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TREATING THE EXPANSIVE SOIL SUBGRADE ON THE GOAF OF MIDDLE-SHALLOW LAYER BY DYNAMIC COMPACTION WITH GEOGRID REINFORCEMENT

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ABSTRACT

Middle-shallow layer goaf left after the excavation of small coal mines in expansive soil areas always brings much trouble to expressway construction, the section of K21 +400~K22 +550 of Nanning outer ring expressway under construction faces such a situation. Based on the grasp of geological condition of the goaf, related national technical specifications and existing technical research about treatment, the dynamic compaction with geogird reinforcement method is applied to settle the roadbed with a good result showed in the field testing. This paper introduces the geological condition and stability evaluation of the goaf, and emphatically presents the technical note, construction procedure, quality inspection of the dynamic compaction with geogird reinforcement and the filling method of the upper expansive soil subgrade, which can offer a reference for the similar treatment projects in other expansive soil areas.

INTRODUCTION

Goaf is refers to the empty area which buried in underground mineral resources be after mining,and be divided into old, now and future goaf three categories according to the time mineral resources has been mined. For the old goaf, the surface residual settlement unpredictable because of mining time, exploitation quantity and mining area are difficult to determine,and bring much trouble to highway construction. Especially the surface subsidence, flex and collapse of goaf, have great influences on the subgrade and pavement.At present, for less than 10m mining depth of shallow goaf, dynamic compaction method is generally adopted to treat the goaf,and generally can receive good resurts; blasting roof rock and backfill after dynamic compaction method is applied to the middle-shallow layer goaf field, but the construction method is miscellaneous and it will consume much manpower and material resources in a way.The paper take the middle-shallow layer goaf which located in Nanning outer ring for example,introduces how to select the appropriate method accoring to specific geology, adopts dynamic compaction with reinforcement method successfully built gob highway roadbed, emphatically presents the technical note,construction procedure of the dynamic compaction method and how to determine the foundation bearing capacity after dynamic compaction through shallow treadmill test.

GOAF GEOLOGICAL SITUATION

Mined-out area is located in Guangzhou to Kunming highway Nanning № 2 contract section of K21 + 400 to K22+550, geological exploration shows that this empty of the formation lithology is mainly for the tertiary mudstone mixed powder sandstone,the thickness about 3 ~ 8 m, according to along the line sampling test results, the majority of the rock is weak in expansibility.

Road surface obviously have a trace of coal mining, mainly take shaft form of shallow coal seam mining,and the depth are less than 30m. Thrrough the surface survey,there are five shafts which the diameter 1.0 ~ 2.0 m, depth is 5~8m, 8 Collapse pit which are abandoned small coal pit shaft collapse. The extension direction of the roadway is about 230~350°, and length is 10~20m.

The excavation of goaf roadway or mining surface generally around the shaft coal,and the abandoned shaft has been mostly artificial or collapse filling.Surface of the goaf area produced large collapse pit, edge of the subsidence area have tension crack distribution,but the three zones characteristics of goaf performance is not obvious,only find caving zone and fissure zone which direct surface without bending zone. The drilling prospecting mined-out area most have collapse and the same geotechnical and groundwater have been fillied, infer the depth is 8m to 15m.

Analysis the K21+400 geological section ,can obtain its geological structure as follows: upper 0~6 m is high liquid limit clay, the 0~3.9m is surface miscellaneous fill, 3.9~5.2m is gray expansive soil (Moderate swelling) ; 5.2~6m is the goaf layer; the second layer 6~10.4m is silty mudstone, the 7.4~7.9m is yellow sand layer,and 9.2~10m is sandstone layer, the rest is pewter expansive soil; the third layer of 10.4 ~ 13.4m is pewter extremely soft mudstone (weak swelling).

Figure 1 marks the goaf's distribution of shaft and trap hole,and diagonal section shows influence sphere of the mined-out area,which can be roughly divided into three small section, meanwhile distribute 8 coal pit in hole(C01~C08), 5 mouth shaft（S01~S05）.Diagram of oblique line shows the area where need to be treat.

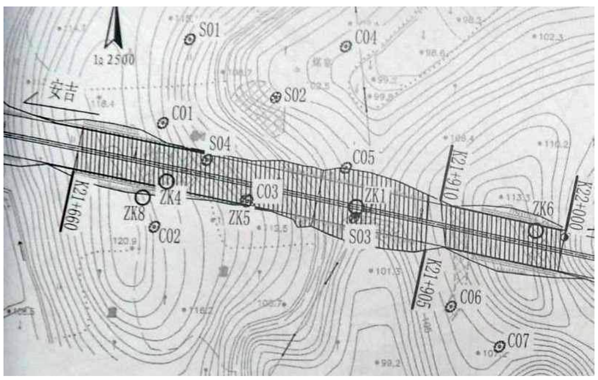

Fig.1 Plane design of the Goaf

GOAF STABILITY EVALUATION

According to the gob roof safety thickness calculation , when the roof is not slump or slump fill residual roof thickness , critical depth of the roof strata which maintain its stable can be determined form the following formula[4] :

$$H_0 = \frac{B\gamma + \sqrt{B^2\gamma^2 + 4B\gamma P_0 \tan\phi \tan^2(45° - \frac{\phi}{2})}}{2\gamma \tan\phi \tan^2(45° - \frac{\phi}{2})} \quad (1)$$

Formula parameters：

B—Roadway width（m），according to investigation take 2.5 m

P_0—Subgrade base unit pressure(KN/m^3)，including road self-respect and dynamic load reduced pressure

γ—Rock severe(KN/m^3),Geotechnical layer take 21.7 KN/m^3;Pavement layer take 26.0 KN/m^3

ϕ—Strata movement Angle（°），take rock Angle of internal friction for 20°

The maximum design fill thickness of goaf roadway section can reach 10.2m, while the largest excavation depth is 9.0m, according to the most advantageous situation, take roadway span B=2.5m, assuming that the roadbed fill 0 m, calculate subgrade base unit pressure, can get the minimum critical depth is 17.8 m. According to the survey data, goaf roof thickness H is in 4~23m range, so the subgrade of goaf is in unstable state, it must be treatment so that the upper subgrade can be constructed.

Within the scope of the goaf roadway and mining surface mostly irregular, did not support or temporary support on the basis of survey data ,and most are in unstable state, generally can take some ways such as: excavation exposed backfill, dynamic compaction, reinforcement, pressure grouting. Comprehensive analysis of the actual geological condition mined-out area, to ensure that under the influence of surface and groundwater, the subgrade don't produce craze and slump destruction , apply the new technogy method— dynamic compaction with geogrid reinforcement method for the goaf treatment.

Figure 2 is the Cross-sectional figure of the goaf treatment and is a typical semi-filling and semi-excavating roadbed, among of which, taking excavation exposed, backfill round gravel compaction for shallow goaf.

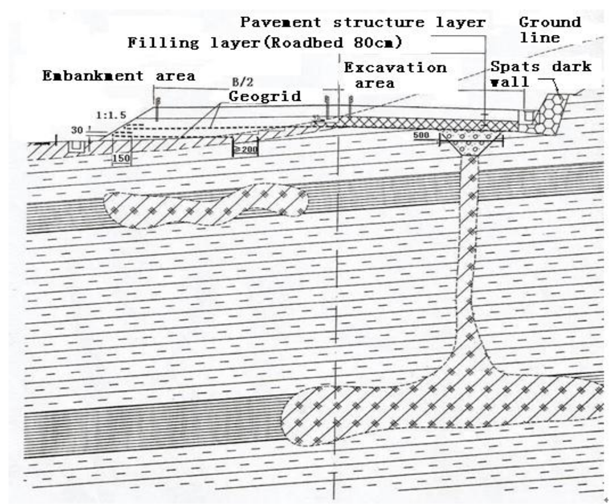

Fig.2 Cross-sectional figure of the goaf treatment

DYNAMIC COMPACTION WITH GEOGIRD REINFORCEMENT

As for shaft or trap hole within the scope of roadbed, after excavation butterfly pit of diameter—5m, depth—2m, backfill round gravel and compaction; while shallow buried goaf affected zone , backfill round gravel and compaction after excavation butterfly pit, the filling area also excavation into a dish, mouth of the cave shouble be above the affected zone line 2m outside.

Trial rammings

Firstly choose a representative area (not less than 20 m × 20 m) used to trial ramming before dynamic compaction, later inspect the effectness of dynamic compaction, if do not comply with the design requirements, the design parameters need to be adjusted.

Dynamic compaction construction

The depth of the mined-out area is about 8 m ~ 15 m, through the MeiNa formula estimate effective strengthening depth H:

$$h = \alpha\sqrt{WH}$$

Formula parameter:

H—effective strengthening depth, m;

W—rammer quality, t;

H—rammer fell distance, m;

α — effective strengthening depth correction coefficient, usually take for 0.5

There are many factors that affect the effective strengthening depth, in addition the hammer quality and its falling height, but also nature of the foundation soil, different soil layer thickness , buried sequence and underground water level, etc. Comprehensive consideration of the above factors, the rammer's size and specifications as follows: circular bottom,diameter 2.2m, height 1.0m, quality 26 tons, and also have two air flow with the diameter of 0.4m. In the construction of tamping,taking combination of grid jump tamper and full tamper ways. The effective design strengthening depth is 8.5m, Lamping energy is 3640 kN/m for point tamper (fall from 14m); while low energy full tamper adopts 650 kN/M (fall from 2.5m), according to trial ramming and roadbed practical situation .

The dynamic compaction process for three times, the first and second time take 5 ×5 m grid mesh lamping arrangement.

The tamping frequency of each point is determined by the maximum tamper hole deflection,the minimum surrounding ground uplift and the last two strike average settlement in less than 50mm to 100mm. By Tamping times and tamper subsidence relationship (figure 3) to determine the number of hammer point is 9.

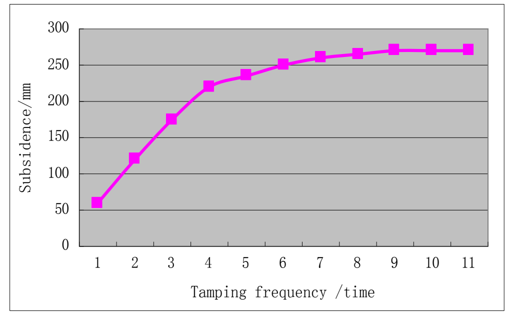

Fig3. Tamping times and tamper subsidence relationship

In the process of construction, surveyors make record of each point and tamping rammer sink quantity using level, when average settlement of last two or three hits reach the prescribed scope, that can complete a single point of tamping; At the third time, make use of the low energy struck again. Every time after dynamic compaction 7 days should detect the effect of dynamic compaction, go on the next time tamping after inspection qualified. Figure 4, figure 5 are the stationing schematic diagram of point tamper and full tamper.

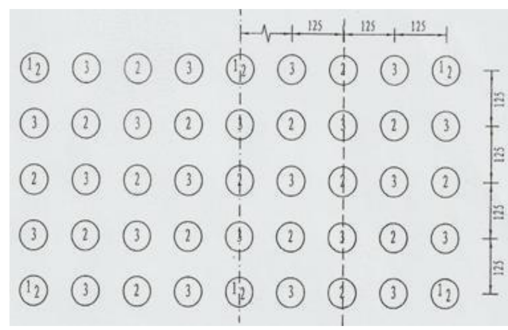

Fig.4 Layout of Point-ramming chart

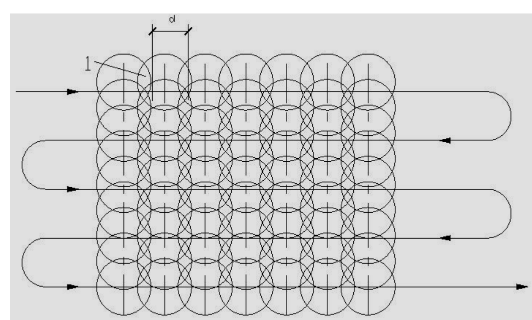

Fig.5 Layout of Full-ramming chart

Dynamic compaction construction note

In the construction, it need certain time interval between every two times lamping, in order to make the excess pore water pressure to dissipate, and the interval time can be maintained according to the permeability of the foundation soil ; if new collapse affected zone appeared in dynamic compaction process, it need to add aggregate (round gravel) and compact again , until stable; dynamic compaction will produce certain vibration for foundation and surrounding buildings, the vibration isolation trench will be excavated between the rammer and surrounding buildings, the groove depth must be greater than depth of foundation, and have sufficient length to surround the dynamic compaction site; as for larger buried goaf or sections which the dynamic treatment effort is not good, it should carry on the grounting reinforcement.

Inspection of quality

Seven days after the completion of dynamic compaction, shallow plate loading test is applied to evaluate the effect of tamping, which the foundation bearing capacity is requested to be no less than 180 KPa.

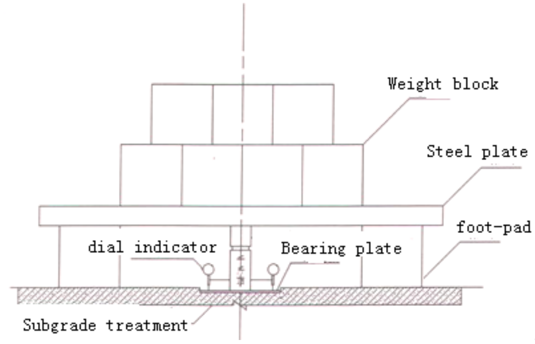

Fig.6 Shallow plate loading test apparatus

Shallow plate loading test apparatus is shown in Figure 6,steel assembly beam is used as the bearing platform, 40 tons concrete block is used as the counterweight on the upper apparatus, the steel plate for bearing platform with side length of 0.71m and the bottom area of $0.5m^2$, the maximum load pressure is 360kpa.The settling volume of bearing platform in an hour is less than 0.1mm within consecutive two hours, which considers that the settlement of foundation reaches steady.

Table.1 Results of the Shallow Plate Loading Test

Serial number	Test dit	Corresponding settlement of the biggest test load		The bearing capacity characteristic value and the corresponding settlement	
		Max test load(kpa)	settlement（mm）	characteristic value（KPa）	settlement（mm）
1	K21+720 left 5m	360	5.35	180	1.93
2	K21+800 right 7m	360	3.07	180	0.85
3	K21+890 right 6m	360	11.86	180	4.83
4	K21+960 left 9m	360	5.75	180	2.48
5	K22+150 right 5m	360	9.81	180	4.48
6	K22+400 right 12m	360	7.53	180	3.52

The six shallow plate loading tests are completed in the goaf section, and result of the tests is shown in the following table. Seen from the table, when the maximum test load of 360kpa is loaded, cumulative total settlement volume of measuring points is from 3.07 to 11.86mm. Comprehensive analysis of P~S curves of the six test points, curves do not decrease significantly and drastically. According to the specification, load values of s/d = 0.01 is used as foundation bearing capacity value. Seen from Table 2, pressure values of each test point are all greater than180kPa when s=7.1mm with the settling volume of 0.85 ~ 4.83mm. It can be drawn from the load test result, the goaf section after the treatment of dynamic compaction method, foundation bearing capacity can meet the requirements of specifications and design.

Filling of upper subgrade and layout of reinforcement geogrid

The filling of the upper expansive soil subgrade is started after dynamic compaction and the quality inspection. when the height of embankment fill is less than 1m, the thickness of 50 ~ 80cm expansive soil near the surfaceshould be excavated and then replaced by non-expansive soil, which is finally compacted according to the highway roadbed construction specification.

For the reasonable and effective use of the expansive soil, the successful experience of the construction of expansive soil embankment soil research projects is applied in western area, and physical treatment program, non-expansive soil treating both sides of subgrade and expansive soil filling internal subgrade, is utilized to fill the expansive soil of goaf subgrade. In order to ensure the strength and overall stability of subgrade fill, the specific approach is as follow: the reinforced geogrid is laid in the bottom of fill embankment, 2 Layers geogrid is applied when the height of filling is Less than or equal to 10m, 3 layers for the height is greater than 10m and Less than or equal to 15m. According to the special geological conditions, 1 layer geogrid is laid in the bottom of road bed in the excavation section; geogrid laid in Cut and Fill subgrade is shown in Reference 4. Every two geogrid is connected by iron wire, and the overlapping length is not less than 15cm, the geogrid laying is operated in accordance with the relevant norms, and drape is not allowed. The soil surface laid by grid should be smooth and be strictly without the broken stone; dimension stone or other hard projections, and the maximum particle size of filler of grid layer within 8cm thick should not be greater than 6 cm.

EPILOGUE

Building highway subgrade engineering case in the expansive soil area of shallow goaf is rarely reported , this paper adopting dynamic compaction with reinforcement method on Nanning outer ring construction solve the technical problems, and easing the roadbed settlement , the bearing capacity of the foundation also have been imporved, new technology of physical treatment is also been used in expansion road embankment filling at the same, and treatment effect is quite good up to now, this paper will introduce the construction technology, technical points and the effect to detect evaluation method which provides other areas of similar engineering construction for reference.

REFERENCE:

Zhang, S and Zhao,B [2006], "Treating SmallShallow Mined Cavity with Dynamic Compaction",*Communications Standardization Issue*, 2006(9),pp.70-72.

"*China Association for Engineering Construction Standardization.Guidelines for Design and Construction of Highway Engineering in the Mined-out Area"*（JTG/T D31-03—2011）,Beijing: China Communications Press.

"The fifth book of Engineering geological investigation report for Nanning outer ring expressway",Guangxi Communications Planning Surveying and Designing Institute,2010.

Zhang Y.L. [2006], "*The latest engineering geology manual*". Beijing: Chinese Knowledge Press,2006.

"China Association for Engineering Construction Standardization",Technical Specification of Dynamic Consolidation to Ground Treatment（CECS 279:2010）, Beijing: China Planning Press，2010

Zhan W.T.[2011]. *"Study of treatment technology and design scheme of expansive soil subgrade for Nanning outer ring expressway"*,Rock and Soil Mechanics,2011, 32(S2),pp.359-365.