From our correspondent in Chongqing, China

A Promising Solution to Surface Congestion: Using the Underground

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Some 2,000 km upstream from Shanghai, at the confluence of the Jialing and Yangtze (Yangzi) rivers, lies the “mountainous” city of Chongqing. Rising steeply 30 to 50 m above the rivers, the peninsula is dotted with narrow plateaus cut by numerous gullies and ridges. In addition to its difficult topography, Chongqing is famous as one of the “furnaces” of China. Its subtropical, long, hot summers extend from May through September, averaging 38 days annually with temperatures over 35°C (95°F).

Adding further strain to the city is the congestion caused by an ever-increasing population. Building density in the metropolitan area is 85%, and in residential areas it is even higher. New housing projects are being built at an average rate of over one million sq m per year, and more public facilities and recreation areas are needed. Surface preservation under these circumstances is a serious problem and a number of ways to deal with it are being tried, including high-rise housing and the use of underground space. The latter is especially promising.

The use of underground structures has gained popularity in China in recent years, as cities have begun using their civil defense shelters for a variety of peacetime purposes. People welcome underground teahouses and restaurants, especially in the summertime. Food storage has been found to be more efficient and economical underground. Air pollution has been reduced since garages, poisonous chemicals, and the like have been placed underground. The main advantage of using the underground, however, is surface preservation.

The following brief sketches illustrate how use of the underground has solved some of Chongqing’s surface congestion problems.

Use of the Subsurface for Surface Preservation

The Sichuan Ship Repair Yard, bound by the river in front and the hills behind, was unable to expand its facilities aboveground, and so, in 1969, began tunneling into the hills for its expansion space. Today, more than 7,275 sq m of space have been excavated to house general and precision manufacturing systems, a 400-kW power station, a 1,200-ton water tank, and an auditorium. The underground plants have been in operation more than ten years, and by using natural and mechanical ventilation to maintain the relative humidity at 65-70% and the temperature at 21°C (69°F), condensation of moisture on and corrosion of electrical equipment has been prevented. The excavated “waste” rock was used to build up the riverfront, so that, ultimately, the shipyard actually gained 30,000 sq m of surface space.

As in most major cities, Chongqing’s Jiuhuashan bus terminal is located in the densely built-up downtown area. As recently as 1970, bus drivers, conductors, and other employees had no place to rest and relax — even on the hottest summer days — and there wasn’t a square meter of land available for building. Excavation began in 1969 and now more than 1,200 sq m of underground space are used for teahouses, rest rooms, waiting rooms, conference rooms, and another 2,000 sq m of subsurface space is available.

Surrounded by the rich fields of the People’s Commune, the Chongqing Watch and Clock Company was unable to afford the high cost of such and for expansion. More than 8,000 sq m of underground space have been excavated in the last 15 years for warehouses, water tanks, and living facilities (kitchen, restrooms, conference rooms). A power station and other plant facilities will soon be housed in lined caverns, and an underground cinema, a hospital, and food storage cells are also planned.

Low-Cost Underground Storage

The northern provinces of China have a long tradition of storing cereals, grains, vegetables, sweet potatoes, and other foodstuffs underground. In spite of severe winters, the underground storage areas remain at 15-16°C (59-61°F), with a relative humidity of 60-70%. Since the founding of the People’s Republic of China in 1949, underground warehouses have been built all over the country, Chongqing, as the communications hub of Sichuan province (the “land of abundance”), is destined by its geographic position to be the largest trade center in southwest China. Strategic location and geological conditions have been of particular benefit to the experimental development of underground storage in this region with a warm climate and high humidity.

One such experimental underground storage area is the Chayunyang granary, utilizing an existing airraid shelter. The air-raid shelter is about 18°C (64°F), with a relative humidity of 55-60%. For air tightness and damp-proofing, two variants were selected, both lined with stone masonry. One chamber is waterproofed outside of the lining by an ashpaltic membrane and sealed by a small door to form an airtight chamber; the other is lined inside with plastic.

A comparative study was conducted over a nine-month period using husked rice stored in three underground chambers and in a nearby surface granary. (Identical quantities of rice from the same lot were identifiedly packed in all three storage areas.) There was little difference between the rice lots stored in the two underground storage areas, both of which, however, were found to be decidedly superior to that stored aboveground.

Turning to the outdoor air temperature, which was 30°C (86°F), the temperature in the underground granary was 29°C (84°F), while the temperature in the underground chambers remained stable at approximately 20°C (68°F). The aboveground rice was found to have a higher moisture content and to have colored slightly. There was no change in color in the underground rice, which retained a 22% moisture content well above and more than the belowground granary. Tests developed two to three months earlier in the aboveground storage chambers, and had to be controlled twice by pesticides, while in the underground granaries vacumming with an air pump sufficed. The study concluded that:

- underground granaries are safe even in the hot summer;
- there is practically no growth of bacteria;
- there is no discoloration of the rice;
- there is no self-heating of the grain;
- there is no need to use pesticides; and
- the grain deteriorates at a much slower rate than in aboveground granaries.

In addition to preserving the nutritive value and flavor of the grain, it is easier to manage an underground granary, and the cost of maintenance is reduced by more than 25%.

The Daibeng refrigerated storage, in operation since 1975, illustrates the energy savings obtained by going underground. Besides an initial investment 25% less than a comparable surface plant (500-ton storage capacity, 12-ton refrigerating capacity), heat flow measurements show that the temperature in the storage tunnels has fallen...
A number of underground facilities have already been built — factories, warehouses, teahouses, classrooms, laboratories, and meeting rooms.

Underground manufacturing facility of the Sichuan Ship Repair Yard.

Underground refrigerated meat storage facility.

Entrance to tunnels in the bluffs around Chongqing. A typical scene.

Taking Advantage of Natural Ventilation

The civil defense shelters are also used to provide natural ventilation to cool cinemas and theaters, commercial buildings, factories, and other public buildings. The first public building to take advantage of underground ventilation (in 1975) was the May First Cinema, whose indoor temperature often hit 56°C (99°F) in the summer. Since using underground ventilation, the auditorium temperature is at least 4°C (7°F) lower than the outdoor temperature, so one feels cool and fresh. Studies show that the higher the outdoor air temperature, the larger the temperature difference between indoors and outdoors. The efficiency and low cost of the system is so attractive that the Shangcheng Wide-Screen Cinema has introduced it in place of the original air-conditioning units.

At the Chongqing cigarette factory, steaming, boiling, and roasting the tobacco drives the indoor temperature up 54°C (129°F) higher than the outdoor temperature. The temperature can reach 40-50°C (104-122°F), and the air is laden with dust. Two years ago, cooling by underground ventilation was introduced. Two 40-kW suction fans, set up at the gallery entrance, draw 540 cm³ of cool air per hour into the workshops through a ventilation duct 300 m long, regulated by a series of vent doors. Not only is the indoor temperature now 3-5°C (5-9°F) lower than outdoors, but the environment is improved: the cool air keeps down the heavy dust.

Underground ventilation is also being used to cool knitting and weaving mills in various textile factories.

Present and Future Usage

Underground space is providing a new field for development in Chongqing. A number of facilities have already been built — factories, warehouses, classrooms, laboratories, teahouses, and meeting rooms.

Underground warehousing of products other than foodstuffs is also attracting attention. Underground storage of oil, chemicals, explosives, flammable materials, and toxic substances offers isolation and radiation control.

Underground biological and agricultural studies are being conducted with mushrooms, yeast, bacteria, and enzymes. An underground transportation system for both passengers and freight is particularly appealing, though much economic and scientific research is still to be done.

In line with China's economic adjustment, the development of underground space in Chongqing will open up a new vista.