Journal of Mechanical Engineering Research and Developments
ISSN: 1024-1752
Website: http://www.jmerd.org
Vol. 38, No. 1, 2015, pp. 20-26

Discussion on Harm of Soft Soil Foundation and Treatment Measures a Case Study of Jinqin Highway

H. W. Du[†]* & S. S. Li[‡]

[†‡]School of Civil Engineering, Nanyang Institute of Technology, Nanyang 473004, China,
*Email: 577684259@qq.com

ABSTRACT: Located in the southwest of Guangdong Pearl River mouth, Zhuhai city is the core city along the west bank of Pearl River mouth with marine depositional plain as the major geomorphic unit and soft soil in large distribution. Due to particularity of geographical formation mechanism, the soft soil here is of high moisture capacity, high compressibility, lower bearing capacity. Zhuhai golden harp in the north of highway Starting from Golden Harp in the north of Zhuhai city and ending at Hengqin Port, the engineering project of Jinqin highway goes through various water channels and seaboards with very complex geological conditions. Through understanding the harms caused by soft foundation in highway construction as well as related treatment measures, we put forward reasonable treatment measures for the problems caused by soft soil foundation, especially the application of cement mixing pile in soft foundation treatment problems so as to achieve the higher smoothness, safety and durability in construction of highway.

KEYWORDS: Highway; Soft foundation; Harm; Treatment measures; Mixing piles.

INTRODUCTION

Generally, soft soils refers to those fine soils with rich water content, high compressibility, low bearing capacity and low anti-shearing strength such as sludge, mucky soil, peat and cumulosol [1-4]. The unique characters of soft soils leave them hardly to be compressed firmly or even merely compressed by the gravity of themselves. Sludge and mucky soil, as soft soils, remain in soft plastic state under normal conditions, but will be easily damaged due to their unstable structures. Moreover, once being disturbed and damaged, they will suffer sharp reduce in strength as far as to zero bearing capacity, even turn into flow state [5-8]. Therefore, the consistence of sludge and mucky soil actually remain in underflow sate. Common treatment measures for soft foundation are (1) Replacement; (2) Drainage concretion method; (3) Dynamic consolidation; (4) Cement mixing piles; (5) Cement fly-ash grave pile; (6) Chemical churning pile method.

REASON ANALYSIS ON DAMAGES CAUSED BY SOFT SOIL FOUNDATION

Reasons for engineering qualitative accidents of soft roadbed are briefly summarized as follows [9]:

(1) No scientific feasible study on highway construction was given in the earlier stage, which led to a hasty construction without clear knowledge of the geology, hydrology and climate of project site.

(2) According to the classification of roads, the national legal design qualification of the design unit should have been required. In addition, another chief trouble in highway design is the designer's failure of performing the design work on the basis of the actual condition of the project.

(3) Negligence and irresponsibility during the road construction.

(4) Project supervisor fails to perform its rights and obligations, nor be strict with quality.

(5) Object causes.

(6) Foundation soils in bad environment.

Danger Control of Highway in Soft Soil Area

Controls of Bridge Bump

To avoid the occurrence of bridge bump, following aspects need to be controlled. First, the thickness of the pavement structure layer should be designed as low as possible on the premise of meeting specification requirements, and materials with large compressibility should be avoided; second, in the case that the roadbed settlement is unavoidable but predictable, a reverse ramp can be preset in the joint section of the main bridge and normal pavement; or in the case that the roadbed treatment is too difficult and energy-wasteful, the transition pavement can be used for basically finish or stabilization of settlement before the real pavement is constructed [10].

Controls of Differential Settlement of Pavement

Preventive measures regarding the root cause should be given to avoid differential settlement of pavement, and specific measures available at the soft foundation treatment stage are:

(1) According to design requirements, the sedimentation rate should be known well so as to control the preloading time, and unload should be done with adequate time.

(2) The compaction degree of the roadbed, pavement base and subbase must be guaranteed, and the levelling cannot be judged by visual inspection.

(3) Soft foundation treatment should be standardized and under observation, and move to the next procedure after the stabilization of settlement.

Notes on Soft Foundation Treatment

(1) Clean and tidy construction site, scientific method of drainage, gravel bedding with enough strength and good gradation, and satisfied permeability.

(2) The specifications of the geotextiles used for reinforcement should meet the requirements of design and relative specification requirements, and materials on site should be attached with certificate of quality.

(3) Machines, tools and instruments used for settlement observation should be embedded prior to construction of soft roadbed, and observation should be done based on the index provided in the design.

(4) Abutment piles, culvert and passages at the soft roadbed should commence following the finish of soft foundation preloading or stabilization of soft foundation settlement.

CONTROL MEASURES FOR ENGINEERING QUALITY OF SOFT FOUNDATION TREATMENT

Recent Development of Soft Foundation Treatment Technology

The development of soft foundation treatment technology in recent years can be summarized into three aspects:

(1) There are more scientific and comprehensive understanding on the application condition of various foundation treatment methods as well as on advantages and disadvantages of each method. In addition, there is more bases for the selection of foundation treatment methods as per the engineering practice. Instead of following the previous experiences aimlessly, the best practical and economic treatment methods have been employed to the local conditions. Questions in dispute and with ambiguity have been studied scientifically, and choose prudent attitude when confirming foundation treatment measures, as well as use several integrated flexible treatment measures of soft foundation, so as to enhancing the reasonability of in the selected measure.

(2) Enhancement of soft foundation treatment capacity. On the one hand, the existing soft soil foundation treatment technology has been developed rapidly. The improvement of treatment methods, construction machinery and construction technology results in the enhancement of the treatment capacity; on the other, during the mass civil construction of recent years, workers at basic levels, by adjusting measures to the local engineering practices, have put forward a series of new treatment technologies to perfect this field.

(3) Formation of composite foundation theory and development of numerical calculation. The composite foundation theory has been widely used in civil engineering. However, in the short application of composite foundation, many issues remain unknown for us to ask and settle. Engineering practice demands further research on composite foundation.

Basic Principles for Soft Foundation Treatment Construction

(1) The principle of "construction as per drawings" should be strictly complied with during construction, and the principle of "while observing while analyzing" should also be followed.

(2) Works need to be finished prior to the soft foundation construction: 1) Materials related to the project such as preliminary work report, surveying data, geological report and construction drawings should be known well; 2) Construction organizing design sheet or construction outline should be prepared to guarantee an orderly construction; and 3) Intensive inspection should be applied to raw materials, semi-finished products, finished products and construction machinery and equipment.

(3) Drainage measures and equipment at site should be well prepared based on the principle of scientific management prior to the soft foundation construction.

(4) The selected materials for construction, upon the confirmation of soft foundation treatment technology, should be in line with local conditions and locally sourced.

(5) Soft foundation construction must be scientifically organized and designed, technically managed at site, and operated strictly as per standard procedures.

(6) During the soft foundation treatment construction, construction notes should be well taken. Actively find and settle problems, and keep gathering and summarizing experiences.

(7) Regulations with respect to safety and environmental protection should be strictly carried out during the soft foundation treatment construction.

Quality Control Points for Soft Foundation Treatment Construction

(1) Quality control of raw materials; (2) Quality control of construction process; and (3) Quality control of finished products.

Implementation of Standardized Construction Management

The implementation of standardized construction management, in overall, is intended to realize "Six Targets"-"one idea, two objectives, three details, four sectors, five requirements and six fist-classes". More specifically, one idea refers to the implementation of the idea of standardized construction management; two objectives consist of standardized construction management applied to all new projects, and standardized requirements achieved in project location construction, construction technology as well as in construction site management; three details are construction site standardization, construction standardization and management standardization; four sectors include design, bidding, construction and management; five requirements mean professional construction management, standardized construction, detailed daily management, informationized management method and human-orientated development idea; and six first-classes are first-class staff, first-class management, first-class material production and preparation, first-class construction technology, first-class operation environment and first-class construction achievement.

SOFT FOUNDATION TREATMENT OF JINQIN HIGHWAY

Overview of Jinqin Highway in Zhuhai

Jinqin Highway, from Jinding to Hengqin, Zhuhai City, Guangdong Province, starts from Jinding at the northern part of Zhuhai downtown, and joints with the eastern line of Jingzhu (Beijing-Zhuhai) Highway. It southwardly goes along with the Harbor Avenue and Jinfeng North Road, successively passing Phoenix Mountain, Zaobei Village at the border of Zhongshan City and Zhuhai City, Crossing Qianshan water channel, General Mountain, Maliuzhou water channel, and ends at Hengqin Port with a total length of approximately 32.55 km, designed speed of 100 km/h and a total investment of approximately 442 million Yuan. Based on the construction arrangement of municipal government, this project consists of two stages. Stage I under construction now is the section from Jinding to Nanpin with a total length of 20.949 km and estimated budget of 347 million yuan. Employing two-way six lanes, it consists of four interchanges, four extra-long bridges (each 8230 m), eight major bridges (each 4206 m) and a long tunnel in Phoenix Mountain (1660 m, existed). Stage II (from Nanping to Hengqin) on hold will employ two-way four lanes with a total length of 11.601 km. It consists of one interchange, six extra-long bridges (1836 m) and an extra-long tunnel (4550 m). Stage I of Jinqin Highway commenced on Dec.25th, 2013, and will be completed and put into service by the end of 2016 as planned.

Geology of the Highway Engineering

Geographic and Geomorphic Conditions

The highway construction (Jinding to Hengqin) is located in Zhuhai City, Guangdong Province, the geomorphic units in which are composed of eroded hills and eroded accumulations (alluvial plain). The alluvial plains are more widely distributed in long and narrow shapes. The overall geomorphy along the highway are valleys alternating with mountains, and the highway goes nearly forward crossing or oblique crossing with the extension direction of mountains and valleys.

Weather and Hydrology

(1) Weather

The project is located in the south of Tropic of Cancer, where subtropical climate dominates with annual temperature averaging 22.4 ℃, rainfall over the years averaging 1998.3 mm and evaporation over the years averaging 1632.5 mm. Summer and autumn are flood seasons, accounting for 80% of the total annual rainfall. Typhoon season starts from May to October, which happens mostly in autumn. This area suffers average four typhoons each year, among which 0.9 times heavy rainstorm and twice twenty-year worst extraordinary rainstorm.

(2) Hydrology

The highway is located in the Pearl Delta river network of Pearl River Basin, which branches into big distributary channels as main channels in the vertical direction and small distributary channels as tributaries in the horizontal direction. The main channel is relatively straight and wide, while the tributary is bending and narrow just the opposite. The channels, crossed or parted from time to time, mainly flows to southeastwards or southwards into the sea, parts of which within this highway twist and turn from east to west or from west to east, gather at the Pearl River estuary before running into the South China Sea.

Geology of Geotechnical Engineering

Engineering Geological Conditions

Table 1. List of sections with unfavorable geology.

No.	No. of the start and end piles	Length (m)	Unfavorable geology overview	Type of unfavorable geology		Remarks
1	K0+000~K2+700	2700	Soft soils, located below the filling formation, are mainly sludge buried to 1-2 meter with thickness 10-15 m. Silt sand or sandy loam are partly distributed.	Soft Soils		
2	K9+500~K20+700	11200	Soft soils, mostly located below the filling formation, are mainly sludge buried to 1-5 meter with thickness 10-20 m. The interlay is silt or sandy loam with thin bedding and low soil property. The burial depth of sandy formation is 10-25 m and thickness 3-5 m.	Soft Soils		
3	K25+800~K32+000	6200	Soft soils, mostly in surface layer and part below the filling formation, are mainly sludge buried to 1-2 meter with thickness 10-15m. Silt or sandy loam are partly distributed.	Soft Soils		

(1) Engineering geological petrofabric

According to the similarity and difference of their hardness, weather-resistant capacity and basic physical natures, and based on characteristics of rock-layers combination, the among rock-layers along the highway can be divided into two

engineering geological petrofabrics: (1) Loose and soft accumulative formation rock petrofabric; and (2) intrusive rock petrofabric.

Table 2. Recommended values for design parameters of pile foundation in each formation on site.

Formation index	**Basic admissible value of bearing capacity {f0} (kpa)**	**Standard value of pile lateral ultimate resistance qik (kpa)**	**Saturated compressive strength of rock (Mpa)**	**Basis friction coefficient μ**	**Calculation coefficient of total characteristic-value of end resistance of supporting rock layer C1**	**Calculation coefficient of total characteristic-value of pile side friction C2**
Filling soil①(Non motorway)	**Self-weight consolidation unfished**					
Filling soil①(Motorway)	130					
Rough sand with sludge ②-1	110	35		0.30		
Rough sludge②-2	200	50		0.35		
Clay②-3	170	50		0.25		
Gravel clay③	220	70		0.25		
Completely weathered granite④-1	300	120		0.40		
Heavy weathered granite④-2	400	140		0.45		
Moderately weathered granite④-3	750		13	0.60	0.4	0.03
Moderately weathered granite④-4	1000		24	0.60	0.4	0.03

(2) Engineering geological zoning

According to the engineering geological characters of the rock along the highway and combining the geographical condition and geological structure, the whole path can be divided.

Unfavorable Geology

Main unfavorable geological conditions, through geological annotation, are collapse, soft soil and sand liquidation. Sections with unfavorable geology are shown in Table. 1 as follows: 4. 5.

Evaluation of Engineering Geology

No active fracture passed through this area, thus leaving small unfavorable impact to the engineering construction; this area is located in regions where earthquake frequently happens, so the crustal stability of this area is basically stable.

According to Code for Seismic Design of Buildings (GB50011-2001), the seismic fortification intensity of this area is 7 degree and the basic seismic acceleration is set 0.10 g. The earthquake group is designed as the first group with seismic response spectrum period of 0.35 s. In general, the engineering geological conditions along the highway are good, leaving small impact to tunnels, bridges and roadbed construction.

Evaluation and Suggestions on Actual Treatment of Soft Soil Foundation Section

Table 3. Recommended values for design parameters of pile foundation in each formation.

Formation index	**Basic admissible value of bearing capacity {f0}(kpa)**	**Standard value of pile lateral ultimate resistance qik(kpa)**	**Saturated compressive strength of rock(Mpa)**	**Basis friction coefficient μ**	**Calculation coefficient of total characteristic-value of end resistance of supporting rock layer C1**	**Calculation coefficient of total characteristic-value of pile side friction C2**
	Suggestive figure	**Suggestive figure**	**Suggestive figure**	**Suggestive figure**	**Suggestive figure**	**Suggestive figure**
Filling soil①	Self-weight consolidation unfished					
Clay ②-1	50	170		0.35		
Rough sludge②-2	60	200		0.25		
Sludge clay②-3	15	75				
Gravel clay③	70	220		0.25		
Completely weathered granite④-1	120	300		0.40		
Heavy weathered granite④-2	140	400		0.45		
Moderately weathered granite④-3		750	12	0.60	0.4	0.03
Moderately weathered granite④-4		1000	24	0.60	0.4	0.03

Evaluation and suggestions on main viaducts in two soft foundation sections of stage I will be raised based on the engineering geological survey report and the progress of the engineering project.

Jinzhu Highway to Jintang West Road (K0+000~K2+700)

See Table. 2.

Interchange of Santaishi Road (K9+500~K20+700)

SEE TABLE. 3.

CONCLUSIONS

With the development of social economy and continuous progress of technical conditions, there have been increasingly thorough understandings on the damages of soft foundation, increasingly strengthened awareness on soft foundation prevention and treatment, and higher requirements on the preciseness of engineering and engineering quality. Suggestions are made to the planned engineering projects by studying from other engineering practices and related standard requirements so as to guarantee the quality and safety of new engineering. The previous engineering accidents provided warnings on measures to be taken in new engineering as well as disasters to be prevented. By obeying specifications as the prerequisite and learning from the previous experiences, the soft foundation treatment should be conducted according to the practical engineering condition. In addition, find problems while construction, continuously perfect the specifications on soft foundation treat men and provide valuable experiences for future engineering.

By analyzing current common soft foundation treatment measures and happened disasters, and with the combination of practices and references to geological data, this paper focuses on the quality control points of this project and relative suggestions, especially on the well performance of cement mixing piles in soft foundation treatment under such geological condition, which can serve as a reference for engineering projects with similar geological types.

REFERENCES

[1] China Railway Construction Corporation Geotechnical Engineering Co., Ltd. Engineering Reports of Pearl River Delta Soft Soil Foundation Treatment Test. Beijing: China Communications Press, 2012.

[2] Hohai University. Handbook for Traffic and Civil Engineering Soft Soil Foundation. Beijing: China Communications Press, 2001.

[3] L. J. Zhang, F. S. Wang, and J. Liu, Highway Soft Soil Foundation Treatment Technology. Beijing: China Communications Press, 2013.

[4] Z. Y. Yang, Soft Soil Foundation Treatment Technology. Beijing: China Electric Power Press, 2009.

[5] Z. M. Li, Theory, Design and Construction of Soft Soil Foundation Reinforcement. Beijing: China Electric Power Press, 2006.

[6] X. M. Mao, Assessment on the Engineering Geological Characters of Soft Soil Foundation-Taking the Urban Area of Foshan City for Example. Wuhan: China University of Geosciences Press, 2010.

[7] Z. M. Li, Soft Soil Foundation Reinforcement and Quality Supervision. Beijing: China Architecture & Building Press, 2011.

[8] Local Standards on Transportation Industry of Guangdong Province, Regulations on Highway Soft Soil Foundation Design and Construction Technology of Guangdong Province (GDJTG/T E01-2011). Beijing: China Communications Press.

[9] J. L. Zheng and J. H. Zhang, Design and Construction Control for the Embankment of Highway Soft Soil Foundation. Beijing: China Communications Press.

[10] Z. Z. Xu, Design and Key Construction Technology for the Embankment of Highway Soft Soil Foundation. Beijing: China Communications Press.

[11] National Industrial Standards of PRC. Highway Foundation Design Specifications (JTGD30-2004). Beijing: China Communications Press.

[12] National Industrial Standards of PRC. Highway Foundation Construction Technology Specifications (JTGF10-2006). Beijing: China Communications Press