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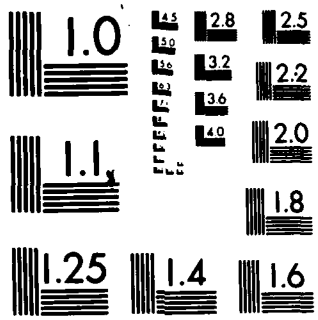


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# FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

UNDERGROUND ENGINEERING

(Selected Articles)

FOREIGN TECHNOLOGY DIVISION



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# INVESTIGATION OF TYPES OF UNDERGROUND GARAGES TO SUIT DEVELOPMENTS IN CHINA

Tong Linxu

There are many types of underground garages but the methods for classifying them are not completely uniform. Each type has its advantages and disadvantages and can be used under different conditions. Starting from the actual situation in China, as to which type is relatively suitable for development under what conditions, we are still lacking in ripe experience and this is a problem which should be studied and investigated. Foreign nations have beneficial experience in this area from which we can draw lessons from but there are also differences due to our socialist system and economic development level so that we cannot blindly and indiscriminately imitate them.

Looking at the situation from the angle of architectural design, the range of the selection of underground garage types includes the service type, architectural type and transport type.

The service type can be divided into underground public garages, underground garages for special purposes and storage garages. Public garages are mainly used for parking small passenger cars and some are specially used for parking trucks; garages for special purposes generally mainly park trucks which also includes various specially used vehicles such as fire engines, ambulances and construction vehicles etc.

There are mainly two construction types: the underground garage buried shallow in the soil and the underground garage in rock. The underground garage in soil is also divided into two types: the single construction and appended construction types. As regards the number of construction layers, underground garages are also separated into single levels and multilevels.

The transport type basically has two types: ramp transport and mechanized transport. The ramp itself is of various types such as the straight ramp, curvilinear ramp etc.; mechanized transport can also be divided into semi-mechanized (i.e. using machinery for vertical transport) and completely mechanized (i.e. using machinery for horizontal and vertical transport).

Below, we will carry out preliminary analysis and investigation of the advantages and disadvantages of the several above mentioned types as well as suitable conditions for their use in China.

## I. Underground Public and Special Purpose Garages

The large number of underground garages built abroad are mainly to supply temporary parking sites for the continually increasing number of private passenger cars so as to resolve traffic congestion, tension in city used land and other problems in the development process of cities. Therefore, as a service enterprise which collects a great deal of fees, aside from public parking and providing necessary services, they are generally not considered for other purposes not to mention what uses they should be put to during war. There are only a minority of countries, especially several small neutral countries, which actually consider using the underground public garages as shelters for people during war and thus we still very rarely see materials on building underground special purpose garages for use during war.

At present, China does not have private automobiles and the number of automobiles produced and used in China is much smaller than in many countries. Given these circumstances, it is worth researching whether or not it is necessary to build underground public garages. Firstly, in view of the present situation in cities, because the majority of large cities in China developed from old cities and towns, they lack modernized municipal administration facilities, the streets are narrow, the populations are dense and even though the absolute number of automobiles is not great yet traffic is already very congested. During peak time, automobile jams are becoming daily more serious, the parking problem is also becoming increasingly acute occupying large amounts of vacant city plots and thus affecting making places green with trees and flowers and increasing pollution. All of these facts show that in suitable locations such as city central areas, commercial districts, factory yards, large public activity places, tourist areas, places with concentrations of foreigners etc., to build a certain number of underground public garages we must improve the above mentioned abnormal phenomena to a certain extent. If we can bring these underground garages into the overall planning of city development and cause them to be connected with the construction of the communications network, then the underground garages will have even more beneficial effects. Some successful experiences of foreign nations in these areas can be drawn upon. The second problem is whether or not underground public garages which are relatively costly to construct can be fully used during war. We should say that if the design of this type of garage reaches a certain level of protection it is relatively suitable as a shelter for people during war because the area is large, it is well situated and it is convenient for a large number of residents or people walking on the street to enter the shelter. Yet, it should be stressed that it is even more suitable as a provisional shelter for people. After a large number of people enter, they should evacuate within a short period of time and disperse to even safer locations; it is not very rational to use them as permanent shelters for people to work and live in for a long period of time because it will then be necessary to prepare a great many (in proportion to the number of sheltered people) life service facilities. During peacetime, with parked cars in it, it cannot be used as it occupies great area and space and just before a war it is necessary to use a certain amount of time, manpower and material resources for rebuilding before it can be used as a shelter for people. Because of this, if it is urgent that we resolve the problems of city traffic but lack the funds, we can consider constructing a certain number of underground garages which are not designed according to protection requirements and for the selection of the location we consider the requirements for the evacuation of residents just before a war. This type of underground garage can still be brought into the civil air defense projects system only it cannot be used as a permanent shelter for people with the "three defenses" capabilities. In a situation just before a war wherein there have not been any air attacks, this type of underground garage can still play a proper role in the civil air defense system. That is, during war, they possess considerable abilities against conventional weapons.

As regards underground special purpose garages, even though relatively few have been constructed abroad, based on China's combat readiness requirements and civil air defense requirements in the civil air defense construction system, we should classify and fit out the various underground special purpose garages so as to implement civilian war service tasks. Therefore, during peacetime, based on plans, it is completely necessary to step by step construct a group of underground special purpose garages. For the problem of usage during peacetime, it is only necessary that this type of garage consider combining with related vocational departments in layout, for example the transport departments, fire brigades, medical units, municipal administrative departments etc. During peacetime, they can as usual be used as garages and in this way they are also beneficial to the protection of underground buildings. Just before a war, they can be transformed into wartime systems.

## II. Single and Attached Underground Garages

The main advantage of single underground garages is no matter what the scale and size, they have no effects on the city space and traffic above ground. Aside from the small number of entrances, exists and vents, the empty area formed after covering the ceiling with soil can be completely used to build factory yards, parks, roads, green areas etc. Aside from this, single underground garages can also be built in those areas of the city where buildings basically cannot be placed such as factory yards, streets or sections dense with buildings. They can even use ditches, pits, old river courses and other factors which are not advantageous to construction. After building the underground garage, it is filled and levelled up which not only eliminates depressions but can also provide new and level usable land in cities. The Chokutsu Underground Garage in Osaka, Japan was built using an old river course and in the 1,100 meter length range, they laid out three single underground garages of different lengths and the total capacity is 750 vehciles. They used soil backfill dug out from the river bed so that the dug area and filled in area were basically balanced. At the same time, on top of the garage was built a two lane road with a total width of 32 meters and they also buried water supply and drainage pipes. See Fig. 1 for the sectional schematic.

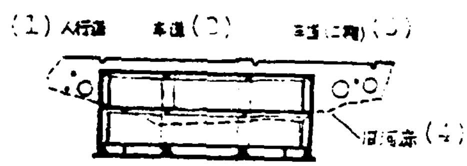

Fig. 1 Sectional schematic of the Chokutsu Underground Garage in Osaka, Japan.

Key: (1) Pavement; (2) Traffic lane; (3) Traffic lane (second lane); (4) River bed.

The column network and external architectural appearance of the single underground garage is not limited by the conditions of usage above ground and therefore, under the premise of rational structure, we can completely determine the column network dimensions based on the technical requirements of the automobile's travelling and parking and as much as possible reduce the poorly used area within the parking lot. At the same time, we can use the large area multispan and relatively large dimensional column network to raise the utilization rate of the area of the parking lot. In view of foreign practices, a relatively large number of underground passenger car garages use 6-8 meter column network units. Two to three cars can park in the 90° right angle between two columns and the span for the cars to pass uses about 7 meters. This type of column network raises the utilization rate of the area of the parking lot. It can also serve as a continuous multispan and can more fully bring into effect the advantages of the single garage. Based on domestic experiences, when considering protection, the dimensions of the column network of an underground truck garage should not exceed 8 meters, that is, it is relatively suitable to park two vehicles in between two columns. Further, single underground garages can also use relatively large span space structure to reduce the number of columns in a parking lot. In this way, although there is some saving in area yet we must consider that the increase of the structural height causes the burying depth of the entire building to increase which results in non-advantageous aftereffects.

Single underground garages generally use the excavation method for construction and this will occupy a certain area of empty land during the construction period. Therefore, they are often limited by the present situation of the city and especially in the central district of a city it is necessary to find an empty piece of land which will be located just in the center of the garage service range and make sure that the construction period does not seriously affect city traffic. This is often comparatively difficult. Therefore, the construction of single underground garages must be carried out under the overall planned guidance of the city so as to avoid the above mentioned shortcomings and limitations and have it play its deserved role.

When large public or industrial buildings require nearby parking but the vicinity does not have sufficient vacant land to build a single underground garage, we can use an attached underground garage which is the use of the basement of a main building to lay out a garage. The arrangement is flexible, it does not use additional land, it can put up window openings so as to decrease moving costs and it can park vehicles nearby. These are the major advantages of the attached underground garage. However, the greatest difficulty in design lies in selecting the most suitable column network dimensions for the parked vehicles and adapting them to the functional requirements of the building above ground. If the above and below ground functions coincide, that is, there is a multilevel garage above ground, naturally this contradiction does not exist. This method is still more common in foreign countries. At present, there are very few attached underground garages in China because of the lack of experience and the different attached underground garages have not resolved this contradiction. There are only the column networks of above ground buildings extending underground and although they can barely park vehicles yet they are not very rational. For example, there is an office building with a pillar network of (4+4)x3.6 meters and the basement is a garage. There is no way to pass through between the two spans and thus a bearing wall is used to separate it into two narrow and long parking areas. The vehicles can only park in twos and the vehicles parked in back have no way of being moved out. It was also necessary for this reason to erect two extra doors.

Generaly speaking, the adaptability of a (6+6+6)x6 meters or (6+6+6+6)x6 meters column network is relatively wide for above ground buildings, for example, light industry factory buildings, laboratories, warehouses etc. This type of column network can have two vehicles, such as the Shanghai model passenger car or the 130 model truck, park at 90° right angles between the columns yet the area has quite enough room and some to spare [calculated by the smallest dimension (5.2+4.0+5.2)x5.0 meters which satisfies the technical requirements]; if we park a Liberation model truck, then we can only use a 30° oblique angle for parking and one vehicle parked between the columns can satisfy the requirements. When getting in and out of the vehicle, it is necessary to further shift the vehicle. The triangular area in the parking area which is not good to use is also quite large. All of this shows that in order to cause a type of column network to simultaneously satisfy the different above and below ground function requirements, the column network of the attached underground garage is made somewhat wider, that is, the average area index required for each vehicle is a little higher. This is unavoidable. Under certain conditions, it can be regarded as a method for resolving this problem.

In order to solve the integration problem of the above and below ground column networks of the attached underground garage, foreign countries often use large public buildings which make great use of the joining of the higher and lower levels and arrange the underground garage in the basement of a lower level section. Therefore it is called the attached garage. Because the lower level section is often the public activities section such as the lounge, restaurant, dance hall, conference hall, shops etc. These functions all require relatively large column network units which quite easily become consistent with the parking technical requirements of the garage.

Like the office building, the column network units of residential buildings etc. generally do not have attached lower level structures and it is very difficult to arrange garages in the basements of these types of buildings. Therefore, if on the side of the basement of a multilevel building a partial single underground structure is added and the two are joined on a plane, only by using a settlement joint for separation on the strucure can we increase the relatively large flexibility. This possibly satisfies the technical requirements for parking. Figure 2 is a section of an attached underground garage in China. Above ground is an office building which has actually already become a mixed form of the attached and single garages. The attached section is used for parking, the single section is used for moving vehicles and the ramp is erected in the single section.

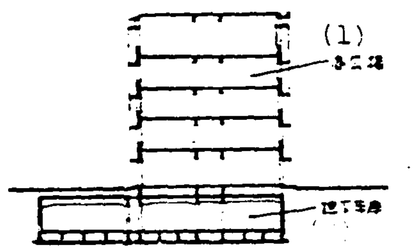


Fig. 2 Sectional drawing of attached and single combined underground garage.

Key: (1) Office building; (2) Underground garage.

Figure 3 is a type of method used in the Soviet Union of an attached garage in the basement of a high rise residential building. The basement uses a completely poured-in-place honeycomb structure as the foundation for the entire building and in the middle is a longitudinal corridor, running conduit and cable. The two sides are two transverse circular stalls and one car can be parked in each stall. The single section's span is 14 meters and uses precast steel reinforced concrete arches (two-thirds arches) which are put up on the entire foundation. In this way, we form two parallel 90° right angle parking on both sides and in the middle is the underground garage for cars to go through which can be used by the residents in the building.

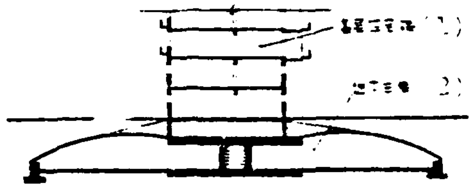

Fig. 3 Sectional chart of attached underground garage under a residential building.

Key: (1) High rise residential building; (2) Underground garage.

## III. Single Level and Multilevel Underground Garages

Single or attached underground garages constructed in the underground soil layer of a city can be built as a single level or in multiple levels.

Underground garages are the same as those above ground and the single level and multilevel layouts each have their advantages and disadvantages. However, in the area of utilization rate of occupied area, construction area etc., each level of the garage has even better advantages. Based on materials from the Soviet Union, if the area of the land occupied by a single level garage is 100%, then when changed to three levels it decreases to 65% and when six levels it decreases to 38%; if the effective area of a single level garage is 100%, then when three levels it is 108% and when six levels it is 118%. These laws also basically match those for underground garages. The difference is that the ceiling load of the underground garage is large and even if it is a single level, it still cannot use a relatively large column network and is not as advantageous as the multilevel in area utilization. Another difference is that single level garages above ground do not require vertical transport facilities yet even if it is an underground single level garage, it also requires ramps, stairs, elevators or other mechanized lift equipment. These devices only lift and descend the height of one level (adding a small amount of cover soil thickness) and therefore their utilization rates are not as high as those of multilevel garages. All of these facts show that if an underground garage is made with one level, not only does it require even more land (because of the adding of ramps) than a similar scale single level garage above ground but it has no outstanding advantages in other areas. Therefore, it can be considered that in most situations the building of multilevel garages underground is superior to building single level garages underground. In view of the large number of underground garages constructed in foreign countries, the vast majority are multilevel and relatively few are large area single level.

The major difficulty in building underground multilevel garages is they are limited by hydrological and geological conditions and construction technical conditions. When the level of the underground water is high or the geological structure is relatively complex, the greater the number of levels, the larger the burying depth of the building and the higher the waterproofing of the building and the higher the costs for structural treatment, the more difficult the construction. Foreign multilevel underground garages are mostly two or three levels which also shows that under conventional excavation construction conditions, it is beneficial for the underground multilevel garage to be two or three levels. Naturally, if special structures or construction methods are used, for example, caissons, open caissons, underground continuous walls etc., we can build underground garages with even greater numbers of levels. For example, Fig. 4 is a ten level underground garage built by West Germany with the open caisson method. This requires certain construction techniques and equipment and can only be realized when there are geological conditions advantageous to this construction method. At present, most of the underground garages built in China are single level and China has also been limited by the two above mentioned conditions. Thus, the capacities of the garages cannot be very large and the area occupied by the ramp etc. vertical transport facilities makes up a very large proportion of the total construction area which causes the index of the average required area of each vehicle to be quite high. At the same time, the roof and floor areas of the single level garage are relatively large which is also not advantageous for protection.

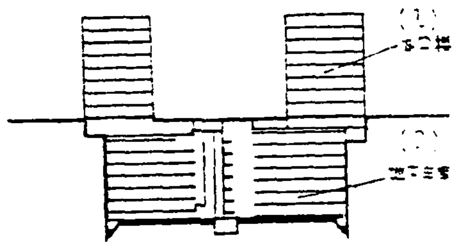

Fig. 4 Sectional chart of West German multilevel underground garage constructed with the open caisson method.
Key: (1) Office building; (2) Underground garage.

It should be noticed that even if there are excellent geological conditions and the necessary construction conditions, it is still not beneficial for the number of levels of the garage to be excessively large because we must consider that the above and under ground travelling time of vehicles in the garage (including mechanical transport) cannot be too long so as to avoid affecting the speed of vehicles entering and leaving. In view of foreign practices, they generally do not exceed ten levels; most of those using mechanical transport are about six levels).

## IV. Underground Garages Buried Shallow in the Soil and Those in Rock

The single, attached, single level and multilevel underground garages analyzed and introduced above are all constructions buried shallow in soil. Generally, it is suitable to build these types of underground garages in cities in plain areas. Their advantages and disadvantages have been enumerated above. Under special conditions such as in cities wherein the underground soil layers are very thick, the soil quality is very good and the level of the underground water is not high; or when the shallow buried construction and original underground communications, civil air defense construction or public facilities have relatively large contradictions, we can also consider the possibility of using dark digging construction to build a deeply buried underground garage. Naturally, in this type of situation, it is best for the underground garage to be built in conjunction with the underground communications network. Otherwise, the cost will necessarily be very high and use will not be convenient in the areas of structure, constructions and vertical transport etc.

Many cities in China are built next to mountains or where the soil layer is very thin so that not far underground is base rock such as Qingdao, Dalian, Chongqing etc.; there are also some cities wherein there are mountains in the near and distant outskirts such as Beijing, Nanjing, Changchun etc. In these types of cities, there are conditions to build underground garages in rock. Some nations in West Europe also have this type of situation.

Underground garages in rock are very different from those buried shallow in soil. The main distinguishing features are protective capabilities are strong, the layout is relatively flexible, they do not require vertical transport and even more important they do not occupy vacant city land; when the topographical and geological conditions are relatively advantageous, the scale can be very large, the capacity seems not to be limited and there is basically no influence on the buildings above ground and the other construction below the ground. Another advantage is that if the parking area is conditionally made into a relatively large span cave room, because the span is large and it does not require columns, the utilization rate of the area is relatively high. China has an underground garage built in granite. The large span of the parking area is 18 meters, it can transversely park large vehicles in rows and the capacity is also relatively large. Figure 5 is a Chinese design plan for another underground garage in rock. Because the mountain is narrow and long, the major parking area cave rooms are arranged along the strike of the mountain ridge. At the same time, several 45° oblique cave rooms are opened on the separating wall between the two parallel cave rooms. This can increase parking and we can also arrange auxiliary rooms as well as connect the two main cave rooms. Each of the two ends of the parking area are arranged with a semi-circular vehicle return ways wherein the cars separately go in and out of the cave openings so that level traffic inside the cave is relatively convenient. Figure 6 is an underground garage in rock in Finland and during war it serves as a shelter for people. It has a total of two parking areas. The span of the large area is 16.5 meters and there is 90° right angle parking at the two ends; the span of the small area is 10.5 meters and there is 60° oblique angle parking on one side. The arrangement of this garage is relatively compact, the functionally divided areas are clear and the level traffic in the garage is also relatively convenient. The cave room's structure uses sprayed concrete, it does not have bush direct parking and the piped are hoisted in the vault space.

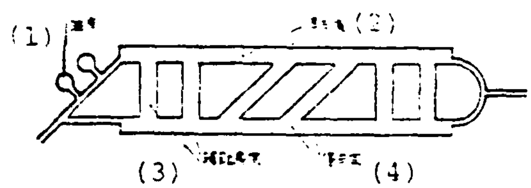


Fig. 5 Arrangement plan of an underground garage in rock. Key: (1) Oil depot; (2) Parking area; (3) Auxiliary rooms; (4) Parking area.

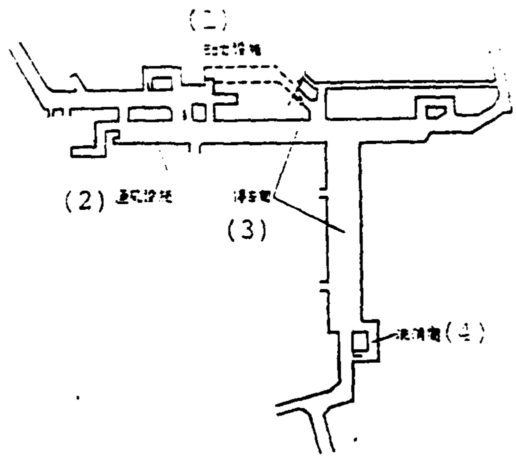


Fig. 6 Underground garage in rock in Finland.
Key: (1) Power facilities; (2) Ventilation facilities; (3) Parking area; (4) Washing and disinfecting room.

The limitation of the underground garage in rock is that the cave room can only be made into a single span and thus the layout of the parking area cave room is relatively dispersed, the distance between the cave rooms is relatively long and the area in the garage used for level traffic is relatively large. When the scale of the garage is relatively large, each parking area forms a long and narrow plane, the travel distance of the vehicles is relatively long and the moving of cars is not convenient enough. In order to overcome these drawbacks, we should especially pay attention to the rationality of the functionally separate areas in the plane layout and the convenience of the connections between each section. We should also organize the level traffic inside the garage well so that the vehicles enter and exit smoothly and avoid intersecting and going in the wrong direction. Aside from this, the number of cubic meters of dug out rock in the underground garage in rock is relatively large. The time limits for the projects are generally relatively long and the costs are relatively high ;

if there are conditions to use mechanized construction (e.g. full-face tunneling of a continuous operation) and relatively advanced structural forms (e.g. the spray anchor structure with bushings). These drawbacks can be overcome to a certain extent.

If an underground garage in rock is constructed in a city, it is suitable for public parking and special purpose parking. If built in the mountains on the outskirts of a city, it is then better for reserve parking. Because the protective capabilities are strong, the capacity is large and it is far from the city, it is only necessary to strengthen peacetime defense. It is very necessary for the vehicles storaged inside for a long time to be strategic reserves of the city.

V. Ramp and Mechanized Underground Garages

There are basically two types of garage transport: ramp transport and mechanized transport.

From the relatively early to the more recent quite modernized underground garages, it is very common for the main facility for vertical transport to be the ramp. Although at the same time the mechanized garage also underwent relatively large advances yet the ramp type garage has not been replaced by the mechanized garage. The main reason for this is that the cost of the ramp is low, the number and location is not limited, they can guarantee needed entering and exiting speeds, they are not influenced by machine and electrical movement conditions and they save on movement expenses; even more important, ramp type underground garages can guarantee non-interrupted movement during war and are not limited by energy sources and power conditions.

There are many types of ramps and the ramp types commonly used for above ground multilevel garages are basically used for underground garages. Among these, the more commonly used is the straight and long ramp because it is relatively simple in use and structure; there are also some which use the curve-linear ramp which are mainly used for transport between each level of a multilevel underground garage. However, the entrance and exit ramps which go to the earth's surface still use straight ramps so as to guarantee the safety and swiftness of the entering and exiting vehicles and to cause the cut open section to be handled quite easily. A small number of underground garages use straight half ramps (cross bedding type) or inclined floorslab to replace the ramp. These two types are relatively suitable for underground garages which have a relatively large number of levels or when used in included topography.

The main drawback of the ramp type underground garage is that it occupies very large construction area and indoor space and after adding a level driving passageway in the garage, the usable area used for communication transport occupies a very large proportion of the entire garage's total area. Based on Japanese materials, the area ratio of the driving passageway and parking places in the parking area approaches 0.9:1. This causes the area of the ramp type underground garage to use a coefficient greatly lower than other types of structures. Because of the increases of the area and volume, there are corresponding increases of the ventilation, water, electrical etc. facilities and it is necessary to have more managerial personnel. Based on Japanese materials, when comparing a completely mechanized underground garage and a ramp type garage (100%) with the same capacity, the occupied land area is 27%, each vehicle's average required area is 50-70%, the structure's volume is 42% and the ventilation quantity and the electricity used for lighting is only 17%. Therefore, within a certain time period, and under specified conditions, foreign nations have made relatively large advancements in mechanized garages, for example when the energy costs are relatively low and when the land used in the city is especially intense yet where they urgently require garages. The mechanization and automation levels are also becoming increasingly high.

In earlier mechanized transport underground garages, only elevators, lifts etc. were used for vertical transport and in the horizontal direction it was still required that the vehicles go by themselves. This only saved on the area of the ramp (the machine also required a certain area) and the level passageway still occupied a large area. Especially when there are a small number of levels, the full effects of the lift cannot be brought into play and the economic results are even less evident. Because of this, there has been a gradual development towards complete mechanization which is using machines for vertical and level transport and shrinking the area and space required for each vehicle to a minimum. In reality, the garage becomes a type of container for storing vehicles and it is basically unnecessary for people to enter the parking area. In this way, the superiority of the mechanized garage can be brought into fuller play.

At the beginning of the 1970's, Bajiula of Switzerland brought forth a "Luotuopake" type completely mechanized underground garage plan which was to transport the vehicles forward in a level direction on a conveyor belt and after it reaches the vertical lift position, it is then automatically changed and goes vertically up and down to the required position. See the schematic in Fig. 7.

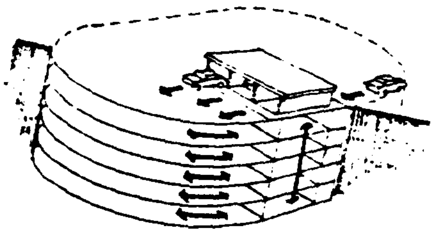

Fig. 7  Schematic of "Luotuopake" type completely mechanized underground garage.

Because this "Luotuopake" type underground garage is flexible, convenient, has a high automation level and good economic effects, it has very quickly gained popularity in over 20 nations. For example, in Japan, this type of completely mechanized underground garage was developed into a serialized final design. The different number of cycles of the level conveyor belt and the different number of levels of the garage together make up 75 different sized underground garage layout plans with volumes which range from 81 to 475 vehicles. It is called the three-dimensional underground garage and a complete set of electromechanical equipment is correspondingly produced.

In recent years, because the use of city land is becoming increasingly intense and the price of land is expensive, Japan has also developed a small scale completely mechanized and automated garage. It only has vertical cyclic transport, each vehicle is parked in a suspended cage on a conveyor chain, the volume varies from 12 to 50 vehicles, the layout is very flexible and it is called the tower type garage. It can be independently built in a narrow section with an area of only several ten square meters and it can also be attached to one side of a multilevel building. Because the tower type mechanized garage requires a relatively great height (the height reaches 50 meters when the capacity is 50 vehicles), the layout is not suitable underground. Therefore, the conveyor chain is changed to horizontal cyclic operations and when the vehicles separately parked on two levels on the conveyor chain drive to the entrance and exit they drive out after ascending to ground level. See the schematic in Fig. 8. This completely mechanized and automated underground garage with a horizontal layout has a capacity of 12 to 23 vehicles, a flexible layout, strong adaptability and occupies small land area.

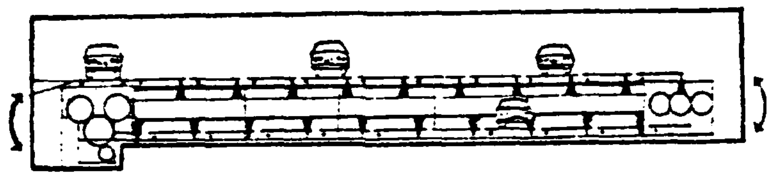

Fig. 8 Schematic of small completely mechanized underground garage.

Because the mechanized garage is limited by the mechanical operating conditions, entering and exiting vehicles require certain time intervals unlike the ramp type garage which can continuously admit and exit vehicles (two vehicles can be separated over 20 meters). Thus, during peak time, this possibly causes a relatively large number of vehicles and the vehicle owners going to fetch their vehicles to wait near the entrance and exit which can even create jams. In order to overcome this drawback, it is necessary to continually improve the facilities and quicken the machine's operating speed; yet even if this be the case, underground garages like the "Luotuopake" completely mechanized and automated garage can only shorten the time required for one vehicle to go in or out to 90 seconds which is still a relatively large discrepancy when compared to the ramp type underground garage which can enter or exit one vehicle every 6 seconds. This is the major limitation of the mechanized underground garage.

Although both the ramp type and mechanized underground garages each have their advantages and disadvantages, both can be used under certain conditions; yet when considering China's present industrial production level, energy resources and combat readiness requirements, within a very long period of time, the transport method of underground garages is still predominantly the ramp type. Naturally, under certain conditions, we do not eliminate suitable mechanization or the possibility of using simple and easy machines as auxiliary measures.

To conclude, we can sum up the recommendations for which type of underground garage can suit the developments given China's specific circumstances as follows:

1. Underground public garages and underground special purpose garages should be developed. The former should be predominantly used during peacetime and consideration should be given to its use during war; the latter should be designed based on wartime requirements and during peacetime its task is parking for nearby units and fully playing a role there.

2. Single underground garages should not be blindly constructed but should suit the requirements of overall city planning, integrate with the construction of a city's underground communications network and layout of a city's green areas as well as carry out rational overall arrangement of civil air defense project plans.

3. The construction of attached underground garages should be integrated with a city's basic construction plans as well as with the construction of large public structures or multilevel factory buildings, warehouses etc. and as much as possible rationally unify the underground and above ground column networks.

4. When conditions permit, garages built in the underground soil layers of cities should be multilevel, predominantly two or three levels, so as to save on underground space and raise the utilization rate of the land.

5. Cities with conditions should develop underground garages in rock. In cities, they can be public and special purpose garages and when on the outskirts it is advantageous for them to be strategic reserve garages.

6. Given the present situation in China, we should predominantly develop ramp type underground garages and when there are conditions, we can appropriately use machinery or simply constructed machinery as auxiliary measures for vertical transport.

References


[1] Design Materials for Multilevel Garages, Beijing Architectural Design Institute, 1975.

[2] Collection of Architectural Design Materials, Beijing Industrial Architectural Design Institute, 1964.

[3] Parking of Motor Vehicles, Brierley, J. 1962.

[4] Parking, Goffrey, Baker, Brund Funaro, 1958.

[5] Multi-Storey Car Parks and Garages, Dietrick Klose,1965.

[6] Parken, Park-haüser in der Stadt, Farmont, Hans, 1965.

[7] Parkbauten, Handbuch für Planung, Bau und Betrieb der Parkhaüser und Tiefgaragen, Sill,O., 1961.

[8] Garagen und Tankstellenbau-Anlage Bau, Ausstattung, Rolf Vahlefeld, Friedrich Jacques, 1956.

[9] Garagen und Tankstellen Bau, R. Vahlefeld, F. Jacques,1953.

[10] The Planning and Design of Parking Lots, Kongen Sei and Okuson Shuichi, 1978 Revised Edition.

[11] Special Architecture, Collection on Architectural Design Structures, No. 6, 1974.

[12] Collection of Architectural design Materials, Vol. 2, 1964.

[13] Architecture Series, Vol. 36, 1960.

References (continued)

[14] Examples of Parking Lot Structures, Reiboku Ichidan and Sasa Bokujun, 1958.

[15] «Подземные автостоянки и гаражи», Г.Е.Голубев, 1976

[16] «Проектирование городских гаражей», Э.М.Хевелев, 1961

[17] «Проектирование гаражей», Л.Н.Давидович, 1960

Periodicals

Architectural Record, Architectural Journal (English), DBZ, Schweizerische Bauzeitung (German), New Architecture, Everyday Architecture (Japanese), «Архитектура СССР», «Жилищное строительство», «Транспортное строительство» (Russian), L'Architecture Française (French).

# PROCEDURE PROBLEMS OF UNDERGROUND ENGINEERING CONSTRUCTION IN ROCK

Zhu Jingmin

Whether or not construction of underground structures in rock can be accomplished with small investment, a short construction period and construction and transport safety to a large extent depends on the stability of the rock cave but the central problem is how to bring the self-supporting capabilities of the rock surrounding the cave into play [1]. This has already been proven both domestically and abroad over the last several years through theoretical research and engineering practices. Because of this, during the entire process of surveying, design and construction, we must pay attention to bring the bearing effects of the surrounding rock into play. In the past, the design of underground structures only took the surrounding rock as passive loads which is also to say that the dead weight of the loosened rock is the load of the supporting structure and therefore is unrelated to the size of the load and the rigidity of the supporting structure. Because of this, in the past, the three stages of surveying, design and construction of the construction procedure of underground architectural engineering is fixed in proper order and unchanging which in common terms is "construction according to diagrams." This is completely the same as the construction procedure of earth surface architectural engineering. Not long ago, the journal Underground Engineering published a paper which proposed that "geological work should be done before construction and not after it" [2]. This idea denies that the surveying and design work of underground construction engineering can be completed at one time before construction. If considered in this way, this belongs in the domain of the old construction procedure of underground architectural engineering.

Underground architectural engineering in rock is done in the complex medium of rock and it is well known that rock is a natural geological substance. Rocks often have marked geological structure traces such as false conformity, non-conformity, bedding, faults, joints, cleavage, cryptofissures etc. These interface are called non-continuous surfaces or structural surfaces. They are the main causes for rock non-continuity and various directional differences; rocks also have natural internal stress which differ with the differences of the region, marked non-uniformity and thus they are the products of long geological effects [3]. As mentioned previously, the rock surrounding a cave room is a component part of the bearing structure and therefore before the cave room is dug out the design of the rock's shape and properties and support structure must be completely and precisely determined which appears to be impossible. Thus, in recent years, the effects of tests have been stressed both domestically and abroad for underground architectural engineering in large rocks. For example, the Fourth Meeting of the International Society of Rock Mechanics listed the testing and monitoring of underground structural design and construction in rock as the meeting's topic of discussion [5]. Below, we will briefly explain the reports given at the meeting on the relationship of each of the stages of planning, design and construction and the surveying tests.

(1) The Planning Stage and Target Tests. We use as much as possible existing materials to obtain geologic mechanical flat sectional drawings and rock classification sector drawings, and the regional characteristics of underground water and primary land stress. The rock classification sector drawings are determined by synthesizing on-the-spot observations, qualitative analyses and quantitative test targets. Underground water is first estimated from ground drainage means, river current, the appearance of spring water etc. and then hole drilling is used to monitor the underground water's location and slope descent or

we carry out pressurized water tests. Primary land stress is only inferred from measurements and tests carried out near the area. Target tests and geological charts require the use of a fast speed simple method to determine the physical and mechanical properties of the rock. The sequence must be first indoors and later outdoors. Afterwards, we then make a small number of test caves, test pits and drilled holes.

(2) Design Work and Design Testing. After obtaining rock target data and geologic mechanical sketch maps, we can begin designing. The method of design can use the empirical method, numerical value calculation or analysis method and model testing. On the basis of the analysis of each parameter of the rock, we determine the small number of "design tests" which need to be done. We can also add an experimental engineering stage for large scale engineering. Experimental engineering is a large model test or foot gauge test. It can be a part of the main body of engineering and can be carried out using guide pits or test pits and its main goal is to study and improve the digging and support methods. Support tests include testing the "quality control" of the structure's material, for example, roof bolt pull tests, spray concrete tests etc. The quality control and support design of the support system are monitored when in dug open test pits and test caves and we carry out regression analysis of the monitored results which is used to verify the design hypotheses and revise the main design.

(3) Monitoring and Quality Control of the Construction Stage. This includes three items: one is investigating the rock's quality indices and if there are discrepancies with the calculations we should revise the digging and support methods; two is verifying the support materials and installation method to guarantee the safety and long term stability of the structure; three is monitoring the digging and support systems to guarantee construction safety and verify whether or not the design is

rational. Because of the complexity and non-uniformity of natural rock, the underground conditions are not clear and thus based on test results we adjust the design and digging method of the support system. Table 1 lists the interrelationship of design, construction, testing and monitoring.

Table 1

(1) Planning and Construction: planning design, feasibility research, initial design, experimental engineering, technical design, construction range, construction, revised design, reinforced engineering, regression analysis;

(2) Mechanical Analysis of Rock and Soil: evaluation of existing materials, surface exploration, underground exploration, calculated model, physical model, experimental digging, experimental support, evaluation of materials:

(3) Collection of Data: target tests, underground water research, surveying of non-continuous surfaces, rock and soil classification and geological maps, determination of land stress, design tests (laboratory/on-the-spot), monitoring, quality control.

A Xinao method, the tunnel digging method, is presently widely used both domestically and abroad. The essence of this method is to as much as possible bring the self-supporting capabilities of the rock surrounding the cave room into play and the special feature of its construction is after digging the cave room, the support is completed by two lining [6]. The first lining is generally composed of two sections, the sprayed concrete and the roof bolt. The faster the time of support the better and as soon as it is dug up we immediately carry out support. The time of the second lining support is longer than the first time and it is necessary to wait until after the layer is stable to carry out support. The design of the first lining is calculated according to engineering geological exploration data and during the digging process we change the design at any time based on the changes of the engineering geological situation and calculated data. Therefore, on-the-spot calculations are very important for the Xinao method. They can only serve as data for the first lining design and they are also important parameters for determining the second lining.

We can see from the above discussion that it is impossible to complete the exploration and design work of underground architectural engineering at one time before the construction. For example, Johansen accurately proposed that during building construction it is necessary to appraise the stability of each site's cave room and thus determine the suitable support measures for this site's cave room. If it is not done in this way, the formulations made beforehand will be harmful [5]. We can see from this that during the construction process of underground architectural engineering, the three areas of surveying, design and construction should be closely integrated. By regulating the design and construction methods of the support system based on the engineering geological situation, we can attain the anticipated goals of economy, safety and short construction period. However, the surveying design procedure of rock caves is presently still a problem of surveying.

References


[1] Zhu Jingmin and Bai Yuanchang, Analysis of Rock Cave Stability and Summary of Support Structure Design Construction Methods, Underground Engineering, 1980, No. 12, 1981, Nos. 1,2,3.

[2] Liu Yiyuan, Construction Geological Work of a Certain Underground Water Sealed Rock Cave Oil Depot, Underground Engineering, 1981, No. 11.

[3] Chongqing College of Architectural Engineering, Tongji University, Rock Mechanics, Chinese Architectural Industry Press, Oct., 1981.

[4] Zhu Jingmin, The Elacticity of Rock Caves and the Viscoelastic Plasticity Stress - Strain Model Theory, Journal of the Chongqing College of Architectural Engineering, 1981, No. 3.

[5] Rock and Soil Mechanics Institute of the Chinese Academy of Sciences, Chongqing College of Architectural Engineering, Collection of Translated Reports from the Fourth Meeting of the International Society of Rock Mechanics, August, 1980.

[6] Gang Xingjun and Yingyuan Shengyan, A New Type of Lining Design Method - the Xinao Method Underground Engineering, 1981, No. 2.

[7] Gumu Qinbo, The Xinao Method Design and Problems of Construction and the 22 Point Principle of Dealing With the Situation, Collection of Translations on Tunnels, 1980, No. 5.