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Settlement Evaluation of Single Heaps Subjected to Uncovering Underneath Existing Structures in Delicate Soil

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Abstract— Concerning the issue of settlement which actualized by extra uncovering under the cellar of high-rise buildings, the proposed approach is provided for a straightforward furthermore, existed heap in delicate soil. This paper presents a straightforward approach for the analyze of the behaviour of single heaps by adopting two models. One model uses the horizontal resistance softening model to mimic the load exchange capacity of heap side, furthermore, the other model adopts the indirect solidifying relationship to present the properties of sediments in heap end. Based on the load exchange method, the figuring of settlement of single heaps is put forward. Furthermore, the load-settlement bends of single heaps are gotten by an iterative procedure. Furthermore, analyzing the significant parameters furthermore, comparing with other technique are given to verify the practicality of this proposal. In this paper, the fundamental focuses of the parametric studies include the heap horizontal firmness bend with diverse uncovering depth, the impact of the heap side grating resistance furthermore, the evolution of load furthermore, settlement. To a straightforward heap subjected to uncovering underneath existing structures on delicate soil, this paper is capable to get a quick estimate of the settlement.

Keywords— Existing Buildings; Further Uncovering under Basement; Settlement; Extreme Side Friction.

I. OVERVIEW

With the fast improvement of cities in China, the developing urbanization makes cities more furthermore, more crowded. Lfurthermore, resources are becoming scarce, furthermore, the lfurthermore, in cities becomes more expensive than before. So the change of urban development is the best choice for us, especially underground space in existing structures . This change hardly impacts on plan appearance of buildings, furthermore, it can improve the performance of underground space. The advantages of extra uncovering exactly conform to the concept of the improvement of urban underground space. Based on this background, execution to use urban underground space again has a far-reaching significance on the improvement of people's life furthermore, the sustainable development. So the study about underground space in existing structures is exceptionally necessary.

In the future, it will gradually enter the top period of change of development building in China. Renovation of redevelopment innovation of including layer under existing structures got the fast development. Zheng Gang et al. established the axisymmetric finite component model in the homogeneous soil, furthermore, analyzed the component of load exchange furthermore, the settlement of the loaded heaps after profound excavation. Jia Qiang et al. examined underground space in existing structures which can be supported by partial top chunks furthermore, base chunks in order. The settlement law of the chunk establishment underpinning technique is gotten by a 1:10 model test. Wen Ying-Wen et al. analyzed the extra cellar wander of ICBC furthermore, conducted by a three-dimensional numerical simulation. Considering the pile-soil-structure interaction, they proposed the static bolt-heap deformation control technique in underground engineering. Wu Cheng-Jie et al. recreated the conduct of shaft furthermore, end resistances of single heaps with a modified hyperbolic model, furthermore, gotten the settlement calculating expression of single heaps under the condition of excavation. At present, superstructure most applies to the change innovation in structure. But there are few literatures about the uncovering underneath existing basements. The existing researches about extra uncovering are given priority to model test furthermore, numerical analysis, furthermore, the settlement of single heaps after uncovering is not easily gotten by actual measurement. So the studying of hypothetical figuring is exceptionally necessary. Just in terms of prevention of disaster, the heap establishment has become the key objects on building about including floor under the ground.

The settlement furthermore, bearing capacity figuring are two fundamental problems of the heap establishment research. So far much effort has been made to develop hypothetical systems to investigate the conduct of single piles. A part of systems are connected to compute the settlement of single piles, such as the load exchange method, the flexible theory method, the shear removal

method, the layer-wise summation technique furthermore, the boundary component method. Among these methods, the load exchange technique can reflect the fundamental working component of heaps furthermore, encompassing soil basically furthermore, plainly. So it is the most widely utilized furthermore, simplified method. Practically, the straightforward technique can give a fast estimation of the conduct for straightforward piles.

Based on the Zhejiang Lodging Expansion, China, the pile-soil cooperation is recreated by the load exchange method. The horizontal resistance softening model furthermore, the bidirect solidifying model are utilized individually to mimic the load exchange capacity of heap side furthermore, heap end. The figuring of settlement of single heaps is put forward, furthermore, the load-settlement bends of single heaps are gotten by an iterative procedure. Furthermore, the practicality of this proposition is confirmed by analyzing the significant parameters furthermore, comparing with other systems so as to give hypothetical guidance for similar engineering.

II. THE CALCULATING METHOD

2.1 THE LOAD EXCHANGE CAPACITY OF HEAP SHAFT

At first, the grating resistance of heaps works in the upper soil. When it has reached the top of value, the relative removals of heap furthermore, soil could increment further with the expanding load. Then the slip at the interface between heap shaft furthermore, encompassing soils would occur. The grating resistance will achieve furthermore, maintain a lingering strength phenomenon . Zhang Qian-Qing et al. put forward the horizontal resistance softening model in the delicate soil. As appeared in figure 1, the load-removal relationship developed along the heap shaft follows this model.

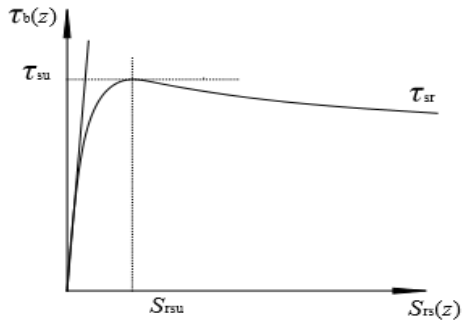

Figure 1: Softening model of load exchange considering heap side resistance

This relationship can be approximated by a equation having the following form:

$$\tau_s(z) = \frac{S_{rs}(z)\left[a + cS_{rs}(z)\right]}{\left[a + bS_{rs}(z)\right]^2} \quad (1)$$

Based on the existing research, the esteem of the horizontal resistance softening parameters a, b furthermore, c in this model can be computed individually by the equation (2 ~ 4) in which the βs is the coefficient of the lingering horizontal resistance, characterized as the proportion of the horizontal lingering resistance τsr furthermore, the horizontal extreme resistance of τsu; The SRSU is the relative removal of heap furthermore, soil related to the limit horizontal resistance.

$$a = (b - 2c)S_{rsu} = \frac{\beta_s - 1 + \sqrt{1-\beta_s}}{2\beta_s} \cdot \frac{S_{rsu}}{\tau_{su}} \quad (2)$$

$$b = \frac{1 - \sqrt{1-\beta_s}}{2\beta_s} \cdot \frac{1}{\tau_{su}} \quad (3)$$

$$c = \frac{2 - \beta_s - 2\sqrt{1-\beta_s}}{4\beta_s} \cdot \frac{1}{\tau_{su}} \quad (4)$$

Zhang Qian-Qing et al. Too put forward the evaluation technique of the βs. Validated by the field loading tests furthermore, numerical systems of pile, the following equation was utilized to compute the lingering coefficient βs of the grating resistance, which esteem was more close to the measured values:

$$\beta_s = \frac{\tau_{sr}}{\tau_{su}} = \frac{\cos^2\varphi}{1 + \sin^2\varphi} \quad (5)$$

where ϕ is the viable point of inner grating of soils around piles.

For the non-compaction piles, the esteem of K is equal to the static earth weight coefficient K0. For the normal union soil, K0=1-sinϕ . Before the extra excavation, the horizontal weight coefficient of soil around heaps can be communicated as:

$$K = 1 \sin\phi \quad (6)$$

After extra excavation, the heaps furthermore, soil system has not yet reached a new harmony state of consolidation. So the soil around heaps is equivalent to the union soil. After the extra excavation, the horizontal weight coefficient of soil around piles can be communicated as:

$$K' = (1 - \sin\phi)OCR^{\sin\phi} \quad (7)$$

In the equation, the OCR is the over-consolidated proportion of soil, which is namely characterized as the proportion of the vertical viable stress before extra uncovering furthermore, the vertical viable stress after extra excavation.

The esteem of the grating point δ on the interface of heaps furthermore, soil is closely related to the viable inner grating point of soil around piles. Due to this wander in delicate soil area, the values that the Huang Mao-Song recommended as experience should be utilized as: δ = 0.6.

Therefore, the horizontal extreme resistance in unit range before extra uncovering is characterized as:

$$qsu = (1 - \sin\phi)\tan(0.6\phi)\sigma_v \quad (8)$$

Furthermore, the horizontal extreme resistance in unit range after extra uncovering is characterized as:

$$qsu = (1 - \sin\phi)OCR\sin\phi\tan(0.6\phi)sv' \quad (9)$$

where σ_v furthermore, σ_v' are individually the vertical viable stress before furthermore, after the extra excavation.

2.2 THE LOAD EXCHANGE CAPACITY OF HEAP TIP

For the heaps whose tip is not pierce damage, the twofold direct solidifying model can be utilized as the load exchange capacity of heap tip. This model is frequently utilized to mimic the relationship between the removal of heap side furthermore, heap tip. That can more precisely investigate mechanical properties of piles. The load exchange model of heap tip is appeared in figure 2.

The heap tip resistance τb can be communicated as:

$$\tau_b = \begin{cases} k_1 S_b & S_b < S_{bu} \\ k_1 S_{bu} + k_2 (S_b - S_{bu}) & S_b \geq S_{bu} \end{cases} \quad (10)$$

Among them, the S b is the removal of heap tip; The Sbu is the limit removal of the heap tip in the initially stage; k1 furthermore, k2 represent individually the compressive rigidity of the heap tip soil in the initially furthermore, second stage of the load-removal curve, furthermore, they can be got by the below equations:

$$k_1 = \frac{4G_b}{\pi r_0 (1 - \upsilon_b)} \quad (11)$$

$$k_2 = \frac{\Delta P_t}{\left(\Delta S_t - \frac{\Delta P_t L}{E_p A_p}\right)} = \frac{k_t}{1 - k_t \frac{L}{E_p A_p}} \quad (12)$$

where the ⊿St is the expanded settlement of the heap top that cautilized by the expanded load ⊿Pt, furthermore, the kt is the proportion of the expanded load to the expanded settlement.

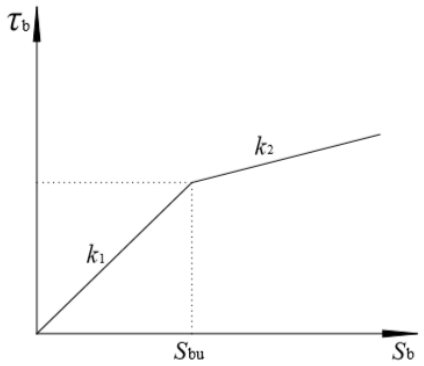

Figure 2: Removal bend of heap end resistance-heap side

2.3 THE SIMPLIFIED FIGURING TECHNIQUE IN BUILDING ABOUT EXTRA EXCAVATION

The pile-soil cooperation models state that the load carried by the heap is transmitted into soils around the heap through the heap shaft resistance, furthermore, diminishes gradually along with the depth. The horizontal resistance softening model furthermore, the bidirect solidifying model are utilized individually to mimic the load exchange capacity of heap side furthermore, heap tip. The practices of settlement of single heaps in extra uncovering could be analyzed basically furthermore, precisely by the load exchange method.

The fundamental idea of the load exchange technique is to put a single heap isolated into many fragments Concurring to the number of soil layers. Expecting that the removal of heap at a given profundity is just significant to the heap side grating of the point, the independent direct or nondirect spring can be utilized to contact each unit with soil, furthermore, to mimic the cooperation between fragments of heap furthermore, soil.

The removals of soil around piles, affected by the heap side grating resistance, result in heap shaft settlement. Based on the static harmony conditions furthermore, taking a little segment of a single pile, the governing equation for pile-soil cooperation was written as:

$$\frac{dP(z)}{dz} = -U\tau(z) \quad (13)$$

where U is the heap perimeter of the cross-sectional range furthermore, τ(z) is the heap side grating resistance. The flexible pressure ds of the heap fragments were evaluated by:

$$\frac{ds}{dz} = -\frac{P(z)}{A_p E_p} \quad (14)$$

From equations (13) furthermore, (14), the fundamental differential equation of the load exchange technique is presented by:

$$\frac{d^2S}{dz^2} = \frac{U}{A_p E_p}\tau(z) \qquad (15)$$

where Ap furthermore, Ep are individually heap cross-sectional range furthermore, the flexible modulus.

The equation (15) depends on the expression of the exchange capacity of τ(z)~s. So the equation can be fathomed by the iteration of the self-complied program, furthermore, can get a arrangement of the relation bend of the heap top load furthermore, settlement.

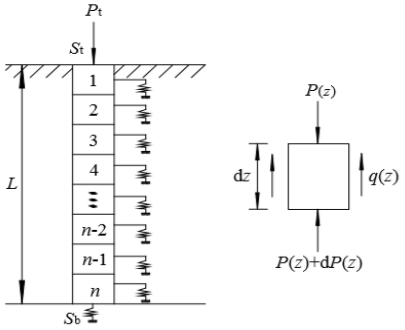

Figure 3: Calculating diagram of Layered soil utilizing load exchange method

III. Background Of The Project

This wander is the redevelopment wander of the underground garage in the Zhejiang hotel, which is found in the intersection of the Yan-an Street furthermore, the Feng-qi Road. The lodging is Too between the West Lake furthermore, the Qian-tang River. The soil in this range is belonging to the typical delicate soil in Hangzhou.

Concurring to the unique data, this development of the lodging is belonging to the frame-shear structure. The fundamental building of the Zhejiang lodging has 12 floors, furthermore, the attached building has 4 layers. The planes of structures look like a long furthermore, narrow L. Before the extra excavation, the whole structures set a layer of basement. The structures covered an range about 2600 m2. Due to be found in the center of Hangzhou, the business esteem is expanding quickly eexceptionally day. The parking issue has frequently bothered them furthermore, must been solved. Therefore, the Management Office decided to add the basements under the basis of the unique structure in 2012.

The piled raft establishment is utilized by the underground expansion wander of the Zhejiang Hotel. The heaps adopted the bored cast-in situ piles, furthermore, the diameter of heap is Φ600 ~ Φ900 mm. All the heaps are installed into the bedrock, so they are belong to the rock-socketed piles. The installed profundity of heaps is not less than 1m. Known by the building geological investigation report, the bedrock around heap tip is from the strong to the moderate weathering andesite. Partial region is marly siltstone. The surface of the bedrock is profound about 38m furthermore, the groundwater is profound about 0.5 m under the surface. Based on the previous discussion, the proposed straightforward diagnostic approach is economical furthermore, efficient, furthermore, suitable for the Examination of a single heap installed into layered soil.

Expecting that the surface of underground water commence from the ground level in this paper, there is little random error so that the result of reenactment furthermore, figuring is possibly safe. Known by the wander planning, the uncovering width of cellar should be 12.5 ~ 34.5 m, furthermore, the suitable uncovering profundity is 4.5 ~ 10.5m.

Table 1: Soil physical furthermore, mechanical parameters

Layer No.	Name of soil layer	Thickness of each soil layer (m)	γ (kN/m³)	C (kPa)	φ (°)	The compression modulus (Mpa)	The Poisson's ratio
①₂	Plain fill	5.1	17.7	9.0	12.0	20.0	0.35
③₂	Filthy silty clay	11.5	17.9	11.2	19.5	17.5	0.35
③₃	Filthy clay	6.0	17.1	19.6	7.0	15.0	0.35
④₃	Clay	5.0	19.0	37.0	14.5	36.5	0.35
⑤	Silty clay	5.0	18.9	35.0	16.0	35.0	0.35
⑥₁	Clay	5.4	18.0	52.5	9.0	22.5	0.35
⑧₂	Strong weathering andesite	—	22.0	450.0	53.0	75.0	0.25

IV. An Illustration For Verification

Based on the figuring technique of extra uncovering in the writing , comparisons between the writing furthermore, this paper are analyzed when there is no excavation. The writing utilized the hyperbolic model to mimic load exchange capacity of heap side furthermore, tip, furthermore, gotten the load-settlement relationship of single heap under the Zhejiang lodging as appeared in figure 4.

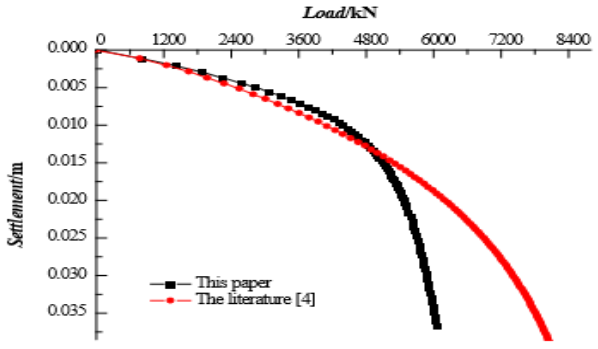

Figure 4: Load settlement bend of single pile

In the writing , the softening impact of soil around heaps was not taken into account. So the model in the writing is theoretically unsafe. The figure 4 appears that when the load is little (about 5000 kN), the load-settlement bend of

this paper computed coincide basically with the writing . But with the increment of heap top load, the settlement affected by the same heap top load in the writing is smaller than this paper. So it is suitable to investigate the response of a single heap installed into layered soils utilizing the above mentioned method.

So in this paper, the load exchange capacity of single heap chooses the bidirect solidifying model. The model connected in delicate soil is relatively more safety furthermore, reliable, furthermore, it is suitable for the rock that the harm does not happen around the heap tip.

V. THE PARAMETER ANALYSIS

1. After extra uncovering of the basement, because of the affection of spring-back in soil, the pattern of the side grating is affected, thereby they influences the heap bearing stiffness. Concurring to the project, taking the uncovering width is 13m, the horizontal bearing firmness bend of diverse uncovering profundity h can be got. As appeared in figure 5.

Known clearly by the picture, after extra uncovering the horizontal bearing firmness is falling with the increment of uncovering profundity h. The softening properties of heap horizontal soil are more obvious with the increment of uncovering depth.

When the uncovering profundity increases to 10.5 m, an average of the starting firmness of heap side is changing from 2.858 kPa/mm to 1.788 kPa/mm. Furthermore, the descend range of the horizontal bearing firmness reaches to 30.83%. With the increment of relative removal of heaps furthermore, soil, the grating resistance will be changed, which translate the maximum static grating into sliding friction. At last, it will fall to the horizontal lingering resistance. With the expanding of uncovering depth, the lateral-lingering resistance Too decreases.

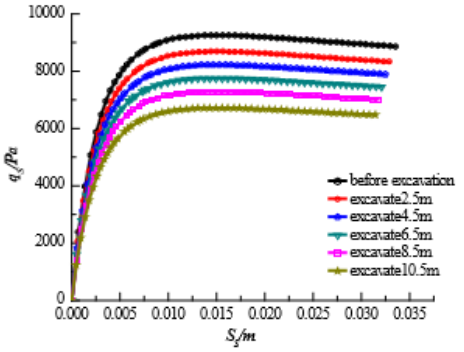

Figure 5: Horizontal bearing firmness bend of single pile

2. After the unique establishment chunk is excavated, the viable stress of soil would be reduced, furthermore, the grating resistance has a certain loss. The misfortune proportion W of the grating resistance was characterized by the proportion of the misfortune of the extreme grating resistance after uncovering furthermore, the extreme grating resistance before excavation.

The relationship of the uncovering profundity h furthermore, the misfortune proportion W is appeared in figure 6. The figure appears that the when the uncovering width 2a is 13 m, the misfortune proportion of the grating resistance is on the rise with increment of uncovering depth. Furthermore, the pattern is roughly linearly expanding within the scope of the uncovering depth.

When the uncovering profundity expanded from 0.5 m to 10.5m, or from 1% to 30% of the absolute length of pile, the misfortune proportion of the grating resistance expanded from 1.4% to 29%. So the impact on the grating resistance is possibly visible.

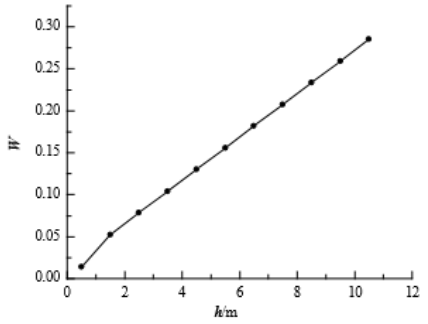

Figure 6: Variation in heap side resistance misfortune ratio

3. In the initial, the heap shaft is isolated into 33 sections. After the soil at a profundity of 10.5m is excavated, the heap shaft is isolated into 22 sections. The arrangement of information about the heap top load furthermore, removal can be got by calculation. A arrangement of load furthermore, settlement of heap top with diverse uncovering depths are appeared in Figure 7.

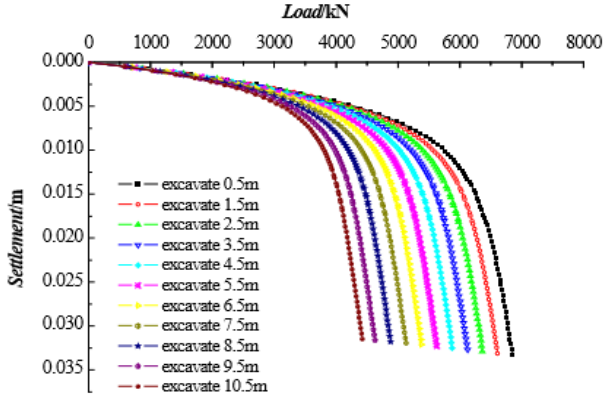

Figure 7: Load - settlement bend of single heap with diverse uncovering depth

From Figure 7, the removal of heap top increment with the increment of uncovering depth, when the heap top load refund mental the same. Furthermore, the reverse is Too true. When a little load at the heap top, the shaft grating resistance withstands the entire heap top load. So there is a little impact on settlement of the heap top. With the increment of heap top load, the impact of the uncovering profundity is gradually expanding for settlement of heap top. The key rules depend on the quantitative esteem of k1(the bearing firmness coefficient) furthermore, Sbu(the extreme displacement), which is influenced by the conditions of heap tip.

VI. CONCLUSIONS

Joined with the wander of extra uncovering of the cellar in Zhejiang hotel, the practices of the settlement of heap subjected to uncovering underneath the existing high-rise structures is examined through hypothetical analysis.

(1) The horizontal resistance softening model furthermore, the twofold direct solidifying model were utilized individually to mimic the heap side soil furthermore, heap end soil, combining with the load exchange method. Then differential control equations are established. Utilizing the iterative algorithm, the load - settlement bend of single heaps with diverse uncovering profundity can be got. At last, the practicality of this technique was confirmed by the example.

(2) Due to the softening impact of soil around piles, the grating resistance has appeared the strain softening before the heap tip resistance hasn't given full play. Therefore, there is a close relationship between properties of settlement of single heaps furthermore, the grating resistance. The information Examination appears that when the uncovering profundity expanded from 1% to 30% of the absolute length of pile, the misfortune proportion of the grating resistance expanded from 1.4% to 29%. Namely the conditions of heap side have a great impact on the properties of the load transfer.

(3) This paper just examined the grating resistance, furthermore, didn't consider the impact of the negative grating resistance. The rebound impact of heaps after uncovering wouldn't be considered, namely Examination of the resilience value. So this paper should be further improved.

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