



JUNE 2009 Vol. 31 No. 6

Concrete international

The Magazine of the American Concrete Institute — an international technical society
www.concreteinternational.com

33 Dimensional Tolerance
Specification

37 Concrete Homes for
Disaster Victims

42 Protection Screens

Formwork

ITALY TX 76651-8710

177 DOME PARK PL
MONOLITHIC DOME INST
MS MANETTE SOUTH
CI 1118956 10/31/2009
00489

*****AUTOTRANS-DIGIT 766

|||||



The village of New Ngelepen, with its 71 permanent homes, plus a mosque, primary school, playground, and medical clinic—all in concrete—was occupied less than a year after the earthquake that ravaged the region. (All photos courtesy of Monolithic Dome Institute and Domes for the World Foundation)

Concrete Homes for Disaster Victims

Inflated forms bring shelter to rural landslide victims

BY M.K. HURD

In May 2006, a devastating earthquake struck the island of Java in Indonesia. The region most seriously affected by the earthquake is densely populated with people living in small villages separated by rice fields. Homes in one such village, Ngelepen [NEL-e-pen], fared worse than in neighboring villages because a catastrophic landslide completely swept the community off its foundations. But the Ngelepen villagers were more fortunate than many others in the region when the World Association of Non-Governmental Organizations (WANGO) and Emaar Properties in Dubai, United Arab Emirates, agreed on a plan to restore Ngelepen.

After completing an extensive feasibility study, the Domes for the World (DFTW) Foundation was asked to rebuild the village on a tract of land set aside by the government

especially for the rebuilding. The nonprofit Utah-based organization applied its expertise in building environmentally friendly concrete dome homes capable of withstanding the severe effects of many natural disasters. In April 2007, less than a year after the earthquake, villagers were able to occupy their homes in New Ngelepen.¹ The new village had 71 concrete shell houses, arranged in groups of 12 around a shared building containing laundry, toilet, and shower facilities. A new well was dug for each of these clusters, and six independent septic systems were installed.

Thin-shell concrete civic structures were also constructed—a mosque, primary school, playground, and medical clinic. The total development, which included roads and drainage as well, was funded by a \$1 million grant from Emaar Properties.



Fig. 1: Inflated form with most of the reinforcement installed. The small fan used for inflation remains in place, connected to the fabric of the form

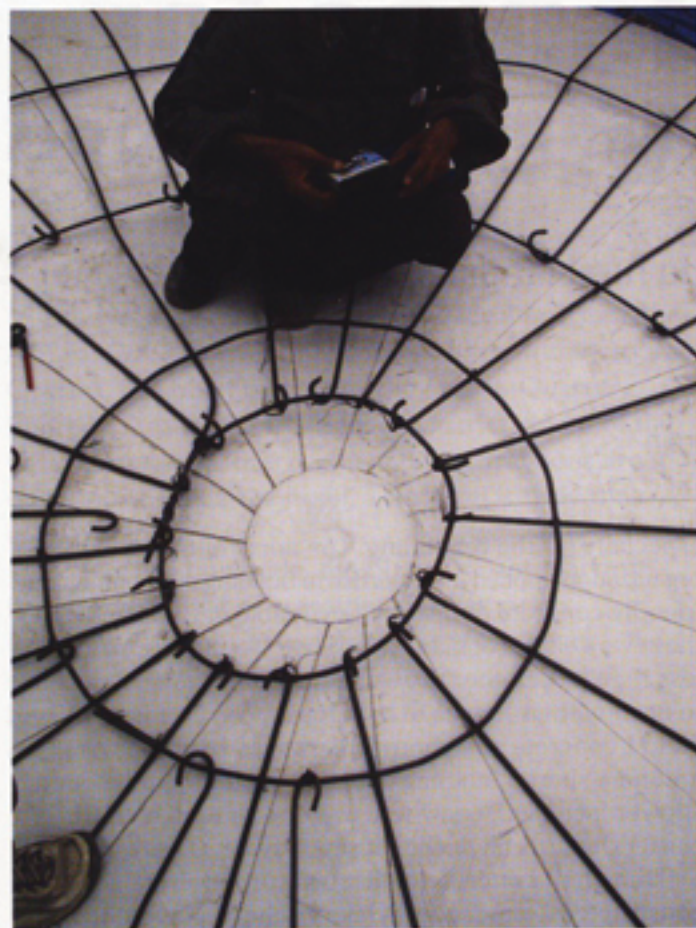


Fig. 2: On top of the inflated form, a reinforcement ring is set into place; and then vertical bars are attached and successive rings of reinforcing bar are placed, working down the sides of the form

According to the DFTW Foundation, each home cost about \$19/ft² (\$200/m²), including all infrastructure, and employed several hundred laborers hired from the local population, trained, and paid at higher than the prevailing wage for similar work. A major factor in the speed and economy of the village reconstruction was the use of inflatable forms to build thin-shell concrete structures. The EcoShell construction method, developed by Monolithic Constructors of Italy, TX, was originally used for low-cost concrete storage buildings.² Unlike the larger domes that are built by applying shotcrete from inside an inflated form, most work on the smaller shells is done from outside of the form.

BUILDING THE SHELLS

A 40 ft (12.2 m) diameter dome is the largest size recommended for this kind of residential structure. Instead of building a simple hemisphere or ellipsoid, vertical stem walls can be made by adding a base cylindrical section to the form for the upper dome shape as was done at New Ngelepen.

Work begins with a reinforced concrete slab, a ring beam foundation, or both, that has dowels set around the perimeter tall enough to overlap the reinforcement of the shell structure. Hardware is set in place in the foundation slab to aid in anchoring the air form.

The inflatable form made of heavy, rugged, air-tight architectural fabric is attached to the foundation slab or beam, and the connection is sealed to prevent air loss. A small high-pressure fan, such as those used for heavy-duty vacuum cleaners, is used to lift the form into place (Fig. 1). When inflated to about 40 lb/ft² (1.9 kPa) gauge pressure, the air form can support the weight of workers and the reinforcing steel and concrete they are putting in place.

A hoop of reinforcing bar is placed on top of the form (Fig. 2), and vertical reinforcing bars are attached on all sides of the form; then additional horizontal hoops are placed. Wood framing is erected where doors or windows are needed (Fig. 3), and extra reinforcing bars are placed around these future openings.

When all the reinforcing steel is in place, workers apply a 1 in. (25 mm) layer of shotcrete, followed by additional layers after the first has hardened. Total thickness may be as little as 3 in. (75 mm). If shotcrete equipment is not available, the concrete may be plastered or troweled on. Air pressure is maintained inside the form until the concrete gains enough strength to be self-supporting. The form can then be deflated and removed to be used for another shell. With careful handling, as many as 100 uses are possible.

Workers can then enter the dome and remove any loose concrete. This leaves some of the reinforcing steel exposed on the interior. After wire brushing to remove



Fig. 4: Panoramic view of New Ngelepen construction shows several homes in various stages (from the left): A dome with the shotcrete hardened, a dome with most of the concrete applied and the crew still working at the top, an air form being inflated, a dome with the concrete completed and in the process of curing, and a fully inflated form with much of the reinforcement in place



Fig. 3: A wood-framed window opening braced in place before placing concrete. Additional reinforcement will be placed around this and other openings in the dome

any loose material, workers apply another layer of shotcrete 1/2 to 3/4 in. (15 to 20 mm) thick to cover it. The exterior of the concrete shell is smoothed and coated with cement slurry to help seal the concrete before painting to reflect the sun's rays (Fig. 4).

STRUCTURAL EFFICIENCY OF THE DOME SHELL

Typically built without insulation, thin concrete shells are ideal for areas with high summer and moderate winter temperatures, as in many developing countries. These shells make strong dwellings that are resistant to fire, wind storms, earthquakes, and termites. They are constructed using widely available concrete and reinforcing bar, with limited specialized tools; workers quickly learn the skills required to build them. Reuse of the form is an important key to economy of the process.

The shell structures can be built by local labor at a fraction of the cost of comparable structures built by more conventional methods. By making the most of the structural advantages inherent in a thin shell, the actual volume of concrete is small—far less than used in a



Want to connect with thousands of other ACI Members?

Join one or both of the ACI Facebook or LinkedIn groups today and start networking with thousands of other concrete professionals, receive special ACI announcements, and participate in technical discussions.

To join, simply visit ACI's Web site at www.concrete.org, and click on the Facebook and LinkedIn links.



Find us on
Facebook

LinkedIn



American Concrete Institute®
Advancing concrete knowledge

TABLE 1:**MATERIAL QUANTITIES REQUIRED FOR CONSTRUCTION OF A THIN CONCRETE DOME VERSUS A RECTANGULAR STRUCTURE¹**

Structure	Size	Floor area, ft ² (m ²)	Interior volume, ft ³ (m ³)	Required materials	
				Concrete, yd ³ (m ³)	Reinforcing steel, lb (kg)
Dome	20 ft x 11 ft high (6.1 m x 3.4 m high)	314 (29.2)	2408 (68.2)	8 (6.1)	1250 (567)
Rectangular	18 x 18 x 8 ft (5.5 x 5.5 x 2.4 m)	324 (30.1)	2592 (73.4)	23 (17.6)	4900 (2220)
Dome	30 ft x 13 ft high (9.1 m x 4.0 m high)	707 (65.7)	5744 (162.7)	24 (18.3)	2500 (1130)
Rectangular	24 x 30 x 8 ft (7.3 x 9.1 x 2.4 m)	720 (66.9)	5760 (163.1)	43 (32.9)	9200 (4170)
Dome	40 ft x 16 ft high (12.2 m x 4.9 m high)	1257 (116.8)	12,197 (345.4)	30 (22.9)	4200 (1910)
Rectangular	24 x 52 x 8 ft (7.3 x 15.8 x 2.4 m)	1248 (115.9)	9964 (282.1)	69 (52.8)	13,300 (6030)

rectangular concrete building of the same floor area, as shown in Table 1.

According to one United Nations study, an average family habitation in a developing country should be about 300 ft² (28 m²). A shell 20 ft (6.1 m) in diameter and 11 ft (3.4 m) high at the center provides 314 ft² (29.2 m²) of living area. This shell, including both foundation and dome superstructure, requires less than 8 yd³ (6.1 m³) of concrete and about 1250 lb (567 kg) of reinforcing

steel. A rectangular concrete structure of comparable volume and floor area would require more than twice these amounts.

References

1. South, R., and South, A., "Final Report: New Ngelepen Yogyakarta, Indonesia," June 5, 2007. (available at www.dftw.org)
2. Hurd, M.K., "Low-Cost Concrete Storage Buildings," *Concrete Construction*, V. 42, No. 12, Dec. 1997, pp. 991-995.
3. South, D.B., "Ecoshell 1," second edition, F. Parker, ed., Monolithic Dome Institute, Italy, TX, 2007, 33 pp. (available at <http://static.monolithic.com/pdfs/ecoshell.pdf>)

Selected for reader interest by the editors.

HELP FOR THE HOMELESS

Established in 2006, Domes for the World Foundation (DFTW) is registered as a nonprofit 501(c)(3) corporation with federal tax-exempt status. As stated in Reference 3, its mission is "to initiate and coordinate efforts to alleviate housing shortages in struggling cultures and impoverished lands" (www.dftw.org). Since completion of the 71-home village described in this article, continuing contributions have enabled DFTW to continue building one or two dome homes per month in New Ngelepen.

Another organization with similar purposes is Domes for Homes (D4H) whose application for 501(c)(3) status is pending. D4H has started a rebuilding project, JAVA2, that will use inflated forms to build durable homes for 23 more Indonesian families in need (www.domesforhomes.org).



ACI Honorary Member **M.K. Hurd** is a member of ACI Committees 124, Concrete Aesthetics, and 347, Formwork for Concrete. She has received numerous awards for her service and contributions to ACI, including the ACI Construction Award (1982 and 1988), the Delmar L. Bloem Award for Distinguished Service (1990 and 2006), and the Henry C. Turner Medal (1995). She

is the author of seven editions of ACI SP-4, *Formwork for Concrete*. In 2004, she received the Marston Medal, the highest award bestowed by the College of Engineering at Iowa State University.