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09 May 1984, 2:00 pm - 3:30 pm

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### Recommended Citation

Shitao, Hou; Siyi, Wang; Jibing, Zhou; and Kezhi, Cao, "A Case of Land Use and Urban Planning in the Expansive-Soil District" (1984). *International Conference on Case Histories in Geotechnical Engineering*. 1. <https://scholarsmine.mst.edu/icchge/1icchge/1icchge-theme8/1>

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# A Case of Land Use and Urban Planning in the Expansive-Soil District

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**SYNOPSIS** Taking the construction and reform planning for new town of Yunxian County as an example, this paper deals with the principles of land development and use and town construction and reform planning in the expansive-soil area in the case of undulating mountain topography, including the problems of treating expansive-soil slope, of treating expansive-soil foundation etc., not involving other aspects of general planning.

## INTRODUCTION

Yunxian County, locating at the communication hub of Hubei Henan, Shanxi and Sichuan provincial boundaries, is an important town in the northwest Hubei Province.

Owing to construction of Danjiang Reservoir, former Yunxian County town was moved northward in 1958. Due to lack of knowledge of the site geology, especially the expansive soil, the new buildings of several hundred thousand square meters were damaged and caused a lot of loss. So reforming and rebuilding this town becomes a big topic of land development and use for the expansive soil area. The construction planning for the new town of Yunxian County is described as follows:

## TOPOGRAPHICAL AND GEOLOGICAL CONDITIONS AND EXPANSIVE SOIL

The new town of Yunxian County locates at 119° 34' east longitude and 32° 54' north latitude. The area for planning is 4.8km like a peninsula with three sides facing Danjiang River and one side backed by Black Rock Hill.

The site is shore deposit terrace, the surface of which has been cut into some ridges and gullies with south-north strike. Later disintegration caused east-west ditches in the ridge and the whole area seemed like a rib, with hill on one side and ridges and slopes on other sides. (See Fig. 1 and Fig 2)

The Black Rock Hill at north is over 270m above the sea level and has a gentle slope on the front side. The terrace surface is 150-220m above the sea level, generally 50-200m wide, gently sloping Southward. General slope is 2-6°, averaging 5°. The gully width is generally 100-500m, the relative deviation is 25-45m. The land slope between ridge and gully is 5°-18°, averaging 14°. There is a bigger or smaller

ditch at every 80-160m in the ridge. The ditch width is about 15m. Narrow and gentle ridge is between wide and stiff gullies, which form an apparent feature of the site topography. Statistically, the area with land slope less than 45° is 9% of the site, with 4.5°-11.3° is 41%, with 11.3-18.5° is 37% and over 18° is 13%. (1)

Black Rock Hill is composed of Sinian System dolomite. Its front slope is also dolomite covered by a very thin layer of slope wash. The terrace rock is purple-red Tertiary sabulous psphyte, covered by 20-30m Quaternary layers, the main of which are downward as follows:

Quaternary Holocene alluvial deposit (Q<sub>IV</sub> d<sub>1</sub>-p<sub>1</sub>)  
The clay at terrace was disintegrated and washed to the gully. So clayey soil is the main part. But there is a lot of mixture and the thickness is small. Generally it is not used as supporting layer.

Quaternary Miocene and Pleistocene Pluvial deposit (Q<sub>III</sub> P<sub>1</sub>)  
Brown-yellow or brown red clay, generally 10-15m thick. Its main physical indexes are natural water content W=16.7-28.5%, volume weight  $\gamma=1.81-2.10$  g/cm<sup>3</sup>, void ratio e=0.545-0.860, liquid index I<sub>L</sub>=0.12-0. It is in half hard to hard state. When it is hard it has high strength and low compressibility. The fissures of the soil body develop well and the surface looks lustrous like grease and senses creamy. The soil body becomes expansive and soft when meeting with water, and shrinks and becomes hard when losing water. So it is expansive soil. Its swelling pressure P<sub>s</sub>=0.3-1.0kg/cm<sup>2</sup>, swelling amount V<sub>w</sub>=2-3%, shrinkage ratio e<sub>sg</sub>=10-20%. This layer is the main one of layers building up the site grade-III terrace, spreads widely and therefore is the main supporting layer for buildings. Since this layer is cut seriously and affects the slope greatly, a lot of buildings on it have been damaged.

Quaternary Miocene and Pleistocene alluvial

deposit ( $Q_{II}^{al}$ ): The upper part is yellow-brown lam, the lower is sand-cailloutis, altogether 3-8m thick. This deposit is beneath the expansive-soil layer and part of it outcrops on the foot of slope or at the gully bottom. It has large bearing capacity and low compressibility, thus the slope formed by it is stable and is a good natural foundation. So the outcropping area of this layer is a better construction site

A series of engineering geological problems were brought about by wide distribution of expansive soil in this planning site. They are mainly slope sliding, earth mass gliding and land cracking etc. Slope slide occurs generally due to expansive-soil layer at the ends and on the sides of the gully, and is a small, shallow and plastic slide. Land cracking often extends along slope Shoulder. Earth gliding and sliding sink can be seen everywhere.

Frequent occurrence of harmful geological phenomena severely damaged the site topography and endangered buildings. Some of building failure are directly caused by harmful geological phenomena such as slope slide, but more are due to frequent, repeated rising - sinking, expanding-shrinking deformation of the expansive-soil foundation. According to research this deformation is cycled yearly. The deformation amount relates to slope and differs at different locations of the slope. For example, for the flat area with ground slope less than 5°, the annual deformation amount is 1-3mm. For 5°-12° slope, the amount is 5-10mm, while for over 12°, the amount reaches up to 30-50mm. In general, slope sinking-shrinkage is greater than rising-expanding until the slope is levelled to a stable angle. (3) Buildings failed mostly in groups of which those on the outward side and facing the sun were damaged more and severely while those on the inner side and with back to the sun were damaged less and slightly. In view of topographical features of site where buildings located, failure is quick and severe near slope shoulder at gully ends where topographical difference is great, whereas failure is less and slight in relatively flat area. In regard to building structure, low-storeyed brick structure with strip foundation is apt to failing. (4)

In summing up the above, it can be seen that expansive soil, especially its nonuniform, cycled, enormous expanding-rising and Shrinking-sinking deformation intensified by rising-falling topography, exerts common damage to buildings. Besides, various harmful geological phenomena led by expansive soil directly damaged site, threatened the safety of building and thus became the most important problem in land development and use and in town planning and construction.

#### LAND USE TOWN PLANNING

Yunxian County town is the political, economical and cultural center of Yunxian County, as well as the center of goods collecting and distributing and communication center for Hubei, Henan, Shanxi, Sichuan provincial boundaries. Flourish-

ing highway and Hanjiang River-Danjiang Reservoir water transports are convenient for town development. Its main business includes collection, distribution and processing of Northern local and special products, maintenance and repair of lorries and cargoes and spare parts production. The emphasis of construction and reform is placed on the buildings for cultural, educational recreational and living purposes of the people. The whole town would be built into a mediumsized county-level town with planned population of 50,000.

With consideration of undulating topography and wide distribution of expansive soil, the general principle of land development and use is: dividing the area functionally and reasonably according to different geological formations; using the land multi-levelly in the light of topographical features. Practical engineering measures should be taken to eliminate or lessen damages of expansive soil so as to make full use of land and work out a realistic town planning. Based on this, functional section-dividing plan is as follows:

At Black Rock Hill foot the field is flat with Sinian System dolomitic limestone shallow-buried which is a good base for heavy buildings as well as fine building material. Hence this area is planned for industry. From half way up to the ridge, there are luxuriant trees and wonderful rocks and a marvellous view over the whole town. So it is a ideal scenic spot.

Down following Black Rock Hill are long and narrow ridges named Wuyang Ridge and Sijiou Ridge, which are high in topography and ideal passage for highway and to town. All streets in town are arranged south-north along ridges and valleys. Using the earth from levelling the ridges to build dam, adding grade separation structures to connect ridges in the planned area and constructing east-west roads, in town, thus a convenient highway-road net is formed. In the shallow valleys among ridges and dams, artificial lakes are worked out and equipped as public park for residents to have a beautiful recreation resort.

The intersection place of the broader ridge and other ridges such as Zhong Ridge etc has a flat field with gentle slope and a thin layer of expansive soil. After a little treatment, this is a good construction site for government administration cultural and educational buildings. Valleys and gullies here are shallow and general topography is flat. Clayey sand and gravel etc. are most outcropped. Such layer has high bearing capacity and low compressibility and is good for multi-storeyed high buildings. Therefore, here is planned as the commercial and residential section and building density can be appropriately increased so as to be the main part of this town.

With regard to the sloping area between ridge and gully, with high slope and the expansive-soil layer as the main one, it is considered that the natural topography should be maintain-

ed as much as possible and artificial disturbance to expansive soil should be reduced. Thus parallel contour strip shape exploration method is employed and different size and length are applied. After appropriate engineering measures, here administration and institution buildings and resident houses are set up in layers and in blocks. Communication here takes small passage as the main one. With the addition of grades, pedestrian culvert, cableway etc., the communication net inside the town section is formed. Along Danjiang Reservoir bank it is quite steep, but the extending part of Wuyang Ridge, Xijiouli Ridge into the lake is not so high and rather flat. The foundation is mainly of unexpansive soil such as clayey soil and sandstone etc. and so the convenient site for quay and large-span warehouse.

Now we can see this town plan makes full use of topography, takes reasonable consideration of geological conditions and has a distinct functional division. (See Fig 3)

Arrangement of buildings should follow the principles below: First, buildings should be parallel to contour as much as possible so as to avoid heavy cutting/filling earth work. Then they should not be in the section such as gully ending, filled pool bank etc. where is potential slope slide, crack, gliding or collapse. Levelling of the construction site should fully reserve natural drainage system and slope vegetation in order to keep expansive-soil stability and foundation uniformity.

Selection of building size and height must put into consideration the expansive-soil distribution and expanding-shrinking potential. Heavy, high buildings, or with underground structure are built in the section with great expanding-shrinking potential; low buildings such as resident houses and pavillions are built in the section of small potential. For the buildings extremely sensitive to nonuniform deformation, Section of thin expansive-soil layer or unexpansive-soil are chosen. Single building should have a simple form, but various forms of Single buildings should be employed to make the building groups not so monotonous and dull.

In a word, reasonable land usage and proper single building arrangement and form selection are two important aspects for town planning in the expansive-soil area.

#### EXPANSIVE-SOIL FOUNDATION TREATMENT

Macroscopically in dealing with expansive-soil foundation, new town of Yunxian County construction follows the principle of "treating water before soil, gully before water, slope before gully, and foundation after slope". That is, expansive-soil foundation deformation is controlled by water. Key point of treating water is drainage, i.e., the drainage system including ditches and channels. Since the planned area has ridge-gully topography, treating gully is not only for drainage but also for using the

land of gully and valley. However, treating gully depends on slope stability. Stable slope can guarantee unblocked and accessible gully as well as safe and stable building on the foundation of expansive-soil. So treating slope is the key to construction in expansive-soil area.

The emphasis of treating slope is prevention, i.e., protection of natural slope surface (including the natural drainage system) and reasonable selection of artificial slope degree. In exploration and survey work for new town of Yunxian County planning, 182 profiles were measured and natural stable slope is averagely  $14^\circ$ . Reversely calculated on the base of 74 slopesliding bodies in China, the comprehensive  $\phi$  is  $22^\circ$ , minimum is  $9^\circ$ , average is  $14^\circ$ . Hence it is fixed that natural slope of about  $14^\circ$  does not need treating; artificial slope without retaining structure within  $14^\circ$  can be regarded safe; natural and artificial slope above  $14^\circ$  should have retaining structure designed on calculation. (3)

Protection of slope surface is an important link of slope stability, including planting trees, covering (keeping-moisture engineering measure), retaining (sliding-resistant engineering measures) and setting-up complete drainage system (slope top pirate ditch, slope surface catchment ditch and slope foot drainage ditch etc.) Besides preventing from erosion, the more important action of slope-surface protection is to stabilize the slope soil mass. Observation has already proved that deformation amount of slope without protection is always 2-3 times greater than that of slope with protection.

Treating slope includes exploration and use of slope surface land too. Ridges are narrow and gullies are deep in Yunxian County. After roads were completed on the narrow ridges, slope surface was used applying the principle of "stairs", i.e., exploration of strip-shaped land parallel to contour, and building up houses on terraces. The former is suitable for gentle slope whereas the later is suitable for scattered steep slope. In the later form, the gable of the house on the lower terrace is the retaining wall of the house on the upper terrace. Thus it protects slope stability as well as house safety. Many houses were built in this way in Yunxian County area and almost no damage occurred. So this method is worth applying.

Another problem of exploring and using the slope land is the safe distance of construction on slope shoulder. Survey work shows that ground deformation amount at slope shoulder is the maximum in the whole slope. Besides, cracks develop around here and cause great harm to buildings. It is observed that if natural change of water content at 10m from slope side is 1%, then that at 6m is 2.8%, that at 2m is 3.8%. Generally cracks develop at about 5m from slope side. Hence, the safe distance of buildings from slope without protection must be over 6m. But it is too long for Yunxian County area where land is very scarce. As a result, retaining structure for protecting slope is used to reduce the safe distance and to save the land.

Stable slopes guarantee the use of gully and valley. The gully and valley in Yunxian County are relatively wide and spread gently to Danjiang Reservoir. While a good drainage System is built in gully, street is opened up at the gully bottom. Terraces are cut on both sides for building houses. Thus, rows of houses, higher and lower, can be seen both from the street and from the highway on the ridge and it is a striking feature.

Various treatment of expansive-soil foundation depends on different condition in construction. With regard to thin layer of expansive soil, changing soil or deep foundation passing is employed. On the relative flat and wide expansive-soil terrace, depth of foundation must be greater than the depth of severe effect of atmosphere (1.50-2.00m). If the building is near slope, the angle between the connecting line of foundation bottom and slope foot and the horizontal line must not be over 5° and drainage work should be done, For buildings near slope shoulder or on the surface of rather steep slope, pier foundation larger than 2.5m or 3-5m pile is employed. With respect of general building, ground ring beam is set whereas ring beam in storeys plus structural column are used for important buildings or those on the section with great expanding-shrinking potential. Under all conditions it is very essential for buildings on expansive soil to have a good drainage System around and to keep the pipes safe.

For safety of buildings, centralized planting trees, flowers and grass in sections, i.e., in parks, banks of reservoirs and artificial lakes etc. For sidewalks, the trees which need less water must be chosen, and bush flower and grass should be planted as much as possible, Around apartments the space between trees must be greater than the height of grown-up trees. Sod must be grown widely to reduce the evaporation and keep foundation soil moist, and maintain building and roads safe.

Guided by the above rules in planning, the new town of Yunxian County construction has made great achievements after several years of efforts. Now such phenomena as dancing dust, muddy roads, cracked houses and collapsed slopes can not be seen any longer. The idea is past that town can not be developed in expansive-soil area. A beautiful town by Danjiang Reservoir, backed by hill and with attractive environment has stood up.

Construction of new town of Yunxian County provides a practical case of success for land exploration, use and town planning, construction in the expansive soil area.

The manuscript of this paper was written by Hou Shitao

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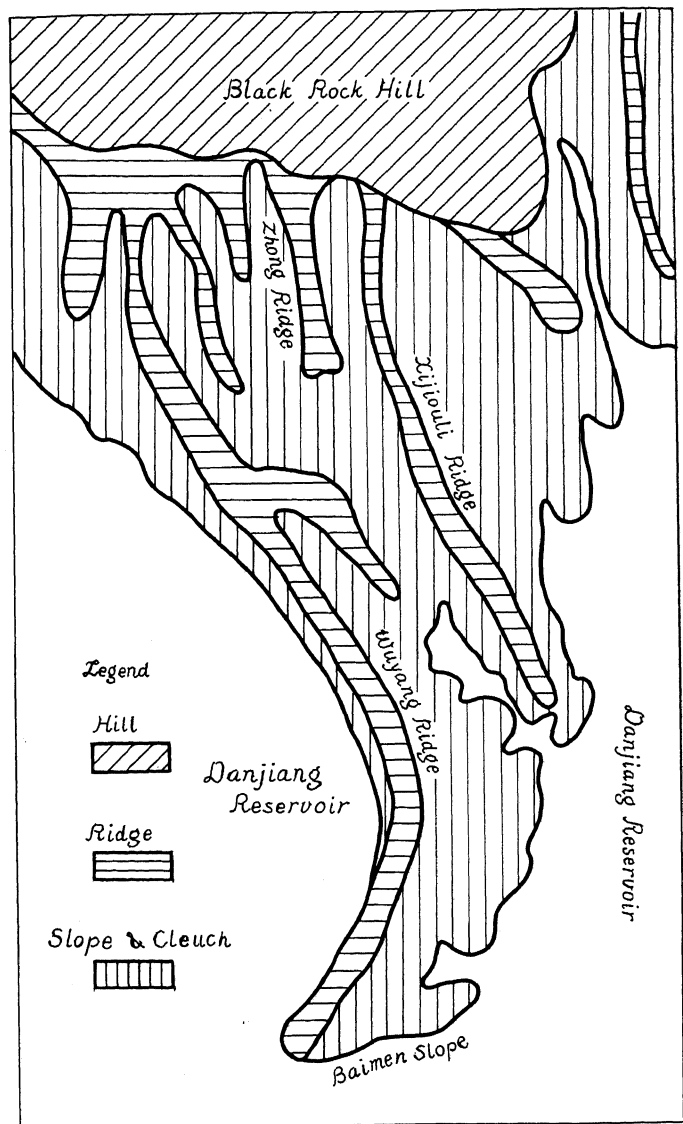


Fig 1. The topographical and geomorphological constructed plan of Yunxian County.

Scale 1:25000

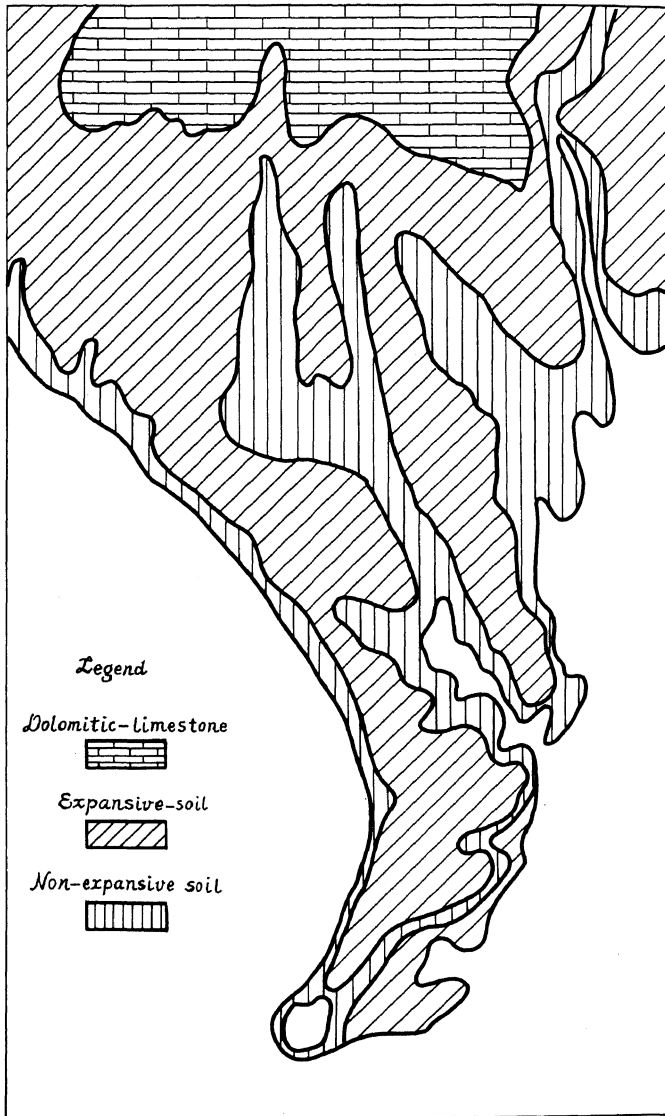


Fig 2. General plan for new town of Yunxian County.

Scale 1 : 25000

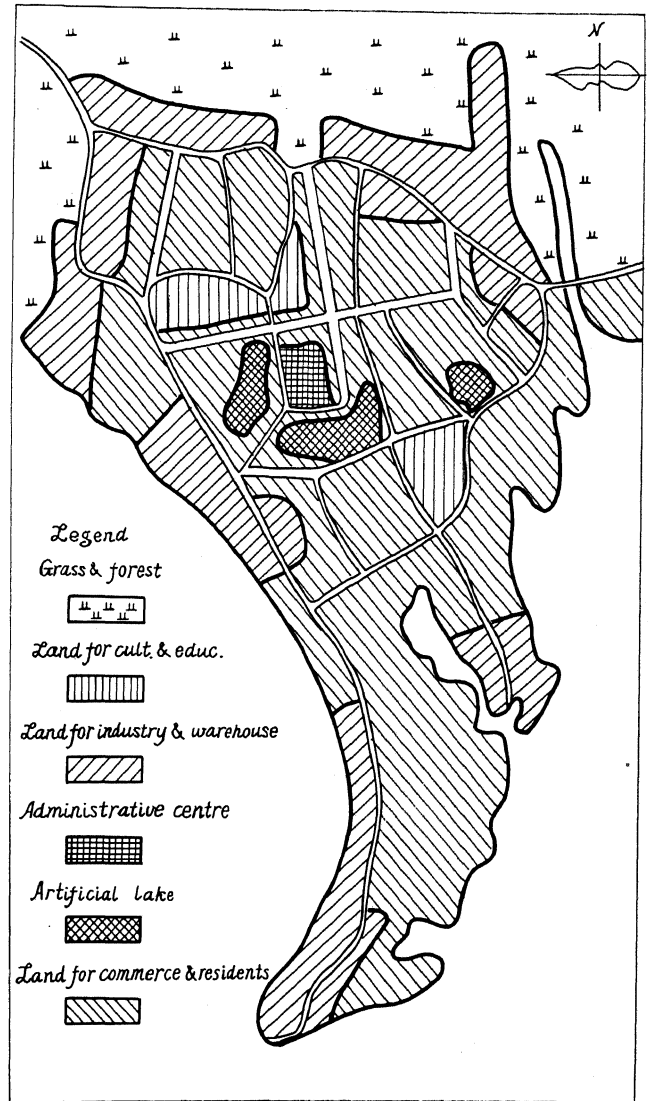


Fig 3. The plan of land use for new town of Yunxian County.

Scale 1:25000