depth of necessary soil coverage over lunar base structures is

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undesirable, in most cases, for both architectural flexibility and light-and-sight parameters of the interior spaces. Thus, the variable magma viscosity can be utilized to reduce the estimated 2-m thickness (Land 1985) of the packed-soil protections. The viscosity of generated magma and the soil-packed covering can counterbalance internal atmospheric pressure, while their pliability would be more accommodating to the nongeometrical forms.

Magma-Rock Roof Composites

Magma-rock roof composites can be formed by laying meteoroids or lava rocks over a mound of regolith in the form of single- or double-curvature shell forms, and void spaces can be filled with unprocessed lunar soil admixture. The loosely packed regolith-flux will be transformed to magma using a direct heat source. The glass-ceramic flux and regolith admixture, when melted, will act as the binding agent to cement the rocks into a monolithic roof structure. The formation of the regolith-rock composite can form a solid roof structure with the possibility of an airtight surface which could also diffuse light. This advantage could be utilized in the areas of non-life-supporting spaces used for storage, or areas designed for horticultural purposes. Agricultural areas can have direct light-filtering through magma-rock composite roofs, which can be built in larger spans and integrated with multilayer colored glass hubs.

Formed Magma Structures

The structures described as lunar adobe construction systems can be cast in situ vertically, then lowered to a horizontal position after the fusion process (Fig. 1). The unprocessed lunar soil containing ceramic-glass (Grodzka 1976) can be cast as magma in its natural stage and transformed to a ceramic structure with added flux derived from the regolith. The magma casting can produce total-space modules in vault forms that are suitable for interrelated room functions. Such modules could be juxtaposed in linear, circular, and multipattern geometries to create a lunar or martian base complex.

A three-vault layout pattern can initiate the complex. The first vault, working as an airlock, will allow entry into the second and third vaults, which are not mutually accessible and can only be entered through the first unit.

Continued expansion of the complex will take place through both the second and third vaults, which in turn become transit routes. Thus the complex will grow by a geometric progression. The expanded pattern of the vault layout can work in circular progressions, as well as grow three-dimensionally, utilizing the single-curvature structures both horizontally as spaces and vertically as passages or chambers.

Lava Tubes—Magma Material as Agricultural Soil

Study of terrestrial lava beds and magma-lava structures and voids has shown that plant successions have taken place where suitable atmospheric conditions were present. Constructing lunar bases with a magma medium that eventually could evolve to agriculturally conducive soil will give an added opportunity to create natural atmospheres where the structures themselves could become the landscaping surfaces. Since the lunar complexes will have the necessary moisture-containing atmosphere for human habitation, plant successions could gradually evolve in the lava flats. Thus, corrosive and other deteriorating characteristics related to the aging of some manufactured building materials could, in the case of magma, evolve into agricultural soil and thus be turned to human advantage.

Natural lava formations, such as Craters of the Moon National Monument in Idaho, can provide an invaluable field study in the design and development stages. The natural terrestrial magma-lava structures can be the training site for material research, construction system studies, and horticultural development to be used in the lunar and martian colonies. A lava tube, a long-span single-curvature structure, is generated by the flow of magma. While moving down the slope, the outer surface of the magma has formed a crust to become a vault, and repetition of the same process has created a long tunnel till the magma river is exhausted. Thus, the ultimate lessons could be learned by observing the natural evolution of lava-tube structures created by molten earth, where the material has become its own form-work, its own structure, its own color and texture finishes, its own landscape, and, finally, its own total environment.

Magma Members Precast

Conventional structural members such as columns, beams, wall panels, and roofing plates can be cast in place with magma-lava composites. The casting system can utilize the trough-cast method in lunar soil beds. Solidified magma-lava structural members can be reinforced with fibers or reinforcing mesh produced from the same material through glass-fiber extraction methods. The precast panels and members can be posttensioned by tendons, or fused with spot mortar composed of materials similar to the magma, with added fluxes.

Magma-lava composites can be used to produce pipes, ducts, vertical shafts, and other members used in precast form for the infrastructure of the lunar bases.

Ceramic Structures

Ceramic structures of limited spans can be cast in situ on the lunar surface. A centrifugally gyrating platform—similar to a giant potter's wheel—with a stationary center zone and movable periphery zone can be utilized to generate total-space ceramic modules. Adjustable rims with parabolic flanges can be utilized for dynamic casting of ceramic structures. A mass of lunar resources can be "thrown" in the stationary zone at the center of the platform and melted with focused sunlight to flow to the rotating periphery zone. The molten composite can form the desired shape by crawling up the flanges moving at the predetermined rate related to material and vacuum atmosphere.

The double-curvature shell structure, in the form of a giant ceramic bowl with parabolic curved upper surfaces, can be formed to be used around a circular plant or a spinal linear corridor to create a complex. The single-curvature structure can be generated in its vertical position to avoid tensile stresses. The vaulted structures can be used in conjunction with the domes in the formation of the complex. They will each be a total-space molded module, eliminating connecting systems, such as panel prefabrication systems. In the case of the circular pattern, a seven-cluster arrangement will achieve the ultimate connection in both two- and three-dimensional designs [Figs. 4(*a*) and 4(*b*)]. The seven-cluster follows the natural formation of the circle around a central core, which yields maximum space with minimum material. Since vaults and domes can be used in conjunction to create an expandable complex, with each module as a total-space entity juxtaposed for varied alternatives, maximum use of sun-and-shade zones and minimum connecting space in the forms of pure geometries will be possible.

Individual modules can be constructed with tensile reinforcing fiber (Blacic 1984), which can be spun on the same gyrating platform utilizing glass-flux composite and generating "cotton candy"–style fiber reinforcing. Such fibers could either be integrated into the shell structure of the ceramic module, or packed in sandwich formation in double-shell cavity space. Ceramic structures sandwiched with vacuum space, and/or packed with insulating materials for radiation/thermal/impact shielding, can provide appropriate permanent structures. Ceramic module spaces can also be transported for temporary shelters. Similar materials and methods could be utilized to generate lunar-base infrastructure parts, such as ducts, panels, pipes, shafts, tunnel rings, and curb modules.

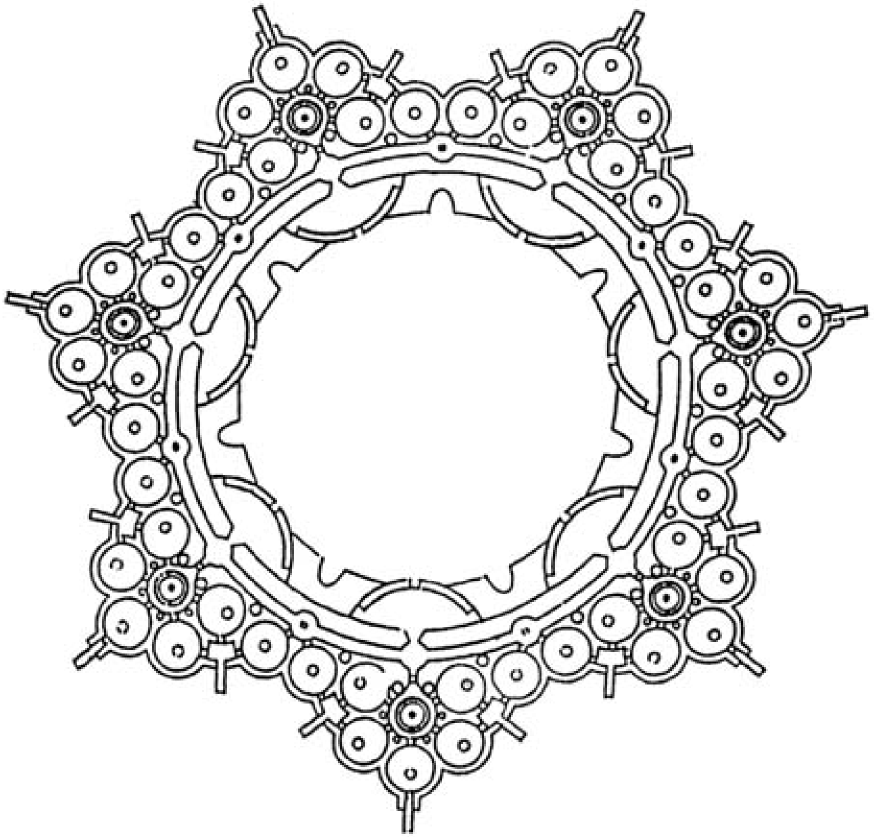
Landing Pads, Roads, Walks, and Regolith Stabilization

Stabilizing lunar soil for landing pads, transportation arteries, and building sites can be achieved with on-site material and available heat sources. Moon dust with a particle size of about 70 microns, which adheres to everything and is churned up by vehicular traffic, needs to be stabilized (Carrier and Mitchell 1976). The proposed use of chemical stabilizers and emulsions, which may include both importing of materials and an ecologically damaging effect on the lunar environment, must be critically researched. As the writer proposed in the 1984 National Aeronautics and Space Administration Symposium on Lunar Bases and Space Activities of the 21st Century, the most economical, nonpolluting, and naturally harmonious process, based on the philosophy of the equilibrium of the elements, will be to directly fuse the top layers of the lunar soil.

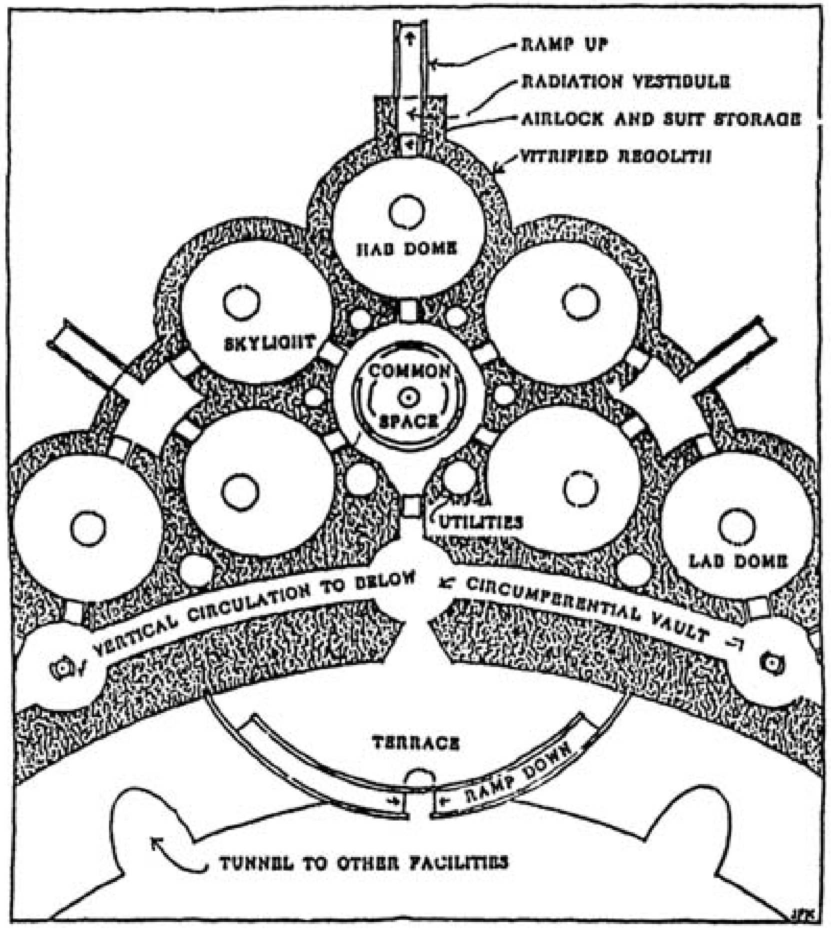
Focused sunlight, microwave, plasma, or other heat sources can form a magma-ceramic crust to arrest unstable lunar dust. Spacecraft landing pads, vehicular traffic roads, pedestrian walkways, and all other surfaces needed for construction sites can be stabilized with a heat source, by on-spot fusion of the top layers. The sintering process can be implemented by an automatic vehicle roving over the surface with a preset, time-fusion-depth program. Stabilized basaltic, ceramic, stoneware, and other durable surfaces can be attained through this process.

Lunar Landscape

The lunar bases of the future, and the expanded colonies on the moon, Mars, and beyond, can create landscapes based on the archemy philosophy that also creates the structures. The natural composites of lunar dust, fused at high temperatures, will generate colors and textures which are in harmony with the human psyche, and in equilibrium with the universal elements. All



(a)



(b)

FIG. 4. Plan for Crater Base with Habitation and Workspace for 70 People, Utilizing Sun-and-Shade Zones and Seven-Circle Compaction Pattern, Creating Maximum Space with Minimum Material: (*a*) Plan View; and (*b*) Detail of Crater Base Habitation

colors of the rainbow are hidden in the gray moon dust, and will leap forth with high flames.

Flat lunar faces, as well as craters and curved contours, can be carved and sculpted in place to create forms in concave and convex shapes, ramps, walks, cityscape furniture, light posts, benches, memorials, and signs. Glaze-fused coloring of moon dust in situ can create heavenly landscapes with heavenly messages in symbols and signs. Fountains of fired-turquoise moon dust beads can quench the thirsty eyes of the tired traveller. And plant successions of leaves of grass and blossoms sprouting from lunar magma-soil can welcome the human child.

All heavenly bodies are like human bodies: marvels of creation in the highest forms of technology, yet filled with poetry and spirituality. Everything we need to build with is in us, and in the place. We must sail into the cosmos not only with zero-defect spaceships, but in ones filled with inspiration, not merely carrying a data bank, but also carrying a sense of unity integrating us with our past and future aspirations. It is good to remember that what we may ultimately reach in space may be the space within.

Conclusion and Recommendations

1. All lunar crew members should learn the principles and techniques of building with unprocessed lunar resources, and understand the accumulated human knowledge of earth architecture and ceramics.
2. A terrestrial site should be designated to initiate a lunar-base simulation program to train crew members in the proposed construction methods.
3. Life-size prototypes of rock, lunar adobe, magma, composite, and ceramic structures should be constructed with simulated soil, rock, and other on-site resources.
4. In situ magma paving prototypes should be developed to demonstrate construction site sintering and automated surface fusing of landing pads, walks, and roads.
5. A terrestrial lava tube should be designated to simulate the lunar-lava-tube environment for research, design, and prototype habitat development.
6. The economic, structural, shielding, and fusing feasibility of all proposed systems should be evaluated.

Acknowledgments

The original Geltaftan Group in Iran, the present Geltaftan Team in New Cuyama, California, and affiliated groups from the Navajo Nation and the Eight Northern Pueblos have continuously supported my work in earth-and-fire systems development. Thanks to Joseph F. Kennedy for his contributions toward design development and for his drawings.

Appendix. References

Blacic, J. D. (1984). "Structural properties of lunar rock materials under anhydrous, hard vacuum conditions." *Symp. on Lunar Bases and Space Activities of the 21st Century*, National Aeronautics and Space Administration, 76.

Carrier, W. D., III, and Mitchell, J. K. (1976). "Geotechnical engineering on the moon." *Lunar Science VII, Special Session Abstracts*, Lunar Science Institute, Houston, Tex., 92–95.

Criswell, D. R. (1976). "On lunar utilization." *Lunar Science VII, Special Session Abstracts*, Lunar Science Institute, Houston, Tex, iii–vi.

Grodzka, P. (1976). "Processing lunar soil for structural materials." *Lunar Science VII, Special Session Abstracts*, Lunar Science Institute, Houston, Tex., 114–115.

Heiken, G. (1976). "The regolith as a source of materials." *Lunar Science VII, Special Session Abstracts*, Lunar Science Institute, Houston, Tex., 48–52.

Khalili, E. N. (1985). "Magma, ceramic, and fused adobe structures generated in situ." *Lunar Bases and Space Activities of the 21st Century*, Lunar and Planetary Institute, Houston, Tex., 399–403.

Khalili, E. N. (1986). *Ceramic houses*, Harper & Row, San Francisco, San Francisco, Calif.

Land, P. (1985). "Lunar base design." *Lunar Bases and Space Activities of the 21st Century*, Lunar and Planetary Institute, Houston, Tex., 363–373.

Meek, T. T., et al. (1985). "Microwave processing of lunar materials: Potential applications." *Lunar Bases and Space Activities of the 21st Century*, Lunar and Planetary Institute, Houston, Tex., 479–486.

Mendel, W. W. (1985). "On lunar construction." *Lunar Bases and Space Activities of the 21st Century*, Lunar and Planetary Institute, Houston, Tex., 362.

Rowley, J. D., and Neudecker, J. W. (1985). "In situ rock melting applied to lunar base construction and for exploration, drilling and coring on the moon." *Lunar Bases and Space Activities of the 21st Century*, Lunar and Planetary Institute, Houston, Tex., 465–477.

Vaniman, D. T., and Heiken, G. (1985). "A closer look at lunar volcanism from a base on the moon." *Lunar Bases and Space Activities of the 21st Century*, Lunar and Planetary Institute, Houston, Tex., 211–222.

Vittore, P. (1987). "Thin shell structures using inflated forms and technology." Design and Constr. Nonconventional Structures, London, England.

Sandbag Shelters, Unidentified, Iran

United Nations Development Programme
Sustainable human development

September 4, 1996

Dear Mr. Khalili,

Final Report

I take pleasure to share with you a copy of the Final Report on Baninajar Sandbag project, prepared jointly by Ms. Mazhari and Mr. Dashti. I hope you find it of interest.

With best regards,

Yours sincerely,

H.R. Ghaffarzadeh
Assistant Resident Representative
(Programme)

Encl.

Mr. Nader Khalili
Director
Cal-Earth. California Institute of Earth Art & Architecture
Calif. - U.S.A.

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Tel: 8732812-15, 8732818 - 8735460 - 8746637 - 8746648 - 8731537
Cable: UNDEVPRO, Tlx: 212397 UNDP IR, Fax: 8738864

United Nations Developmant Programme (UNDP)

in cooperation with

United Nations High Commissioner for refugees (UNHCR)

" Sandbag Shelters " Pilot Project (Phase II)

Construction of 14 Units
Shelters at Baninajar Camp

Prepared by :
Yasmin Mazhari
Mohammad Hassan Dashti
(Technical Assessmant)

August 1996

H.R.C

Jan 23 1995 11:12

BUILDING & HOUSING RESEARCH CENTER

Minisrty of Housing & Urban Development

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URGENT

your ref:
our ref.
date: Jan. 23 1995

Mr. Nader Khalili
California Institute of Earth Art and Architecture

Dear Mr. Khalili

Please be informed that the Building and Housing Research Center (B.H.R.C) in Tehran has been invited to attend a Work-Shop in Nepal on Jan. 30th 1995, regarding Low Cost Housing Technologies for the Central Asian Countries.

We would like to introduce the Sand-Bag Shetter designed by you at the above seminar.

Please be advised that all due credit will be given to you as the inventer of this construction technic.

Please do not hesitate to contact us if you have any questions regarding this matter.

Sincerley yous

Dr. F. Daneshjoo
The President of B.H.R.C.

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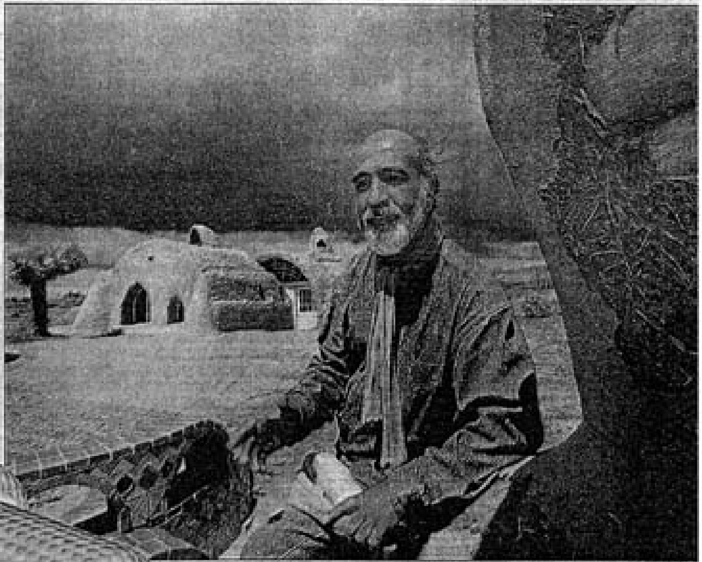
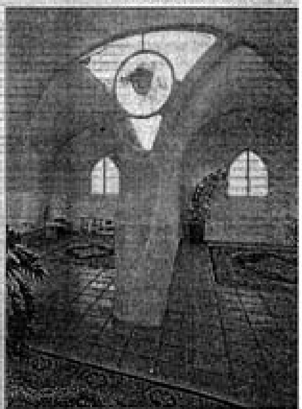
CIRCULATION: 1,098,347 DAILY / 1,385,787 SUNDAY

Down TO Earth



Photos by CON KEYES / Los Angeles Times

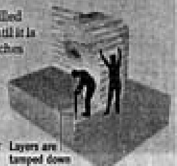
Nader Khalili at a home built using his Superadobe construction system. The home's interior, right, is spacious, cool and light.



Superadobe Construction Steps

1. A 12-inch to 18-inch deep by 20-inch wide trench is dug; its outlines are the basis of the structure's exterior walls. A mixture of moist soil and cement is pumped into the bags (or shoveled by hand) as the bags are laid into the trench to form the base of the walls. Strands of barbed wire are placed between layers to anchor the bags.

2. Each layer of adobe-filled bags is tamped down until it is slightly flattened to 6 inches high by 20 inches wide. Layers are added until the walls are 5 to 6 feet high (this takes about four days). Openings are cut into the walls for doors and windows.



3. Plumbing and electrical lines are placed on the floor and fitted into the grooves between layers of bags. A Superadobe floor is poured. The inside walls are finished with straw and plaster (or drywall, if preferred) and painted with a nontoxic milk and linseed oil mixture.

4. A curved piece of metal mesh is placed on top of the walls, and the adobe mixture is spread over it, forming an arched roof. This process could take two to three weeks. The roof is waterproofed with tarpaper. The exterior is covered with adobe balls fixed to exterior surfaces in whatever

The work of a few earthen home architects is cracking building code barriers in Southern California.

By DIANA MARCUM
SPECIAL TO THE TIMES

HESPERIA—City boosters must cringe when architect Nader Khalili describes why he chose this sprawl of stucco tract homes surrounded by desert as the place to experiment with houses made of earth.

"There are boiling summers, freezing winters, howling winds, flash floods and lots of earthquakes. It's perfect," he said. "If it doesn't break here, it doesn't break anywhere."

Though earthen structures, which can lower energy bills and save dwindling timber resources, have proliferated in eco-conscious Napa County and bloomed in the New Age openness of New Mexico and Arizona, stricter building codes have left little room for experimentation in Southern California.

Until now. The groundbreaking, or in this case ground-building, work of a few architects is cracking code barriers and setting the stage for the Southland to get down to earth.

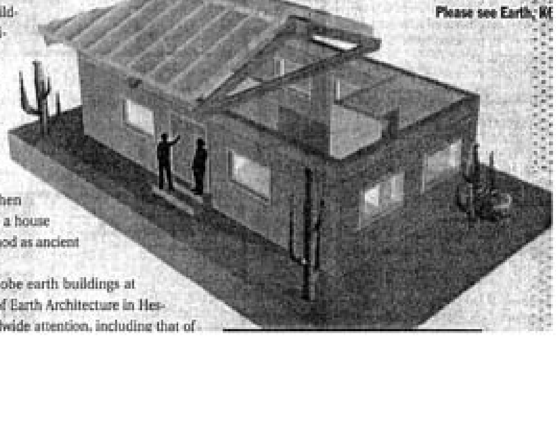
In San Diego County, for example, architects Jacek Lisiewicz and Laurie Weir wrote earthen structure codes to build a house of rammed earth, a method as ancient as the walls of Jericho.

And Khalili's Superadobe earth buildings at his California Institute of Earth Architecture in Hesperia have caught worldwide attention, including that of the International Conference of Building Officials.

If the building officials' group includes earthen architecture in the international code it is expected to release in 2000, is that it could open the door to such buildings even in earthquake-wary Los Angeles County.

On a gusty High Desert day at Cal Earth, a group that included Australian aborigines, Texas survivalists and environmentalists with Oasis Preserve International, actor Woody Harrelson's rain forest action group, wrapped up a weeklong, $2,000 workshop at which they learned to build homes out of earth, sandbags and a little barbed wire. Superadobe, the architect's term for his building system, is an adaptation of traditional adobe that begins with a fiber bag up to a mile long and 16 to 18 inches in diameter.

Please see Earth, K6



Sandbag Shelters, Unidentified, Iran

Earth

Continued from K1

The bag is pumped, or shoveled, full of dirt that's been amended with a small amount of cement, then coiled or laid in place as it is being filled.

With a cement pump, bags can be filled at a rate of 10 to 15 feet a minute. Hand-filling is much slower.

Barbed wire is placed between layers of the bag to keep it from sliding out of position. No reinforcing bar or additional support is needed because of the building's design of self-supporting domes and arches.

The completed walls are finished with mud plaster and painted white with a nontoxic mixture of milk and linseed oil. Scattered about Cal Earth's 7½-acre yard are earlier generations of experiments in Khalili's quest to find an architecture created from earth, fire, water and air, an undertaking he ties to the poetry of Rumi, a 13th century Persian poet who, Khalili says, "taught the unity of the elements and the soul."

Some look like upside-down teacups or igloos. But the latest incarnation, called Earth One, is a three-bedroom, two-bathroom home with a two-car garage.

The earth walls insulate the home from outside temperatures. In addition, there are chimney-like "wind catchers" for cooling and solar panels for heating. There are tile floors, windows, skylights and vaulted ceilings.

A one-bedroom prototype was built for $5,200, Khalili said. A contractor familiar with the process could build a Superadobe house for half the cost of an equivalent wood-frame house, he said.

The original emphasis of Khalili's work was low-cost housing solutions for impoverished parts of the world. He became a housing consultant to the United Nations and later for NASA, developing structures to be built from lunar dust.

But Khalili's vision of the earthen house is more prosaic than mystic poets or moon houses.

"I need a mortgage company. What I'm after is a housing development with at least 500 houses," Khalili said.

"These are houses that are more than affordable. They are warmed with the sun, cooled with the wind. We need to get them into the mainstream."

The curves of Earth One's domes and apses are more reminiscent of Bedrock than of the suburbs, but Khalili believes many home buyers won't have trouble making the adjustment.

"The idea of the American dream house is changing very fast," he said. "It's no longer enough to live in a house built with 2-by-4s that come from cutting the forests, to live with toxic paint and toxic floors, to struggle with a 30-year mortgage," he said. "People are ready for change."

Khalili, a specialist in the design of high-rise buildings, quit a lucrative Los Angeles corporate architectural practice in 1975 to spend five years traveling alone on a motorcycle through his native Iran studying its earthen buildings.

The book about his travels, "Racing Alone: Fire and Earth, A Visionary Architect's Passionate Quest," established him as a guru of earthen building.

Khalili sees such structures as a global solution to deforestation but is convinced that he must begin in California because "as California goes, so goes the rest of the United States and the world.

"Even children growing up in the Middle East, when asked to draw a house, will draw a pitched roof and chimney, even if they've never seen one outside a book," he said.

"That image of a pitched roof has destroyed more forests. I want to teach children to think of houses in the shape of bubbles and rainbows."

The city of Hesperia is backing Khalili.

The high desert city in San Ber-

Please see Earth, K7

Earth

Continued from K6

nardino County might not seem to be a likely cradle of alternative architecture. Nevertheless, Hesperia approved building permits for Earth One and commissioned the first Superadobe public structure, a $1.2-million museum and nature center now under construction beside the town's artificial lake.

It's an abrupt change from when Khalili first proposed buildings made of earth-filled sandbags.

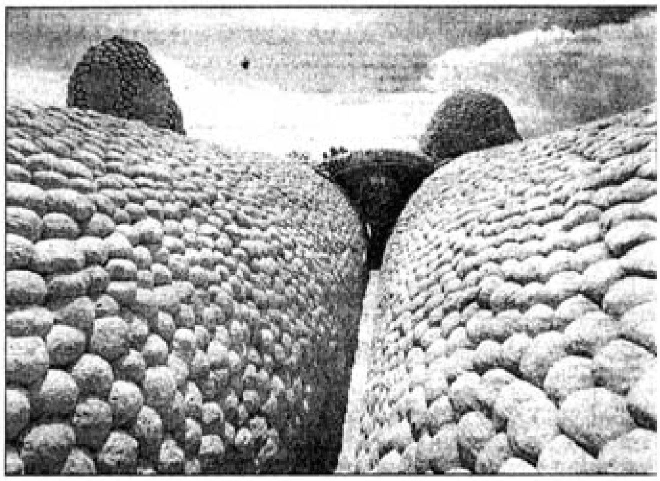
"If we hadn't been trained to be courteous, we would have laughed out loud," wrote Hesperia's planning director, Tom Harp, in an article for Building Standards, the magazine of the International Conference of Building Officials.

But the city conducted tests, under the supervision of the conference, and found that Superadobe stood up to twice the amount of weight that would crush a pitched-roof house.

City works wrapped steel cables around a dome and tried to pull it over with hydraulic jacks. The dome didn't budge.

Now Hesperia building officials are among Khalili's most vociferous supporters in his goal to have earthen structures included in an international conference's building code.

□



Photos by CON KEYES / Los Angeles Times

The Superadobe home is covered with adobe balls, top. Above, worker inside dome building at the Nature Center Museum in Hesperia.

4 sections, 28 pages

GOOD MORNING, HIGH DESERT, MONDAY, JULY 23, 2001

DAILY PRESS

Royal Ranger of the Year in Apple Valley

See High Desert, B1

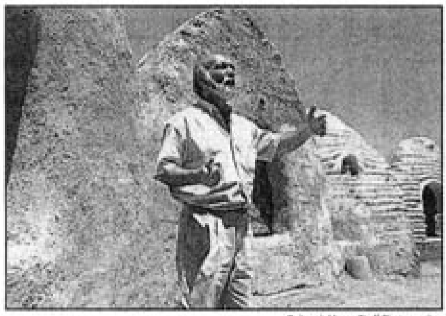
Tony Green races to get season back on track

See Sports, C1

Deborah Mason/Staff Photographer

United Nations correspondent Afsane Bassir, right, talks about the possible uses of earthen dome houses in refugee camps as Hesperia Mayor Pro Tem Bill Jensen and Cal Earth Institute Director Nader Khalili, left, and his daughter, Sheefteh, listen. Bassir and U.N. officials toured the institute Sunday.

United Nations officials tour Cal Earth



Deborah Mason/Staff Photographer

Khalili talks about the dome homes to United Nations representatives.

▶ WORLD AFFAIRS: Cal Earth founder hopes to see earthen homes in disaster-prone areas.

By ELLIE MOON
Staff Writer

HESPERIA — Several United Nations officials toured a collection of beehive-like earthen buildings at Cal Earth on Sunday to judge their feasibility as emergency shelters.

"I'm very positively impressed and I can see what this technology can do for the people of the world," said Omar Bakhet, director of the emergency response division of the United Nations.

Architect Nader Khalili, founder of the Hesperia-based Cal Earth project (short for California Institute of Earth Art and Architecture), uses sandbags to build not just shelters, but homes.

A mixture of ordinary desert dirt and cement goes into the sandbags, which workers stack on top of each other more than six feet high and top with domed roofs. Open-air windows made out of plastic tubing provide light.

The sandbags insulate against heat and cold and be-

Please see CAL EARTH, A6

CAL EARTH / From A1

cause there is no wood involved, the buildings are fireproof.

The buildings have stood against Khalili's earthquake testing and actually improve under heavy rains because the water packs tight the earth inside the sandbags.

The shelters take about a day to build, Khalili said. His idea is to eventually use these structures as regular housing in disaster-prone areas rather than simply as emergency shelters.

Construction supplies are just about everywhere. The idea is to use what's available to build something durable.

"They come to see this technology to take it to the world, because it's a local technology," Khalili said.

That's what interests the United Nations, said Lorenzo J. Jiminez de Luis, program adviser for country operations in the agency's emergency response division.

"Every emergency situation I have witnessed has had shelter implications," he said. "The alternative is tents. Tents are not viable."

Jiminez de Luis cited flimsy construction, poor protection against the weather and shoddy conditions. He added Khalili's earthen homes are much more aesthetically appealing than a tent and even beauty helps people get through disasters with hope.

"That has implications on privacy, dignity," he said, shaking his head. "It's the dehumanization of humanitarian efforts."

Peru is still recovering from a devastating earthquake and more than a million people remain homeless in India after that country's latest bout of flooding, Bakhet said.

"Just as we sit, in India it is the monsoon period and people are living without shelter," he said. "And how much would these bags cost in India? Peanuts."

Bakhet hopes to set up demonstration sites abroad and have United Nations workers come to Hesperia for Cal Earth to train them in earth architecture.

Anyone can build a Cal Earth shelter for about $80 or a small two-bedroom house for $500. The United Nation's least expensive family tent is $500 and it must be replaced every season.

Emergency workers use sandbags on the field now. The difference will be learning to build homes with them rather than simply keep back flood waters.

"If you want to make an impact, you have to start with things that work," Bakhet said.

Asfané Bassir-Pour, a correspondent covering the United Nations for Paris's Le Monde newspaper, pointed out the irony of available construction materials.

"He uses sandbags and barbed wire, which are materials of war," she said, pointing to Khalili. "Now they can be used to build homes."

Sandbag Shelters, Unidentified, Iran

BIOGRAPHY
of architect Nader Khalili

E. Nader Khalili, Iranian-born California architect and author, is the innovator of the "Geltaftan" Earth-and-Fire technique known as Ceramic Houses, and of the Superadobe construction technology. Khalili received his architectural education and philosophy in Iran, Turkey, and the United States. He has been a licensed architect in California since 1970, and has practiced both in the U.S. and abroad. Since 1975 he has been involved with Earth Architecture and Third World Development, and has been a consultant for the U.N. (UNIDO) in these building techniques. In 1984 the award for "Excellence in Technology" went to him for the innovation of Ceramic Houses from the California Council of the American Institute of Architects (CCAIA), and in 1987 Khalili's project "Housing for the Homeless: Research and Education" received a Certificate of Special Recognition from the U.N. International Year of Shelter for the Homeless and U.S. Department of Housing and Urban Development.

Since 1984, lunar and space habitation have become an integral part of his work after his presentation of "Magma Structures" designs, based on "Geltaftan" (Ceramic Houses), and "Velcro-Adobe" (later called Superadobe - sandbag and barbed wire system) at the 1984 NASA symposium, "Lunar Bases and Space Activities of the 21st Century". He was subsequently invited to Los Alamos National Laboratory as a visiting scientist. Since that time, he has presented papers and been published in space-related symposiums and their publications including those of NASA, and the "Journal of Aerospace Engineering" for which he was awarded by the American Society of Civil Engineers. Khalili was a member of the team of the "Lunar Resources Processing Project," along with the Princeton - based Space Studies Institute, McDonnell Douglas Space Systems, and Alcoa.

Since 1982 Khalili has been directing the Architectural Research Program (ARP) at SCI-Arc, California (Southern California Institute of Architecture). He founded the Geltaftan Foundation in 1986, and directs it's institute Cal-Earth (California Institute of Earth Art and Architecture) . Recent architectural projects include the Sustainable Moon Village and Hesperia Museum & Nature Center, for the Mojave Desert city of Hesperia, erosion stabilization of Hesperia Lake, a FEMA related project, Holy Ressurection Monastery, and "Earth One" Sustainable Housing. At Cal-Earth he continues to build and test prototypes in Earth Architecture for inclusion in the Uniform Building Code. Prototypes for emergency housing are also being tested at Cal-Earth. Recent work has been funded by grants from the National Endowment for the Arts, the Katharine Tremaine Foundation, the Rex Foundation, the Leventis Foundation, Our Ultimate Investment (Huxley) Foundation, the Flora Family Foundation, and the Turner Foundation.

His five books were written while evolving these techniques and philosophy of architecture. "Racing Alone", and "Ceramic Houses and Earth Architecture: How to Build Your Own", while developing the Geltaftan "Earth and Fire" system for building ceramic houses; "Sidewalks on the Moon", while designing for the moon, a journey through tradition and technology; "Rumi, Fountain of Fire", and "Rumi, Dancing the Flame" translations of poems from the Persian language mystic poet, Rumi whose wisdom concerning humanity and the unity of the elements of Earth, Water, Air and Fire are the inspiration behind his work.

Khalili's "Works and Words" have been widely exhibited and published in the US and internationally including the Centre Georges Pompidou in Paris, the Contemporary Museum of Arts in Teheran, and the Institute of American Indian Arts Museum in Santa Fe, New Mexico; and broadcast on national and global TV channels including CNN, BBC, ABC, Fox TV, PBS, Discovery Channel. Over 100 hands-on workshops and lectures have been conducted in the U.S. and abroad, from Princeton University/ Princeton New Jersey, International Space University/MIT Boston Mass., to inmates of Chino and other prisons, from NASA (National Aeronautics and Space Administration) / Washington D.C., Los Alamos National Laboratory/ New Mexico, to many Native American Reservations, the Eight Northern Pueblos/ San Juan New Mexico, and from children in South Central Los Angeles hospitals to the Universities of California, national and international universities.

Khalili's architectural works also include: the design of a future-oriented community for 5,000 inhabitants for Future City/Villages, Intl. in New Cuyama, California in 1988 (prototype structures were built on-site, and pre-fabricated vault modules were built, fired and glazed at a brick factory); the design of a community for 20,000, near Isfahan, Iran; the Middle East headquarters of Dupont/ Polyacryl was designed and supervised, completed in 1978; over 300 projects of conventional buildings ranging from high-rise to single residence.

EARTH ARCHITECTURE- NADER KHALILI

" Khalili's Superadobe earth building at his California Institute of Earth Art and Architecture have caught worldwide attention, including that of the International Conference of Building Officials" *Los Angeles Times*

" We had seen this style of building meet and exceed the testing of rational analysis as required by our code." *- Hesperia Building Official* *ICBO's Building Standards*

".......in Hesperia, the houses were beautiful, well-insulated, structurally rigid, and cost almost nothing to build." *Los Angeles Times*

"To this visionary architect the earth houses....are the obvious response to 21st century housing shortages, deforestation, the energy crunch and even the physical sickness brought on by the toxic exhalations of modern building materials." *Orange County Register*

"Look inside the demonstration houses he's built and you see spacious beauty. They meet all building codes, are energy efficient, weathertight, and so solid they passed the most gruelling stress tests." *CNN World News*

"The building was stronger than the testing equipment" *(Hesperia Building Official)*

"People are coming from all over the world to Hesperia, California to learn this simple way of building" *-Hesperia Mayor* *CNN World News*

"The buildings are cool in summer and warm in winter, probably the most environmentally friendly homes you'll ever come across....." *BBC (British Broadcasting Corp.*

"We think this design has the potential of revolutionizing the housing industry!' said Hesperia Mayor." *Hesperia Resorter*

"A Hesperia Architect has seen the future of affordable housing." *San Bernadino Sun*

"His hope is to create truly low-cost housing in many parts of the world." *AIA Journal : Architecture*

"The Excellence in Technology Award, California Council/American Institute of Architects, went to him for his work." *Los Angeles Times*

"...a family should be able to walk to a piece of land and build themselves a home without timber, steel or concrete. Just the earth alone should suffice." *Ceramic Monthly*

"... a vision that could be of considerable value to architecture in development" *Mimar*

"Earth architecture exists at the point....where poetry has crystallized into structures" *New York Times*

"Khalili is also at work on prefab ceramic vaults, modular units that can be trucked and linked together easily. And sometimes his vision goes much, much further: he's worked with NASA on scenarios in which the moon's soil could be melted, then, after molding, fused into structures by concentrated rays of the sun." *Mother Jones*

""A novel 'magma structure' concept presented by him...proposed melting mounds of lunar soil with focused sunlight to create a pliable material that could be sculptured into facilities ...at the NASA symposium, 'Lunar Bases and Space Activities of the 21st Century.' " *Aviation Week & Space Tech.*

"Khalili's perspective on lunar architecture provides an interesting and thought-provoking contrast to 'orthodox' scenarios." *Lunar Bases and Space Activities of the 21st Century. W.W.Mendell, NASA-sponsored symposium - National Academy of Sciences.*

Sandbag Shelters, Unidentified, Iran

LECTURES AND WORKSHOPS CONDUCTED BY KHALILI INCLUDE:

Princeton University/ Princeton, New Jersey
Space Studies Institute/ Princeton, New Jersey
International Space University/ MIT, Boston, Mass.
Carnegie Mellon Institute/ Pittsburgh, Pennsylvania
Los Alamos National Laboratory, New Mexico
National Aeronautics and Space Administration/ W D.C.
Ohio State University/ Columbus, Ohio
California Art Education Assoc. Conf./ San Diego, Calif.
Ball State University/ Muncie, Indiana
Rensslaer Polytechnic Institute/ Troy, New York
Catholic University of America/Washington, D.C.
North Dakota State University/ Fargo, North Dakota
University of Wisconsin/ Milwaukee, Wisconsin
University of Arizona/ Tucson, Arizona
Pitzer College/ Claremont, California
Claremont Graduate School/ Claremont, California
California Polytechnic Institute/ San Luis Obispo
California Polytechnic Institute/ Pomona
University of California/ Riverside
University of California/ Santa Barbara
University of California/ Los Angeles
Southern California Institute of Architecture
Southern California Ceramic Association
Ojai Foundation/ Ojai, California
Institute of American Indian Arts/ Santa Fe, New Mexico
Eight Northern Pueblos/ San Juan, New Mexico
College of Santa Fe/ Santa Fe, New Mexico
Rough Rock, Navajo Reservation/ Arizona
Tsaili Community College/ Navajo Reservation, Arizona
Lindisfarne Institute/ Creston, Colorado
University of Baja/ Mexico
San Jose/ Costa Rica
University of Cairo/ Egypt
University of Tehran
Eos Institute/Laguna, California
American Institute of Architects/Los Angeles
American Institute of Architects/Inland Empire
Arcosanti/Arizona

TELEVISION AND RADIO PRESENTATIONS

CNN World News
BBC (Bitish Broadcasting Corporation)
Fox TV ("Millenium Housing", national broadcast Jan. 1, 2,000)
Discovery Channel ("If ThereWere No Moon", documentary)
National Geographic
PBS ("Futures", space and lunar documentary)
NBC news
ABC radio
Channel 28, Los Angeles, Public Broadcasting System
Channel 2, Los Angeles, a CBS Station
Channels 9, 4, and 8, Los Angeles
KPFK Radio, Los Angeles
Group W, Westinghouse Cable TV/ Sierra Madre, Cal..
KCST, International Channel, Los Angeles, California
Voice of America English and Farsi Services
BBC World Service, London

EXHIBITIONS

Institute of American Indian Arts Museum, Santa Fe, NM
Centre Georges Pompidou/ Paris, France
Museum of Contemporary Arts/ Tehran, Iran
Various Universities and Educational Galleries in U.S.

BOOKS BY NADER KHALILI

Racing Alone
Ceramic Houses and Earth Architecture
Sidewalks on the Moon
Rumi, Fountain of Fire
Rumi, Dancing the Flame

PAPERS (SPACE)

Magma, Ceramic and Fused Adobe Structures Generated In-Situ
Lunar Structures Generated Shielded With On Site materials

MAGAZINE & NEWSPAPER ARTICLES

The New York Times
Los Angeles Times
Building Standards (ICBO)
Orange County Register
San Bernadino County Sun
Architecture Magazine
MSNBC
Reuters International News Agency
and over 100 major national and international publications

Sandbag Shelters, Unidentified, Iran

Racing Alone,

Fire and Earth and a Visionary Architect's Passionate Quest for the Ultimate House, By Nader Khalili (Harper & Row, 1983, San Francisco; Burning Gate Press, 1990 , Los Angeles)

"His unusual, lyrical odyssey, Racing Alone, is rich in poetry and observation, it is also a moving meditation on the human costs of technological progress and the quest for harmony with nature...When he writes about the soul in clay, he makes you believe it." *Publishers' Weekly*

"He is an exceptionally graceful, even poetic, writer. His book is delightful as well as informative. It is, in fact, downright exciting." *Atlantic*

"Many cogent observations on some of the negative aspects of contemporary society/loneliness, materialism, the bureaucratic morass." *The Library Journal*

"Evocative book. An appropriate gift to a member of the profession." *Los Angeles Times.*

"Racing Alone is not just a book about architecture. It is also a stunning expose of the limits of Western ideas and technology when they are applied to largely rural cultures." *San Francisco Chronicle*

"His book is of the highest theoretical value, yet with a hundred per cent sense of practicality." *Design-India*

Architect Nader Khalili spent five years of his life searching for a method to fire mud houses and turn them to stone...the book documents not merely Khalili's architectural achievements, but also his inner discoveries: the divinity of creativity, the power of beauty, and perhaps most of all, the truth of simplicity" *Arts & Architecture*

Ceramic Houses & Earth Architecture,

How to Build Your Own, By Nader Khalili (Harper & Row, 1986, San Francisco; Burning Gate Press, 1991, Los Angeles)

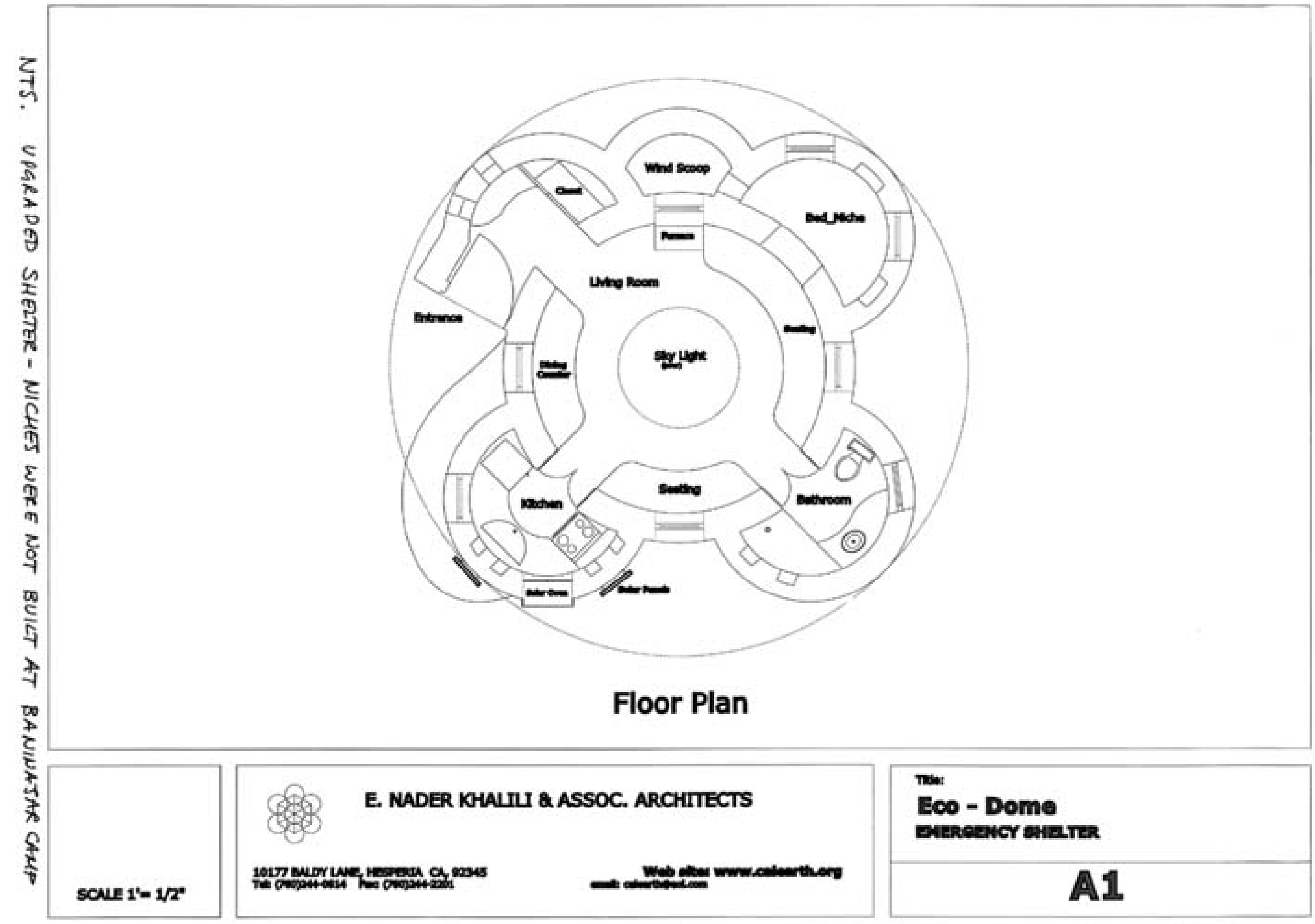
"In Ceramic Houses, internationally renowned architect Nader Khalili shows step-by-step how to construct, glaze, and fire adobe and rammed earth buildings...A fascinating text!" *Ceramic Monthly*

"His message--told in a haunting mix of prose and poetry, of memory and idealism--is that we can teach the poor to build their own homes even though they have access to nothing more than dirt and community kilns." *The Fessenden Review*

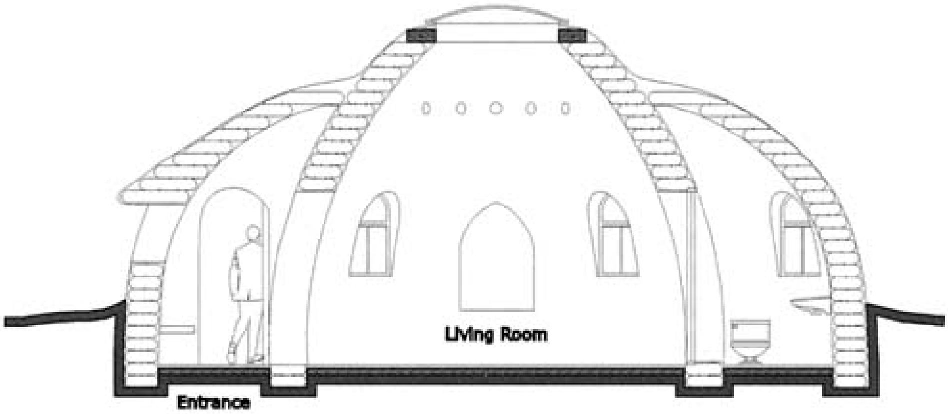
"Human need was the inspiration for this book...which attracts mainly by its simplicity and the beauty of applying ideas." *Manus*

"It's not that often that something really exciting presents itself to the field of construction..." *Journal of Real Estate Development*

"This is an extraordinary work. Though very much the personal expression of an impassioned visionary, *Ceramic Houses* is full of experiential advice, technical guidance, and encouragement to those who would join the author in his search for cheap, durable, attainable housing for much of the world." *Fine Homebuilding*



Sandbag Shelters, Unidentified, Iran



Section I

SCALE 1'= 1/2"

E. NADER KHALILI & ASSOC. ARCHITECTS

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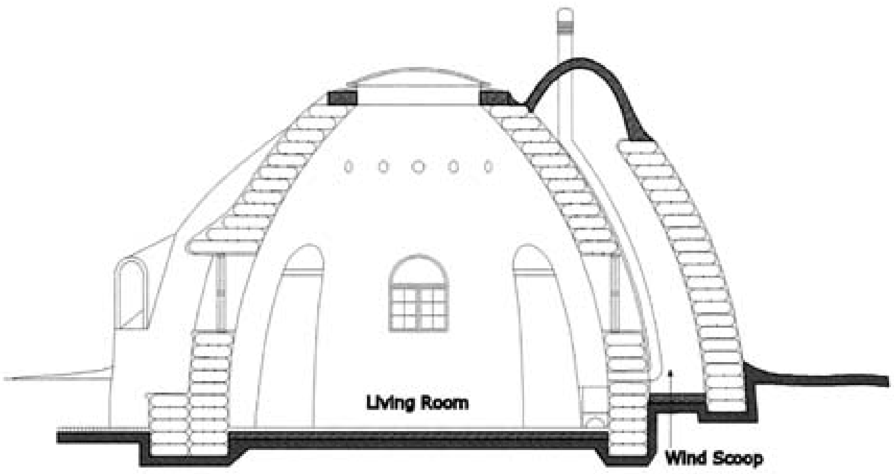
Tel: (760)244-0614 Fax: (760)244-2201

Web site: www.calearth.org
email: calearth@aol.com

Title:
Eco - Dome
EMERGENCY SHELTER

A2

NTS: UPGRADED SHELTER - NICHES WERE NOT BUILT AT BANINAJAR CAMP & WINDSCOOP



Section II

SCALE 1'= 1/2"

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Title:
Eco - Dome
EMERGENCY SHELTER

A3

NTS: UPGRADED SHELTER - NICHES WERE NOT BUILT AT BANINAJAR CAMP & WINDSCOOP

Sandbag Shelters, Unidentified, Iran