USE OF UNDERGROUND SPACE

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STATE OF THE ART

The worldwide increase in population and urbanization and the accompanying problems of congestion, environmental disruption, and pollution increase the need for and the importance of using underground space. Present use is extensive and growing. Increased costs of land and surface facilities, both economically and environmentally, and improved underground excavation methods make use of underground space more attractive. Mining for various minerals can often be carried out with planned later use of the mined-out space. In some locations the value of the excavated rock as concrete aggregate or special fill may pay the cost of creating the underground space. Savings in energy needed to heat and cool underground space, compared to surface facilities, can be as great as 60 percent or more. In all instances, the geology of the area will determine how and to what extent underground space can be used.

Tunnels are vital arteries for water supply, communications, and transportation of people and goods. For instance, New York City has more than 210 km (130 miles) of large-diameter tunnels for its water supply system. Water utilization projects in the West involve several hundred kilometers of tunnels. Future needs will entail moving water over long distances, requiring many more tunnels than in the past. Transportation of sewage to treatment plants and disposal involves many tunnels. Chicago, for example, is well along with a program including more than 160 km (100 miles) of large-diameter tunnels as part of a wastewater transport and storage system to handle peak storm and sanitary sewage flows for later treatment. The increasing emphasis on positive control of water pollution means more tunnels.

The United States now has more than 725 km (450 miles) of rail rapid transit tunnels and expects to double that amount during the next decade. More than 100 highway tunnels, mostly through topographic barriers but some under high-density urban areas, have a portal-to-portal length of about 145 km (90 miles). Twenty additional tunnels, primarily on the Interstate Highway System, are under design and construction.

Utility tunnels have long been used in institutional building complexes such as college campuses. Originally constructed to distribute lines from a central heating plant, they now generally include most other utilities. Multiutility tunnels have not reached important acceptance in the United States, although the potential appears great. As density increases, more need develops for underground utility space. A large subdivision in Stockholm, Sweden, is being planned with all transportation access and utilities, including hot water for heating, in tunnels.

Construction of water and sewage treatment plants underground offers advantages of controlled conditions and absence of environmental disturbances. An outstanding sample of effective sewage treatment is the Kappala plant in Stockholm. Built to serve a population of 540 000, its 60.3 km (37.5 miles) of tunnels comprising the underground works can be expanded to serve twice as much population without adverse effect on the choice surface residential areas.

Underground storage for fossil fuels is growing. In 1974 there were 365 underground storage areas that were used for 184.1 Gm^3 (6.5 trillion ft^3) of natural gas, about one-third of the yearly production. Under favorable geological conditions, unlined underground caverns lend themselves well to storage of water, oil, and other liquid products.

Where temperature and humidity control is important, underground offers many advantages to warehousing and manufacturing and provides especially favorable storage space for frozen foods. The Kansas City area, with its mined-out limestone space, leads the nation in using underground facilities. A manufacturer of precision instruments has found the controlled humidity, temperature, and vibrationless floors with heavy loads especially favorable. Weather hazards are reduced, maintenance costs are less, and energy savings are 65 percent and more. Development of a large-scale underground industrial park is under way, and planning is being done to use all the available underground space.

Underground facilities are placed in tunnels and caverns that honeycomb the great Rock of Gibraltar. Peking, China, is reported to have underground facilities in which the entire 7 million population can be accommodated. Poland has a 500-bed hospital 213.4 m (700 ft) underground in an old salt mine, which appears to have medical value to those suffering from bronchial asthma and other respiratory problems. A similar installation is at Solotvino in Soviet Carpathia.

Parking garages underground are increasing in number, and their cost compares favorably with surface construction. Shopping plazas and malls, such as the Place Ville Marie underground complex in Montreal, Rockefeller Center in New York, and the underground plaza connected with the new subway system in the center of Paris, demonstrate the remarkable possibilities with an easily controlled environment. A new similar development under Tokyo already has 350 enterprises. Similar developments are under way in Osaka and Nagoya.

About a fourth or more of the hydroelectric plants being designed and constructed in the world today are being located underground. One of the world's largest is the Churchill Falls Project in Canada where 1.76 Mm^3 (2.3 million yd^3) of rock were excavated to provide the large underground chambers. Completely underground pumped storage facilities are being actively considered at several locations. For instance, a two-state, Francis pump-turbine installation in a 1097.3-m (3600-ft) vertical shaft would support a 1600-MW, 10-h peak capacity with underground storage of about 5.4 Mm^3 (7 million yd^3). Costs are becoming increasingly favorable. The example just cited would require a capital cost of about $200/kW. Such installations offer a great many advantages such as freedom from topographical controls and environmental constraints. They can be located close to load centers, reducing transmission costs and environmental problems, and can provide a source of concrete aggregate and rock near market centers. Underground nuclear plants, such as the 266-MW pressurized water plant in

Ardennes, France, and a 500-MW plant being planned in Stockholm, Sweden, offer potentials that are receiving intensive study. Underground transmission of electricity in built-up areas is increasing, and extensive research is developing ways to improve technology and reduce costs for this major problem.

The needs for the use of underground space are great, and the potentials for better meeting the goals of a quality life for people are growing. With an aggressive, positive research and development program covering the full range of physical, economic, social, and environmental considerations, the use of underground space is expected to accelerate.

FUTURE RESEARCH

Methods of Analysis, Design, and Construction

Research needs include the full range of physical and geological methods of analysis and design of underground openings. Shape of openings, types and degree of supports needed, actual performance records, and methods of strengthening various geological formations are representative of the problems needing additional research. More geological information is a big requirement. Methods by which underground excavation can be improved from the standpoint of economics and accomplishment need further advancement. Safety provisions for underground construction and labor relations need improvement. Better methods of contracting for underground work need to be developed and used. The best way to provide ventilation, fire protection, and regular and emergency access requires specialized study directed to the specific needs of underground space use.

Effects of Underground Environment on People

With the potential that underground space use appears to have, especially as economic advantages of surface space disappear, a better understanding of the effects of underground environment on people is a must. The usual adverse reaction to working underground needs careful examination. General reactions from those actually working underground, for instance in Kansas City and in Sweden, appear favorable. However, specific facts and data need to be established. From a medical standpoint, underground workers appear to be less susceptible to common colds; and accident rates for underground workers seem to be lower (those engaged in office, warehousing, and manufacturing activities, not construction). Attitudes of underground workers suggest a feeling of security and composure, and this may reflect favorably in underground plazas and shopping malls. Healthful and healing influences are indicated in some underground environments. These probabilities need to be well researched and documented by psychological and medical professionals. The influences of decoration and lighting adapted to underground operations should be established from existing information and from additional experimenting and research.

Best Use of Underground Space

How the underground space can contribute to the entire goals of society, not just from the technical and physical standpoint but from full consideration of a quality life for people, needs continuing objective analysis with multidiscipline considerations. More study needs to be made of what should be placed in underground space for the greatest overall benefit. With this determined, then ways to adapt institutional arrangements, which have been established generally without consideration of the use of underground space, need careful research and analysis to determine how best to adapt them to optimize underground space use. Factors to be considered include tax treatments, ownership, insurance rates, zoning, and the whole array of related problems.