Armenia struggles to rebuild

A forest of cranes strain skyward from the rugged, rock-cropped highlands and valleys of Soviet Armenia. Beneath them, some 25,000 workers from throughout the Soviet Union dart between the long shadows that fall on the remains of four cities devastated in the December 1988 earthquake that shook the small southern Caucasus republic.

Their directive—which will cost 15 billion rubles, or $24 billion at official exchange rates—is to build 43 million sq ft of housing—in some cases rebuilding entire cities—and give shelter to 500,000 people displaced by the quake.

Problems have plagued the job since cleanup began. Now, almost two years after the earthquake, most people who were displaced are still living in dilapidated temporary shelters, often nothing more than shipping containers left over from initial relief efforts. Only about 15% of the first two-year goal is complete. As refugees face a third winter without permanent housing, Soviet and Armenian agencies are pushing to take the pace of construction to another level.

Whether they will succeed is an open question. Despite the massive construction buildup, few people are optimistic that ambitious schedules can be met. Through Herculean efforts, planning and design of the reconstruction was accomplished in just five months. But the inefficiencies of the Soviet central system hamper construction, supply and project management. And the surprising inability of Moscow to ensure the passage of supply trains to Armenia stopped work last year just as it began.

Soviet republic kicks starts rebuilding plan for 500,000 earthquake victims, as 300,000 refugees swell the number of homeless

An additional burden is a $2.4-billion program to rehabilitate and strengthen damaged housing to stiffer seismic standards. Upgrading all structures within the republic to new standards is estimated to cost a whopping $56 billion, says Samvel Katolikian, deputy chairman of the Armenian state architecture committee. Local construction officials admit that they have little expertise in the subject and not enough money to carry it out. Western observers blame the lack of expertise on a long-term isolation of the Soviet engineering community.

"I think they really have to come into the world community in terms of developing strengthening programs," says Robert Englekirk, a Los Angeles structural engineer who has reviewed the Armenian program.

Needs. The lack of technology is a big problem. Before the quake, seismic designations were based on crude methods of microseismic zoning. Those designations were later upgraded throughout Armenia, but the Armenian institutes of geophysics and engineering design still lack sophisticated equipment needed to produce precise maps and detailed site evaluations for future construction, says Mishagh Yegian, Northeastern University's civil engineering chairman. Yegian is now conducting detailed geological studies in Armenia.

All of that has combined to break the promises of Soviet President Mikhail Gorbachev and Prime Minister Nikolai Ryzhkov to rebuild within two years. Those schedules have been revised twice already. Also at stake are plans pushed by the Soviet Ministry of Architecture, Goscomarchitec-ture, to rethink urban plan-
ning practices and radically alter construction practices, particularly for housing, throughout the Soviet Union.

Armenia offered an opportunity to test new ideas of housing construction developed by Alexander Krivov, Goscomarchitecture's deputy chairman. Named head of the State Town Planning Committee charged with defining the extent of earthquake damage in Armenia and planning reconstruction, he found himself in the right place to implement his ideas. Krivov is straining to modernize building techniques in the USSR and change long-term urban planning policy by moving away from "anonymous" high-rise concrete structures toward traditional one-family houses and two to three-story structures. Call it the suburbanization of the Soviet Union.

"We tried to plan and build to a different style, form and size," says Krivov. "We wanted to come back to the old understandings of neighborhoods and yards. It is quite a big jump forward."

While perestroika—and the constraints of tougher seismic standards—permitted him to pursue his goal in Armenia, it also brought work there to a standstill. When Moscow loosened its grip on the Soviet republics, long-simmering ethnic tensions were unleashed in Armenia's neighbor, Azerbaijan. The predominately Moslem republic, with historic links to Armenia's ancient foe, Turkey, still contains a large Christian Armenian minority centered in Nagorno-Karabach.

**Blood feuds.** The age-old blood feuds that resurfaced there sent some 500,000 Armenians fleeing to their homeland, already on its knees from the earthquake and ill-equipped to handle the refugees. By mid-1989, the total number of homeless had jumped to 800,000.

At the same time, the Soviets had massed a small army of workers with equipment and material for reconstruction work. Fourteen Soviet republics gathered crews and material and sent them to Armenia. Last summer, more than 50,000 workers were poised to begin work at the four hardest hit cities: Leninakan, Spitak, Kirovakan and Stepanavan.

After a flurry of start-up activity, work halted in midsummer when the Azerbaijani's blockaded rail lines into Armenia, refusing to let supply trains pass. The central government was unable to break the blockade and, by the end of last summer, nearly half of the labor force had left.

Until the blockade was lifted early this year, the only earthquake-related work performed was by western relief organizations (see p. 30) and Armenian-led projects that obtained cement from the republic's only two cement plants. Just 100,000 sq ft of a planned 26 million sq ft of housing was built during 1989 because of the blockade, says Galina Gorokhova, Goscomarchitecture's deputy chairperson for the Center of Town Planning and Design.

**Quake.** Armenia, generally considered the boundary between Europe and Asia, is situated in the southern Caucasus mountains in a "moderately" seismic area, compared to major zones in neighboring Turkey and Iran. Prior to the 1988 quake, the area was classified as zone 8 on the Soviet MSK-64 intensity scale, which ranges from 1 to 12. The system is similar to the Modified Mercalli scale.

The 1988 Armenian earthquake surpassed all previous known quakes in the region. The quake measured 6.9 on the Richter scale and destroyed more than 86 million sq ft of living space, or 17% of the republic's total residential space. On the Soviet scale, it was measured as 10 in Spitak and 9 elsewhere.

"Perhaps the most striking aspect of this earthquake is that the worst damage and the majority of deaths resulted from the collapse of relatively modern buildings," states a report compiled for the Electric Power Research Institute, Palo Alto, Calif., by EQE Engineering Inc., San Francisco.

Others put it more bluntly: "The buildings were conceptually weak and
structurally weak," says Frederick Krimgold, a member of the U.S. technical assistance team sent to Armenia from the State Dept.'s Agency for International Development. "And, basically, they low-balled the seismic risk."

Although the region was designated a zone 8, Soviet and Armenian officials allowed buildings to be designed for zone 7 standards. Soviet officials also admit that the risk was further exagerrated through lax and faulty construction practices. Post-quake investigations condemned corruption in Armenian construction and quality control (ENR 1/12/89 p. 11). Investigations showed, for instance, that sand was freely substituted for cement during building construction.

That explanation may be too simple, however. The same construction methods were used in Leninakan and Kirovakan. Buildings in Kirovakan sustained less damage even though the two cities are roughly the same distance from the epicenter and location of surface faulting, notes Yegian.

Local soil conditions are probably to blame, he says. Leninakan is built on about 1,300 ft of silty clay interspersed with damp, saturated sand conducive to amplification. Kirovakan is built on shallow areas of soft clay, but also areas of volcanic deposits.

"I'm convinced that the poor quality of construction or cement is not the only answer," says Yegian.

Whatever the cause, the results were devastating. The quake rattled a 154-sq-mile area occupied by about 700,000 people northeast of Yerevan, the Armenian capital. Officials estimate that about 80% of Leninakan, Armenia's second-largest city, was destroyed. Almost all structures in Spitak, to the southeast of Leninakan, downtown Kirovakan and nearby Stepanavan also took heavy damage.

Of the four predominant types of structures common to Armenia, only one—large-panel precast concrete buildings—survived the earthquake. A five-story precast panel building was the only building in Spitak to make it through the quake with little structural damage. Masonry-bearing-wall, precast-concrete-frame and concrete-lift-slab with concrete-frame structures suffered tremendous damage. And, basically, all buildings were the most common and almost all were destroyed. The buildings were also common in Leninakan, where they were substantially damaged. In structures built since 1950, the floors and roofs utilized precast, hollow-core planks that bear on the walls. In general, planks were not tied together and topping slabs were not used, resulting in a poor diaphragm for transferring loads, according to the EQE report. During the quake, walls tumbled away from concrete floor planks and floors collapsed. In many structures, "end walls survived, but the middle of buildings collapsed, indicating that the precast planks did not transfer loads through the diaphragm and into the end walls," claims the report.

Speedy planning. While investigations continued in the aftermath of the quake, the Soviets quickly produced a master design plan for reconstruction. Working without computers, which are scarce throughout the Soviet Union and nonexistent in Armenia, Krivov's team churned out plans in just five months to build a new city for 100,000 people on a 160,600-acre site 3 miles northwest of the center of Leninakan.

The complex includes about 2,500 three to four-story, multifamily buildings, he says. Scattered throughout will be semi-detached two-story houses that may be privately owned, if reforms are pushed through. Only 10 to 15% of the complex is to be prefabricated. Structures are being built mostly using cast-in-place concrete or a composite of brick and cast-in-place concrete. Some large precast panels are used, as are traditional building materials—volcanic tuff.

Planning and design for Leninakan and Spitak are managed through the Yerevan Project, the city planning institute. The reconstruction of Kirovakan and Stepanavan, as well as the design of two new cities being built for refugees from Azerbaijan, are managed from Armgosproject, the state planning agency.

Still, the Leninakan plan is controversial, not only because of philosophical changes in urban planning but also because of political decisions and the threat of another quake. Construction of the new district, called Marmashen, and the smaller, adjacent development of Ani, meant destroying a large chunk of land-poor Armenia's best cropland. And many questioned the wisdom and the cost of building on a site that was seismically upgraded to 9.

Hovels. The upgrade of downtown Leninakan and Spitak to zone 10 presents planners with another dilemma. People, many now living in hovels where high-rise buildings once were, refuse to leave for new housing on the outskirts of both cities. But planners are forbidden by the Soviet building code to construct any building more than one story high in those downtown zones.

"It was very difficult to find areas safe for reconstruction after the quake," says Oganyan Avakovich, chief of seismologic microzoning. "Sometimes speed is a very dangerous thing. We were very rushed because we must give the answers to the architects in a matter of weeks. Even now we have no precise computer analysis."

Still, most Soviet officials and western observers agree that in Leninakan, it is cheaper and faster to build on a site that at least has access to existing lifelines rather than on one further removed but without any existing infrastructure.

Soviet officials admit to working with incomplete data. But the severity of the situation demanded expediency, they say. "At the time, it was difficult to say what the precise geologic conditions were of different areas," says Gorkhova. "Usually, you do this [planning] after all the data are accumulated."

The sprawling Marmashen site dwarfs the old city of Leninakan even in its initial construction phase. Tower cranes sprout from every house under construction. "There are more boom cranes than I've ever seen in my life in one location," says Ronald Alton, a partner in Los Angeles-based Altoon & Porter Architects. Altoon led a seven-person team sponsored by the American Institute of Architects to assist the Armenians in redesign and the strengthening of unreinforced buildings that can be salvaged.

Although the large numbers of
Speedy western relief plays only a small part

While the overwhelming majority of construction throughout the earthquake area is being done by Armenians and other Soviets, a handful of western firms and relief organizations stepped in to provide technical assistance and build temporary housing and social infrastructure—schools, hospitals and clinics.

Among the most successful is OPAK AS, an Oslo construction firm that in just nine months built a 200-bed hospital in Spitak. OPAK and others worked quickly because they brought everything with them, including work crews, construction equipment, building supplies and tools. Except for labor, all are scarce in Armenia.

But Armenian engineering officials say what they need most is access to international state-of-the-art engineering technology and exposure to western engineering and construction methods. It appears that they won't get it from the U.S. Congress, which has authorized $10 million for assistance, but the State Dept. says that despite staff recommendations it will not use the funds for engineering research programs or equipment.

American construction assistance is centered on the Armenian Assembly of America, a nonprofit organization of Armenian-Americans. The Washington, D.C.-based organization is building a $4 million manufacturing complex outside of Leninakan. The job includes three small factories that will produce building supplies—panels, trusses, sheet metal roofing, windows and doors. Local work crews are supervised by Russell Berry, a 20-year Corps of Engineers veteran. All material was shipped to Armenia via Soviet cargo planes under an arrangement negotiated by Hralt Hovnaniian, chairman of the assembly and president of Hovnanian Industries, a Tinton Falls, N.J., developer.

The assembly is trying to train local workers in American construction techniques while emphasizing quality, says Berry. "There is no concept of maintenance or quality control here," he says. Hovnanian says he will try to introduce incentives—cash bonuses—to reward good work and speed progress.

Hovnanian's brother, Kevork, a Red Bank, N.J., homebuilder and president of K. Hovnanian Enterprises Inc., is supplying technical assistance for a 624-unit condominium-style complex in Stepanavan funded by the American Diocese of the Armenian Orthodox church. Eleven New Jersey area tradesmen are training local workers building the project.

cranes emphasize the massive scale of work, they also point out one of the inefficiencies of Soviet construction. "There aren't any forklifts," says Russell Berry, the American project manager supervising construction of three small western-financed building supply factories outside of Leninakan. "They need the cranes to lift anything and everything."

Because of the increased seismic designation, buildings at Marmashen could not be designed for more than five stories. The site was chosen because deep layers of volcanic tuff came within 6 to 10 ft of the surface. But in two-thirds of the area, workers found the tuff deeper, some 32 ft beneath the surface.

To lay the foundation, about 20 ft of soil is excavated before placing a 6½-ft-deep blanket of heavily compacted gravel. Workers then pour a 6-in-thick reinforced concrete slab. Re- construction emphasizes poured-in-place methods and extensive use of reinforcing steel. Post-quake investigations blamed the lack of rebar as contributing to the failure of many buildings.

"The quality of construction here is probably better than anywhere else in the Soviet Union," says one Soviet planner. "But you really should not compare it to Western European or American standards."

Confident. Krivov is confident that the buildings will withstand any future quake, noting "very conservative designs. Is it too conservative? It appears they are now going into design overload," says Yegian. "About 60% [of each of the three and four-story structures] are concrete shear walls."

But most agree that the new structures are sturdy. "Everything is poured in place and integrated and tied together," says Altoon. "There are no cold joints."

At Marmashen, space is divided into quadrants assigned to construction firms from various republics. Site coordination is difficult and construction costs are at least 20% higher to meet code for the higher seismic region in Leninakan compared to the average $100-per-sq-ft cost in Yerevan, says Marmashen's chief architect, Levon Galumian, of the Yerevan Institute. "But costs are actually much higher because materials must be transported from other republics," he notes.

Site coordination is difficult. Designers and contractors curse the system. Architectural drawings, all generated by hand, remain in the main offices at Yerevan, some 80 miles and almost two hours away, "because it is impossible to make copies," says Galumian. If problems between the contractor and designer cannot be resolved by phone, the contractor must drive to Yerevan to check the drawings because the designers have no cars to make the trip. "It can take hours to solve the most simple problem," he says.

Still, crews are working 12-hour days at all sites to bring the job in by the end of the year. Local planners are doubtful, noting that the blockade could resume at any time. Either way, it will probably be another long winter before large numbers of refugees can move into the new housing.

By John F. Kaouzian in Yerevan