

Intermediate Shelters in Bam and Permanent Shelter Reconstruction in Villages Following the 2003 Bam, Iran, Earthquake

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The earthquake of 26 December 2003 destroyed about 85% of the housing stock and left up to 75,600 people in the city of Bam homeless. With the convergence of migrants from nearby villages, it is estimated that 155,000 people were in need of shelter in Bam and surrounding villages. A municipal governmental Master Plan for the reconstruction of Bam was completed in September 2004. Permanent housing construction in the city of Bam began in October 2004, and is scheduled to take three to five years. In the interim, intermediate shelter construction in Bam and reconstruction of permanent shelter in the surrounding villages is ongoing and work is being done to integrate relief operations into long-term recovery, rehabilitation, and reconstruction programs. At the time of the reconnaissance trip in late May 2004, 16,200 intermediate shelters were assembled in Bam, either on the sites of original dwellings or on campgrounds on the outskirts of the city, and over 2,500 permanent shelters were constructed in the surrounding villages. [DOI: 10.1193/1.2098907]

INTRODUCTION

The Iranian government is providing shelter for the earthquake-affected communities in the urban areas of Bam in three stages: (1) temporary tent shelters in urban areas that are located either on the sites of original dwellings or in campgrounds in the outskirts of the city; (2) intermediate or semi-permanent shelters (structures built out of prefabricated components) that can be erected in a short time and are either built on original plots or in the campgrounds on the outskirts of the city; and (3) permanent houses in the urban areas as laid out in the Master Plan, which was adopted in September 2004. Permanent housing construction in the urban areas is being implemented through the Housing Bazaar. In the rural areas surrounding Bam, intermediate shelters will not be constructed; instead permanent shelters are being constructed in over 92 villages pursuant to the village Master Plans. The affected population, number of destroyed houses, and the planned number of intermediate or new village houses are listed in Table 1.

Early estimates put the cost of reconstruction at U.S. \$1.5 billion (IFRC 2004a). On

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Table 1. The affected population, destroyed houses, and number of shelter units built to date

	Total affected population	Total homeless population	Buildings destroyed	Shelter units constructed		Shelter units occupied in camps
				in place	in camps	
Bam	92,000	75,600	25,000	26,900	9,005	5905
Villages	48,000	Unknown	24,000	2,500 ⁺		n/a

October 28, 2004, the World Bank approved the five-year Bam Earthquake Emergency Reconstruction Project (BEERP), which consists of a U.S. \$220 million loan from the International Bank for Reconstruction and Development and a U.S. \$15 million contribution from the government of Iran. Eighty percent (U.S. \$180 million) of the project budget will be allocated for housing and commercial building reconstruction. The BEERP will finance the procurement of: construction material (steel bars, steel components for frames, and Portland cement) for housing and commercial buildings; construction equipment; and design and supervision activities (World Bank 2004). Although early estimates from Iranian authorities indicated that reconstruction could take as little as 18–24 months, it is now anticipated that the project will take 3–5 years. Thus, the intermediate shelters are being used to provide a more secure and climatically suitable living environment during the reconstruction. The Housing Foundation, the Iranian quasi-government unit charged with rural development and post-disaster reconstruction since the Islamic Revolution, is offering a U.S. \$1,500 grant and U.S. \$4,000 low interest, 15-year loan to rural residents with collapsed houses. The progress of reconstruction is shown in Table 2.

INTERMEDIATE SHELTER CONSTRUCTION IN BAM

During the reconnaissance trip in late May 2004, five months after the earthquake, more than half of Bam's estimated 75,600 displaced and homeless populations were still living in tents (IFRC 2004d). At the insistence of residents, the majority of these tents were placed on private property near homes that were destroyed or located on streets

Table 2. Physical progress of reconstruction as of October 31, 2004 (Hawaii 2004)

Stage of work	No. houses in bam city	No. houses in villages
Site layout	527	16,493
Excavation	464	16,031
Foundation concrete	242	12,122
Steel superstructure	155	5,048
Wall masonry	40	2,145
Roof	24	1,204
Finishing	1	80



Figure 1. Tents placed near homes.

adjacent to former dwellings (Figure 1). Others had moved into tents erected in congregate camps established early in the emergency operation, most of which had been provided by the Iranian Red Crescent Society. Tent camps are being used mainly to house former renters and migrants from nearby villages. The tents are very small (Figure 1), and while some are equipped with air conditioners, most have no capacity for cooling. Conditions were particularly difficult for people still in tents because of the mounting summer heat and desert sandstorms. The sandstorms have caused frequent disruptions to the electricity supply and are wearing away the tents. No additional tent camps were planned because the focus was being placed on intermediate shelter.

Intermediate shelter construction initially took place by erecting units from prefabricated components in camps, mainly on the eastern outskirts of the city (Figure 2). To date, 9,005 intermediate shelter units have been assembled in 23 camps and although all of these units are now completed, the government is having trouble filling the camps and 3,100 units remain vacant (Ashtiany 2004). The primary reason for the lack of transition from tents to intermediate shelter camps was the reluctance of the people of Bam to relocate to compounds that were judged to be too remote from the city center, their farms, or their neighborhoods. About 25% of Bam residents are farmers and want to stay close to their plots to resume farming. Furthermore, many feared that they might lose their land if they relocated to the camps on the outskirts of the city. Consequently, while the original proposal called for the building of intermediate shelters in camps, the effort was redirected to construct prefabricated units on the site of the original plots of land (Figure 3). It is now estimated that two-thirds of the intermediate houses are constructed on privately owned lots and about one-third of the units will be in camps. The camps visited



Figure 2. Intermediate shelter construction on the outskirts of the city (photo from Rashestan Co.).



Figure 3. Intermediate shelters located on private property.

Table 3. Intermediate shelter assistance for earthquake victims (Ashtiany 2004)

Contractors and Donors	Units in camps	Units in place	Total units
Housing Foundation	1,188	7,100	8,288
IRI Defense Ministry	4,310	0	4,310
Government of Turkey	800	0	800
Islamic Relief of London	400	0	400
World Relief	207	0	207
Private Contractors	2,100	19,800	21,900
Total	9,005	26,900	35,905

during the reconnaissance were occupied by a mix of former renters from Bam, traffic policemen, injured or disabled war veterans, construction laborers from the villages, reconstruction workers (such as truck drivers) from other parts of Iran, and migrants from rural areas. Although the original plan was that everyone living in a tent would have moved into intermediate shelters by the end of April, completion of the intermediate shelters has taken more time than anticipated.

DESIGN, COST, AND CONSTRUCTION

Initial construction in campgrounds began as early as February 2004, using funds from the Iranian government and international donors. However, the main phase of intermediate shelter construction occurred only toward the end of May. A four-month period saw 76,000 square meters of shelter built (Ashtiany 2004). The Iranian government delegated responsibility for intermediate shelters to the Housing Foundation and the Ministry of Defense. These agencies were either directly involved in the construction or hired contractors and labor to carry out the construction (Table 3). For example, Rashedan Company, a Tehran-based supplier of modern prefabricated building systems, was employed by the Housing Foundation to build 5,025 intermediate shelters (Toutounchian 2004). International donors also contributed to the intermediate shelter construction. For example, the Turkish government, in partnership with the International Blue Crescent (IBC), provided 800 container houses in four camps. World Relief and Islamic Relief of London also contributed 207 and 400 intermediate shelter units in camps, respectively. By the end of May, 16,200 prefabricated shelters were ordered by Iranian authorities, of which about 8,000 were being constructed by the Housing Foundation through private contractors. At the present time, a total of 35,905 intermediate shelter units have been constructed in Bam, of which 26,900 are built on private property and 9,005 in campgrounds on the outskirts of Bam. Additionally, there are plans to build 4,000 shelter units on private property (Ashtiany 2004).

The intermediate shelters built from prefabricated components typically consist of a single room of 16–20 square meters (generally 3 m × 6 m or 4 m × 4 m in plan), which costs about \$2,500–\$3000 to build (Figure 3), or multiple room, multiple-family duplex or triplex type structures (Figures 2 and 4). Because different materials suppliers and contractors were involved in the construction, there was some variation in the materials



Figure 4. Intermediate shelters in camps later finished with plaster on the inside and outside (photo by R. Langenbach).

used. The structural system for one type of intermediate shelter encountered during the field visit consisted of steel struts and roof joists with welded connections (Figure 3). The building rests on a 6-cm-thick concrete slab, with the steel struts welded to a steel strip that is embedded in the slab. The interior walls are covered with drywall that is bolted to the steel struts. The exterior and roof are covered with galvanized iron sheets. Another shelter visited during the field reconnaissance employed a bolted steel frame with ceramic block masonry infill (Figure 4), similar to the permanent structures being built in the villages and described later in this chapter. The intermediate structures were finished with plaster on the inside and outside.

SUPPORT OF BASIC INFRASTRUCTURE

Nearly 20,000 people in Bam are being supplied with water in temporary and intermediate camps. Multilateral donor agencies and NGOs are providing technical and material support (pipes, pumps, chlorination equipment, water testing equipment, and consumables) and are working with the authorities to ensure that the water distribution system reaches the planned sites for the prefabricated housing units procured by the government (UN OCHA 2004). Planning for water supply to many of the camps was underway and, in some cases, implementation was taking place.

Although most of the shelter camps have electricity and running water, sanitary units (showers and latrines) were still lacking for many of the camps during the reconnaissance trip. For tents or prefabricated units erected on the sites of the original dwellings, showers and latrines were for the most part non-existent during the reconnaissance visit,

Table 4. Number of sanitary units installed for intermediate shelters in camps and on private property (Ashtiany 2004)

Contractor	Units Planned for	Units Completed
Housing Foundation	7,000	5,700
Defense Ministry	5,600	4,300
Private Contractors	700	700
Kerman Municipality	2,000	1,500
Nongovernmental Organizations	8,500	5,000
Total	23,800	17,200

and people were using the existing facilities of nearby schools. In most camps where sanitary units were set up, they were located outside the prefabricated units as separate, temporary, single-stall toilets and showers. In some instances, the shower and latrine facilities were inside the prefabricated units, in which case the shower was usually in the stall, using the toilet for a drain. Some camps only had communal facilities consisting of groups of stalls joined together. As a result of a gradual decrease in support from the other provinces responsible for the environmental health of the camps in the aftermath of the earthquake, waste management has become a problem. The removal of wastewater, which is the responsibility of the Bam Task Force, has also been a cause for concern. The stagnant water and drainage was attracting numerous flies and insects and extensive insecticide spray activity was in process.

Multilateral donor agencies, such as UNICEF, are distributing dustbins, disposable garbage bags, squatting plates, and latrine slabs, while the Iranian authorities and international nonprofits continue to concentrate their efforts on providing more permanent facilities. Construction of sanitary units for intermediate shelters in camps and on private properties is summarized in Table 4. The number of units in four of the largest intermediate shelter camps, where 7,500 people reside, for which water and sanitation provisions are either being planned or implemented as of early June 2004, are shown in Table 5. In some cases, efforts to provide reticulation systems in the intermediate shelter

Table 5. Status of construction of sanitary facilities, reticulation systems, and water supply in four major camps serving 7,500 people (IFRC 2004c)

Camp	Agency	Units serviced/ Status as of June 2004	Service Provided
Golestan	Federation and PNS	178 completed, 250 pending, 92 by the end of July	Water supply and reticulation system
Rashestan	French/Spanish/Swiss Red Cross with IRCS	2,500 in final stage of planning 1,500 to be completed by July 2004	Water supply Sanitary facilities
Wahad	Swiss Red Cross	300 units to be connected in planning	Reticulation system
Sina	Swiss Red Cross	500 to be completed by end of July	Reticulation system

camps have been faced with delays due to unforeseen problems with the very hard clay soil, which has made trenching virtually impossible (IFRC 2004b).

SOCIAL, EDUCATIONAL, AND HEALTH SERVICES IN INTERMEDIATE SHELTER CAMPS

There are six active intermediate shelter camps in Bam providing a wide range of services and a number of less populated or smaller camps in which minimal services are provided. Besides the various temporary schools throughout Bam, schools in each of the two largest shelter camps have been built and staffed by Relief International. A few of the larger intermediate shelter camps are equipped with health clinics. These clinics provide basic health services; more serious cases are transferred to one of the Bam or Kerman hospitals. In addition to health services, local and international nongovernmental organizations (NGOs), as well as participating national societies (PNS), are providing social services in the camps. Some of these activities include Children's Social Centers, where psychologists coordinate psycho-social intervention activities and teachers work with children in the camps. Many of the camps have child care centers and nurseries run by groups such as the Society for Protecting Rights of the Child (SPRC). Community educational and cultural centers, such as libraries and computer/internet centers, have been built adjacent to the largest camps, which are also utilized by the greater community. In addition, two large tents with concrete flooring and air conditioning, each with a capacity to serve 200 people, were set up by Relief International as a community center. Among other activities, one center is used as a cinema with one nightly film screening, and the other is used as a Women's Center to train women in computer skills (Relief International 2004).

ISSUES IN INTERMEDIATE SHELTER CONSTRUCTION

Climatic Requirements

While the intermediate shelters produced from prefabricated components can be constructed quickly, require little maintenance, and exhibit a lightweight, earthquake-resistant design, they are poorly adapted to the hot, arid desert climate of Bam. To compensate for this shortcoming, air conditioners have been provided or were being planned for most of the intermediate shelter occupants by the Housing Foundation. Also, the intermediate shelters lack an extended overhang or lintels over the windows. Most intermediate shelter camps have no tall trees; the lack of shade in the intermediate shelter camps creates very unfavorable conditions given the extreme desert temperatures (Figure 5). Shelters on private property allow for better living conditions, largely because they are built within gardens where tall trees provide cool shade in the morning and evening (Figure 6).

Cultural Requirements

Intermediate prefabricated shelters and camp layouts have been constructed without adequate consideration of cultural requirements. For example, many people were dissatisfied with the latrines being located inside the shelter units as they are used to having their dwelling separated from the sanitary facilities. Concerns have also been expressed



Figure 5. Lack of shade in intermediate shelter camps creating very unfavorable conditions.



Figure 6. Many shelters on private property are built in areas where tall trees provide cool shade. Here the shelter footprint has been increased by combining two units.



Figure 7. Makeshift curtains separate adjacent units from each other to provide some privacy.

regarding the congregate toilet/shower facilities, both because women may be reluctant to use them owing to modesty concerns, and because no funds have been allocated to maintain the facilities. In some cases, modifications to the existing designs have been made to fit with the traditional way of life. Extensions to the shelter units in the camps that are adjacent to each other can be seen where people have drawn curtains separating their units from the neighbors to provide privacy (Figure 7). Improvements were also made to the prefabricated units built on private property to be consistent with typical dwellings in Bam, where traditionally several families live under one roof. In some cases, where families took the initiative by contributing some of their own funds, it has been possible to increase the footprint size and create a more suitable living space by combining two intermediate shelters allocated to them (Figure 6).

Property Rights

To minimize ownerships disputes, the government of Iran is preparing legislation that will forbid the buying and selling of land in Bam during the later reconstruction phase. In-situ construction of intermediate shelter was granted to individuals who were able to demonstrate legal ownership of property. It is uncertain to what extent land and property ownership records have been systemized to avoid competing claims during the reconstruction process. Property inheritance follows the Islamic inheritance law, regardless of whether or not the heir is local. During the reconnaissance visit, it appeared that there have not been any disputes with inheritance issues. While it is stipulated that if

there is no heir, the unclaimed property would revert to the government after a court proceeding, it is unclear if there has been any unclaimed land to date and, if so, what has happened to it.

Debris Removal

The shelter sector reconstruction problem in Bam is exacerbated by the continuing presence of thousands of tons of rubble in the city. In many parts of the city, especially those where entire streets were destroyed, the debris was still meters deep at the time of the site visit. A report by the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA 2004) estimated about 12 million metric tons of debris needed to be removed in the aftermath of the earthquake. While some of the debris had been removed, salvaged, and recycled, due to a shortage of heavy machinery and lack of coordination, rubble removal was progressing slowly at the time of the site visit. In cases where people took the removal of rubble into their own hands, no concerted effort was made to unload the rubble into a designated dump site, leading to the creation of scores of rubble piles across the desert on the outskirts of the city. During the site visit, a campaign was initiated by the Housing Foundation to coordinate the rubble removal, whereby banners requesting the owners' cooperation were widely distributed throughout the city. Owners must be present at the site when the debris is removed to identify and claim any valuable belongings.

Site Selection

In several cases, it was observed that prefabricated units were built on private property, using the footprint of the original houses. While this allowed for faster shelter construction due to the available level ground, this may create future problems when the best sites are not available during the permanent reconstruction.

Long-Term Use Of Intermediate Shelter

As demonstrated in the aftermath of the devastating earthquakes in Armenia in 1988, Turkey in 1999, and India in 2001, intermediate structures often continue to be occupied indefinitely by renters and migrants who are not landowners. The issues that must be carefully examined with people living in such "semi-permanent" structures include what happens to the inhabitants once the services provided to the camps are discontinued, and whether or not these structures are adequately earthquake-resistant, especially if they are expanded upon. As most of the inhabitants in the intermediate shelter camps are renters in Bam or migrants from the villages, there is also a question of permanent housing for this group. The Housing Foundation is in the process of building a 5,000-unit apartment building for renters and migrants on the outskirts of the city to address this issue (Ash-tiany 2004).

PERMANENT RECONSTRUCTION IN VILLAGES

More than 24,000 dwellings were destroyed in rural areas during the 26 December 2003 Bam earthquake (UN OCHA 2004). The Housing Foundation estimates that 25,022 houses will be rebuilt in rural areas and 7,378 will be repaired (Hawaii 2004).



Figure 8. An 18 m² steel frame structure, concrete being mixed by hand.

Rural residents who have not received assistance from a nonprofit organization are eligible for a U.S. \$1,500 grant and U.S. \$4,000 low-interest, 15-year loan to rebuild their house. Reconstruction was well underway at the time of the site visit in late May and early June 2004. Master Plans for at least 92 villages had been completed as of October 2004. Status of the reconstruction at the time of this writing is listed in Table 2.

DESIGN, COST, AND CONSTRUCTION

Design

The design for the new rural dwellings built through the reconstruction program was provided to builders and nonprofit organizations by the Housing Foundation. Any deviation from the design required the Housing Foundation's advance approval.

Three different floor plans were observed in various stages of construction:

- An 18m² single-room, steel frame masonry infill structure with an inclined roof, considered an intermediate shelter suitable for a family of 3, or fewer (Figures 8 and 9).
- A 43m² single-room, steel frame masonry infill structure with a flat roof and two doors, considered permanent and suitable for a family of 4, or fewer (Figure 10).
- A 60m² three-room, steel-braced, frame masonry infill structure with a flat roof, considered permanent and suitable for a family of 5 to 7 (Figure 11).

The foundation supporting the 18m² structure (Figure 8) consists of a shallow strip footing of burned brick masonry in cement mortar. The steel channel sections that form



Figure 9. An 18 m² structure with air entrained ceramic hollow block infill.

the superstructure are doveled into the strip footing, and the steel beam at the plinth level is encased in hand-mixed concrete. No bracing is present. Both welded and bolted connections were observed (Figure 12).

A similar strip foundation is used for the 43m² structures, which are also steel frames with bolted connections (Figure 10). Diagonal tension rods are connected to the roof (Figures 13 and 14). The roof consists of a sheet of Styrofoam hooked to welded wire mesh (Figure 14), and covered with 1–2 inches of screed.

The 60m² structures are supported by reinforced concrete (RC) shallow spread footings with grade beams (Figure 15). The square footings are 55 cm deep and 130 cm wide at the base of the excavation (Hawaii and Hosseini 2004). The excavations for the grade beams are 35 cm deep and 40 cm wide. Design drawings for the 60m² structures



Figure 10. A 43 m² steel frame structure with solid fired-brick masonry infill.



Figure 11. A 60 m² steel frame structure with inverted V-type Chevron bracing.



Figure 12. Air entrained ceramic hollow block infill in welded steel frame 18 m² structure.



Figure 13. Bolted connections and tension rods on 43 m² structure.



Figure 14. Styrofoam hooked to welded wire mesh covering roof of 43 m² structure.



Figure 15. Steel reinforcement in spread footing, 60 m² structure.



Figure 16. Steel columns bolted to reinforced concrete column starter, diagonal brace bolted to gusset plate.

are available in Hawaii and Hosseini (2004). The steel columns in the superstructure are bolted to the RC column starter (Figure 16), and inverted V-type chevron braces, present in four of the eight bays, are bolted to gusset plates (Figure 11).

In all houses, the steel frames are infilled with masonry in cement mortar, in which the masonry unit in the houses surveyed was either solid fired brick (Figures 10 and 17) or a lightweight, hollow air entrained ceramic block (Figures 9 and 12). The design drawings provided by the Housing Foundation recommend the use of English bond with 90-cm-long, 8-mm-diameter, shear connectors placed every three courses (Hawaii and Hosseini 2004).

Materials

The structural steel components and steel rebar for the foundations were manufactured by certified factories in Isfahan and Tehran, located 860 km and 1,260 km from Bam, respectively. Portland cement is available on the local market, but the cost and quality varies; with some brands, a higher cement to sand/aggregate ratio is necessary to achieve the same strength. At least eight concrete batch plants are located in and around Bam, including a privately owned plant in Arg-E-Jadid, the industrial center 30 km southeast of the city. Plants operated by the Housing Foundation offer concrete at subsidized prices, reportedly as much as half the cost of privately owned plants. Prior to the earthquake, local kiln-fired bricks were common; however, they are being replaced by



Figure 17. Solid fired-brick infill hooked to steel column, note orientation of bricks.

hollow ceramic blocks trucked from Kerman or Yazd (200 km and 560 km from Bam). One local oil-fired brick kiln visited during the reconnaissance has ceased to operate as a result of the earthquake.

Construction and Supervision

According to nonprofit organizations, contractors and site foremen from Tehran, Kerman, and Azerbayejan are building the houses. Skilled and unskilled workers come from local areas as well as other provinces. Local unskilled labor has been used to dig foundations when time was not critical. Some women have participated in site excavation. Except for on-the-job supervision, no training or capacity-building efforts were reported by any of the organizations interviewed. Construction supervision and enforcement are provided by the Housing Foundation.

ROLE OF INTERNATIONAL NONPROFITS AND MULTILATERAL DONOR AGENCIES

At least seven international nonprofit organizations and multilateral donors were taking part, or planning to take part, in reconstruction of permanent shelters in the villages. The organization name and the number, location, and cost of houses planned are listed in Table 6.

Caritas Netherlands, Medair, Relief International, and World Vision are following the design guidelines provided by the Housing Foundation and building (or planning to build) steel-frame structures, as described previously. Medair, Relief International, and

Table 6. International nonprofits and multilateral donors building houses in villages around Bam

Organization	Number and Location of Houses Completed or Planned	Status (June 2004)	Cost
Caritas Netherlands/Cordaid/Trocaire	300 total in Tahmik, Nartije Zaidabad, Cheltok	Underway	7000–8000 Euros for 60 m ² house
Caritas Switzerland/Trocaire	265 in Baghchamak	Underway	U.S. \$10,000 for 60 m ² house
	135 in Pakam		
	33 in Gavmurdeh		
Habitat for Humanity International	Assessment team visited Bam in June 2004	Planning stage	
Medair	35 in Sarjungle	Underway	
Relief International	780 in Esphekan and Poshtrood	Completing 7–10 per day	
UN-HABITAT and UNDP	50 model houses for widows, disabled	Identifying beneficiaries	50 for \$400,000
World Vision	135 in Kork	72 excavated, 50 foundations poured, 26 steel frames as of 9/2004	U.S. \$3,733 per 60 m ² house
	90 in Amir Abad	82 plots allocated, 68 excavated, 59 foundations ready for steel as of 9/2004	U.S. \$4,654 per 60-m ² house

World Vision are building the foundation, steel frame, and ceiling only; they are not providing the masonry infill. Beneficiaries will finish construction with assistance and supervision of the Housing Foundation. Several reasons were mentioned for omitting the masonry infill, including: (1) limitations on donor funds and a desire to reach more beneficiaries with a minimum skeleton structure; (2) the view that beneficiary participation in the housing construction process is positive because it builds character; (3) the Housing Foundation has restricted the nonprofits from doing so. Caritas Netherlands/Cordaid is the only nonprofit providing the masonry infill (without plastering) free-of-charge to the homeowner. Caritas Switzerland was granted permission to build reinforced concrete structures.

Table 6 indicates that approximately 1,800 houses are being built by international nonprofit organizations and multilateral donors. Organizations currently in the process of building houses are unlikely to expand their programs for several reasons: (1) lack of funding; (2) for U.S.-based nonprofits, expiration of their license from the Office of Foreign Assets Control of the U.S. Treasury Department; or (3) non-renewal of permits or contracts by Iranian government officials. Consequently, the majority of the houses in rural areas are being constructed by the beneficiaries with oversight and assistance of the Housing Foundation.

MATERIAL SUPPLY AND COST

Shortages in materials, particularly concrete and steel, have slowed the completion of the houses in the villages. Medair reports delays of up to three weeks for structural steel (IRINNEWS 2004). Several concrete batch plants are providing concrete to the village sites; however, some of the plants are located at least 40 minutes from the nearest village. Given that concrete has a 1.5-hour useful life and it can take up to 30 minutes to pour, there is very little time to accommodate traffic and construction delays.

Sharp increases in the cost of steel and concrete have resulted in a reduction in the number of houses planned by some of the international nonprofit organizations. Relief International has had to cut back on the number of shelter units they were going to complete from 1,060 to 780, mainly due to an increase in the price of steel and cement and the increase in the number of shelter units of 60 square meters.

MATERIALS QUALITY

The decision to substitute bolted connections in the steel frames for on-site welding was largely a result of the lack of skilled welders in Bam and surrounding villages. Welding was done at certified factories where quality is easier to control. However, Medair staff reported quality-control issues among the prefabricated steel frames, some of which were rejected by the Housing Foundation's inspectors in Bam (Reitkert 2004).

According to nonprofit organizations working in the villages, concrete testing is regularly done, and independent inspectors, as well as those from the Housing Foundation, periodically visit the building sites. However, one reinforced concrete foundation located in Poshrood village had cracks in the concrete at spacing consistent with the stir-rup intervals, indicating insufficient cover or improper curing of the concrete (Figure 18).

AVAILABILITY OF QUALIFIED CONTRACTORS AND SKILLED LABOR

Several nonprofit organizations reported difficulties in finding qualified building contractors (Caritas 2004). In Kork village, World Vision had initially used one contractor to build the entire house, but due to delays and poor quality of construction, decided instead to assign individual subcontractors for each component, e.g., excavation and foundation, erecting steel frames, roofing (Frost 2004).

MASONRY INFILL CONSTRUCTION

The quality of the masonry infill in the houses surveyed varied. This is especially problematic for the 18m² and 43m² structures, in which the lateral load-resisting system relies in part on the shear capacity of the infill. Also, this is of particular concern for the houses built by nonprofit organizations, for which the construction of the masonry infill is left up to the homeowners themselves, and training and capacity-building programs for masons were beyond the scope of the programs led by nonprofits.

Several deficiencies were noted in the solid fired-brick masonry infill for a 43m² house in Esphekan village. As shown in Figure 17, all bricks are oriented perpendicular to the plane of the wall, while design drawings recommend English bond; the bond used

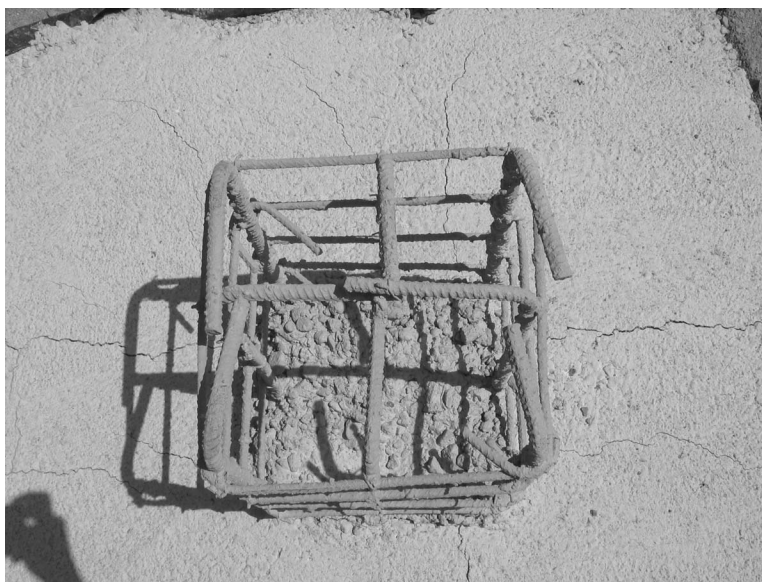


Figure 18. Cracks in reinforced concrete foundation for 60 m² structure.

results in an undesirable continuous vertical joint. Head (vertical) joints are not completely filled with mortar, and bed (horizontal) joints are thicker than common practice. Steel shear connectors are placed every six courses, instead of every three, as recommended by the design drawings. Also, the hooks do not extend into the brickwork for the full 90 cm, as recommended in the design drawings. Floor-to-ceiling doorways in all three panels in the short direction of the buildings result in a significant difference in stiffness in the two orthogonal directions (Figure 10).

Deficiencies were also noted in the hollow ceramic block masonry infill for a house in Poshtrood village. The bond is inconsistent, with the blocks laid flat on the short walls and on end in the long walls. No mortar is present in the head joints. Gaps are present between the masonry panel and the steel frame. The only effort to restrain the walls against out-of-plane failure is a spot-welded diagonal rod on the interior of one end panel (Figure 19). Two different masonry units are used ceramic hollow blocks for the majority of the wall and solid bricks at the top of the walls and around the window frames (Figure 12).

It should be noted that, following the field reconnaissance, the deficiencies in infill construction and the poor quality of the concrete in the foundation was brought to the attention of the Housing Foundation, which pledged to take immediate action to improve the quality of the construction.

Caritas Netherlands (Cordaid) is the only nonprofit that is constructing masonry infill, as well as the foundation and steel frame. They use ceramic hollow blocks laid on



Figure 19. Diagonal restraint in 18 m² structure with hollow ceramic block infill.

their sides and at a slight outward angle so that walls will fall outwards if they collapse. Cordaid does not provide the shear connectors as recommended in the design guideline, but instead they add a wire mesh on the inside.

APPROPRIATE DESIGN

In selecting the design and materials for housing reconstruction in Bam and the surrounding villages, the Housing Foundation was proactive in attempting to satisfy a list of criteria, including earthquake resistance, environmental and architectural suitability, durability, and low cost. The 60m² braced steel frame structure, if built properly, will likely provide sufficient resistance to earthquakes. Likewise, exchanging the heavy earth and brick roofs used prior to the earthquake with lightweight Styrofoam and screed roofs is a positive change in terms of earthquake resistance. However, the lightweight building materials are less appropriate for the climate, which is one of intense heat in the summer and cold nights in the winter. Also, environmental suitability concerns, such as planning for flood zones or site characterization issues, were not always satisfied, as can be demonstrated by one house situated directly on the bank of a stream (Figure 20), which may present flooding and differential settlement hazards.

In addition, it was reported that village residents were accustomed to houses with larger floor plans, on the order of 120 to 150m². There is some concern that residents will reject the smaller floor plans of the houses built by nonprofit organizations. In addition, there is no provision for vertical or horizontal extension in the rural houses. An alternative viewpoint was present among the younger segment of the population, who preferred multiple smaller houses. Regardless of the preference for one large house or



Figure 20. 43 m² house located on a stream bank.

several smaller units, should the homeowner choose to extend or build a second house, it is unclear whether the materials used in the rural reconstruction (e.g., braced steel frames) will be available on the local market at an affordable price after the reconstruction program is finished. Lastly, given the substantial reliance on contractors and builders from other parts of Iran, it is not clear if rural homebuilders will continue to have access to construction personnel who are capable of building quality, earthquake-resistant structures in the future.

CONCLUSIONS

The observations presented in this chapter were based on a six-day field visit to Bam and four additional days of meetings in Tehran. Fact-finding meetings were conducted with many organizations, including the International Institute of Earthquake Engineering and Seismology (IIEES), U.N.-affiliated organizations, national-level entities concerned with loss reduction and disaster response and recovery, international nongovernmental organizations (NGOs), local NGOs in Bam, city and provincial government officials and agencies, health care and mental health care professionals, builders, masons, homeowners, and tenants. A comprehensive study of all of the intermediate shelter camps and the houses under construction in rural areas was not done. However, issues raised here may be representative of larger problems and warrant further study.

The principal findings of this study on intermediate shelter construction and reconstruction of permanent housing in the villages are as follows:

1. To date, 75% (26,900) of the intermediate shelters in Bam are constructed on

- private property and only 9,005 intermediate shelter units, of which 3,100 units remain vacant, have been assembled on campgrounds.
2. The authorities have been forced to recognize the reluctance of people to move into the shelters on the outskirts of the city and have revised their plans accordingly, working with NGOs and U.N. communities to provide basic infrastructure and services throughout the town, rather than just the prefabricated camps.
 3. The main phase of intermediate shelter construction in Bam took place in a four-month period starting at the end of May 2004. Delays with completion of intermediate shelters are reportedly due to the change in plan from building intermediate shelter camps to assembling the units on private properties, large volumes of rubble still present on properties, delays with paying the contractors, and environmental conditions such as sandstorms, which can halt construction work for several hours at a time.
 4. Intermediate shelters can be constructed quickly, require little maintenance and exhibit a lightweight, earthquake-resistant design; however, they are poorly adapted to the hot, arid desert climate of Bam. Moreover, the campgrounds lack adequate shade and, in some cases, do not adequately consider cultural requirements.
 5. More than 25,000 houses will be rebuilt in rural areas outside Bam. The structures are 18m², 43m², or 60m² in plan and are primarily steel frame with masonry infill.
 6. Most of the materials and skilled labor are imported from other parts of Iran. Cost and quality of materials and labor have fluctuated.
 7. International nonprofit organizations are funding and facilitating the construction of approximately 1,800 houses; most are building the foundation, steel skeleton, and roof only.
 8. Deficiencies in masonry infill and reinforced concrete foundations were observed. The breadth of these problems is not known, as only a few houses were surveyed early in the reconstruction process.

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