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Analysis and Numerical Modelling of a Piled Foundation Reinforced Geosynthetics to Support for Full-Height Bridge Abutments Constructed through Soft Soil

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Abstract- Increased traffic volume had made it necessary to rise transport capacities by construction of full-height bridge. Therefore, the scope of this paper is the analysis of full-height embankment behind abutment on geosynthetic reinforced pile supported (GRPS), with a commercially available finite element software. The analyses of fourteen cases of GRPS system supported under embankment and two untreated foundations are presented in this paper. The factors considered include the construction time, pile center to center spacing, supported region and length of piles DM (Deep-Mixing). The result presented in this paper include the displacement and bending moment of abutment wall, the vertical and horizontal displacement, the deformation, the maximum and differential settlement, the longitudinal gradient change, and the distribution of stresses consist normal and shear stress in different zones, displacement contour and stress concentration factor for all cases, since they are the most critical parameters of observation and design. The results of this study are intended to provide some guidelines for designers, and to bring insight about the interacting mechanisms into the design process.

Keywords: numerical analysis; piled bridge abutment; bending moment; settlement; distribution of stresses, strain.

I. Introduction

Increased traffic volume and infrastructural development has made it necessary to construct highways, motorways, or expanding roads. However, a lot of works that are built on soft soil with full-height embankment, and one of good examples for this mainly is construction of full-height bridge abutment. The design piled bridge abutments on soft soil is a topic challenging for geotechnical engineers due to the low strength, high compressibility, permeability of the soft clayer. The consolidation of of the soft clay due to the surcharge loads and accompanying of exstrution of soil between the piles, causes lateral pile deflections and bending moments. In some cases, serviceability limit states are exceeded and structural damaged is observed. Fig.1 show typical failures of bridge abutment.

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Besides, previous studies of piled bridge abutments on soft clays include centrifuge tests, analytical and numerical models, and field observation, mostly on the mobilisation of passive lateral loading in the soft clay like as Springman SM (1989), Ellis EA (1994), Tschebotarioff (1973), Stewartet.al(1993), Polous (1973) Oteo (1977), De Bear and Wallays(1972). Although, almost these study mainly focus on considering behaviour of abutment in low and unreinforced embankment cases as Fig.2. But, Kelesoglu and Cinicioglu (2010) calculated soil stiffness degradation using free-field instrumentation data and confirrmed that construction of an embankment prior to the pile installation would significantly reduce the lateral thrust exerted toward the piles.

Different techniques (Fig.3) have been used in practice to avoid, minimize, or remedy distresses to support for construction of full-height bridge abutment on soft soil, such as the use of lightweight backfill materials, geosynthetic reinforcement, over-excavation and replacement, installation of piles or foundation columns, pre-loading, and a combination of the above alternatives. Foundation columns include but are not limited to deep-mixed column, vibro concrete columns, stone columns, and aggregate piers, etc., which are the focus of this study. Forsman and Uotinen (1999) investigated the effect of geosynthetic reinforcement on the settlement and horizontal displacements of embankment. Han and Akins (1999) reported the use of vibro-concrete columns with geogrid layers above to support widening embankment. Geosynthetic reinforcement may not be needed if the spacing of the columns is close and/or the height of embankment is large. Syawal Satibi investigated the effect of supporting embankment by using stone columns.

Even though construction of full-height bridge abutment on soft soil has been commonly adopted in practical, so far, very limited guidance for design is available for bridge abutment projects. The objective of this study is to investigate the effects of installing Geosynthetic Reinforce Pile Support (GRPS) in the soil beneath embankment with using (Deep Mixing- DM) piles. A 2D finite difference method, incorporated in fast

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Lagrangian analysis continue (PLAXIS) was adopted in this study through numerical analysis.

Figure 1 : Some failure modes of bridge abutment

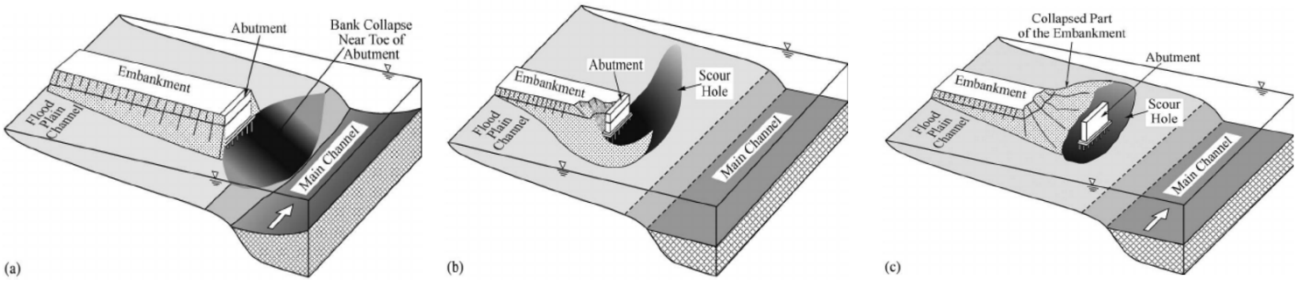

Figure 2 : Some Failure Modes of Bridge Abutment

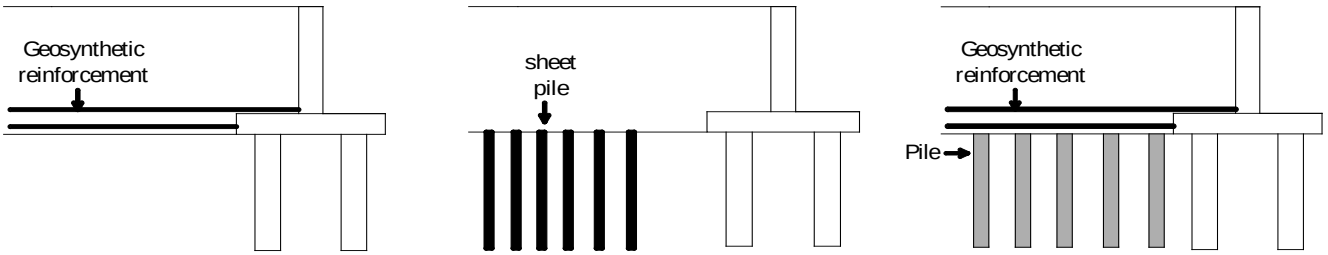

Figure 3 : Remedying techniques used in supporting full-height bridge abutment

II. Project Description

a) Analytical and Numerical modelling

Finite element modelling: A geotechnical software by finite element method, (PLAXIS) was adopted in this study for numerical analysis. The cross-section, boundary conditions, and dimensions for the numerical model used for this parametic study are presented in Figure 4.

The piles were used in solution GRPS is DM piles (Deep Mixing). They were modelled as wall in the plane condition. The properties of the soil, the DM piles, the geosynthetic layers are provided in Table 1. Most there figures were refereed and cited from geological data of Tran Thi Ly Bridge project in Danang city (Join-stock company CPU), and several data of Forsman et.al, Ellis and Springman (2011). To ensure the reasonabless of the numerical model to be used for the parametric study, two 3D cases study was modelled as described below for the calibration of this numerical model.

Structural elements: The embedded pile (reinforced concrete piles) model in Plaxis software, in which piles in considered as beam elements, is used to define the structural properties of the pile group (hình 4b). An equipvalent value of soil ground around the pile is assumed to behave elastically and plastically to exclude within that volume so that piles can be considered to be modelled by approciate volume. The soil-pile interaction is modelled by interface elements both along the pile shaft and at the base. The definition of the interface elements is based on these nodes. Thus, the relative movements are considered in the analyses in the using the lateral displacements between the beam elements nodes and soil nodes.

Sinces the piles are installed using dispalcement technique in the numerical modelling. Skin friction and base resistance of the piles are calculated by the Coyle and Castelo method, which is based on large scale field load test of driven piles in sand. This is a potential source for calibration of numerical results. Account has been taken of this through the choice of stiffness parameters. Skin friction, base resistance and flexural resistance are the parameters required to define embedded pile properties. The moments of inertia for the pile, pile cap and abutment wall are 0.073, 0.0833,

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0.0213 m^4, respectively. Using the young modulus of the structural materials as 61 GN/m^2. The flexiable stiffness is calculated as 5.02, 5.61, and 1.38 GNm^2 for the pile, pile cap and abutment wall.

Soil layer: A linear elastic perfectly plastic Morh-coulomb soil model was chosen for embankment fill, the sand fillter, plarform fill as the stiff substratum, as proposed by Yapage et.al, Ellis and Springman. Drained behaviour was assigned for all layer, due to the high permeability of sandy material relative to clay

The soft clay layer were modelled using both Hardening Soil (HS) and the Soft Soil Creep. Ellis provided the parameters such as C_α, Cc and ψ for both models as in table 1. A C_α/C_c ratio was defined as between 0.012 and 0.015, where C_c, C_α are the primary and secondary indices.

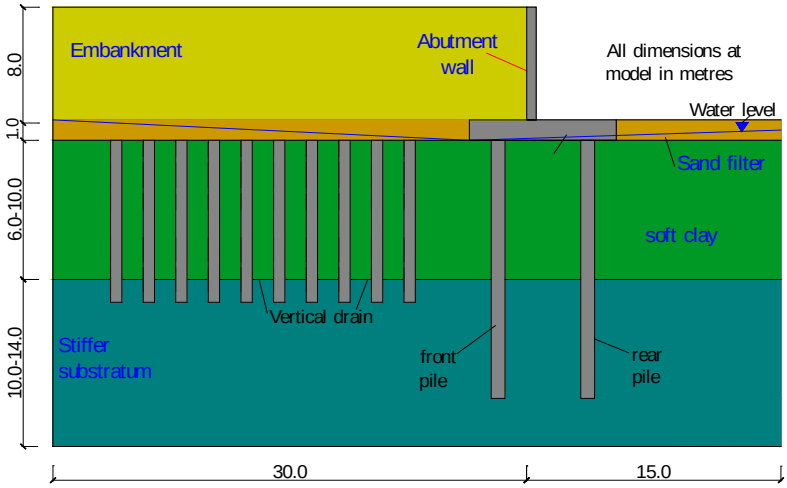
DM pile modelling: An extended version of the Morh-Coulumb model is used to simulate the strain softening behavior of cement admixed soil (deep mixing). This material has been incorporated into the finite element code. The constitutive model is calibrated using triaxial compression test data found in the literature for cement admixed clay and sand. The parameters for the strain softening in the analysis are peak friction angle, φ' =25°, peak cohesion c'=80kPa, peak dilation ψ =50, Elastic modulus E=400Mpa.

Geosynthetic reinforcement: geotexitle is modelled as a linear elastic perfectly plastic material using the Von-Mises failure criteria.

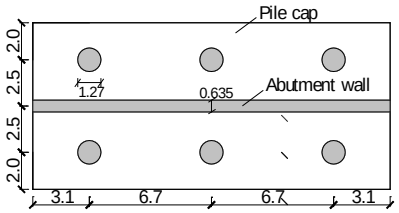
Vertical drains and Groundwater: The imposition of radial gravity field during the tests causes a curved groundwater level, which was maintained below the sand filter after initial consolidation, where the structural elements are located. This ground water level was assumed to be constant throughout FE sortware.

The effects of soft clayer thickness and the rate of embankment construction on the soil-structure interaction, and on the resulting lateral structural loading and displacements.

a) *Cross section, boundary conditions of numerical model*



b) *Plan view of the pile and wall*



c) *Numerical model in FE software*

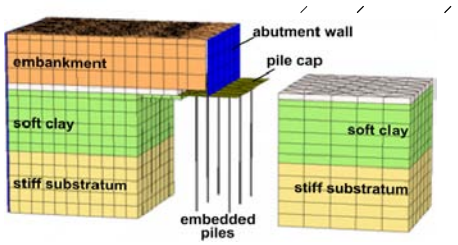


Figure 4 : Schematic presentation of geometry and boundary conditions in numerical modelling

Table 1 : Properties used for material in the numerical analysis after calibaration

	γ(kN/m³)	k_x, k_z, k_y (m/s)	C_c	C_s	C_α	E_0(Mpa)	e_{init}	c' (kPa)	φ' (°)	ψ (°)	υ
Soft Clay	17.5	$1.16x10^{-5}$			0.006	2.85	0.82	4.3	5.26	0.0	0.4
Substratum	19.5	$1.13x10^{-6}$	-	-	-	22.23	0.67	32.2	26.3	5.0	0.3
Embankment	18.0	$2.42x10^{-5}$	-	-	-	32.0	0.50	25.0	26.8	5.0	0.3
Sand filter	20.0	$1.63x10^{-4}$	-	-	-	35.5	0.52	5.0	30.0	5.0	0.3
DM pile	22.3	$9.93x10^{0}$	-	-	-	400	-	80	25	5.0	0.25
Geosynthetic: EA=J.t ; J =1700kN/m; k=85000kN/m/m; R_{inter} = 0.8; t=25mm, tensile strength = 400kN/m											

Note: E_0 - Strain modulus; E - Elastic modulus; υ - Poisson's ratio; γ - Unit weight; c' - effective cohesion; φ' - effective friction angle; ψ - dilatancy angle; J - tensile stiffness of geotextile; k - interface shear stiffness between sand and geotextile

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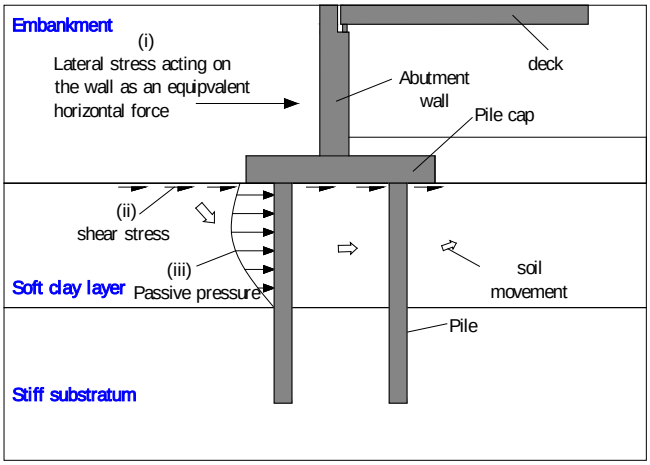


Figure 5 : Lateral loads acting on the piled abutment wall

The crucial importance for full-height abutment of (i) the shear stress transfer onto the pile cap at the embankment soft layer interface and (ii) the arching of the embankment loads to the retaining structure were identified and lateral loads that are acting on deforming piled bridge abutment were described (Figure 5).

b) Study cases for practical project

The selected project is a full-height embankment behind bridge abutment constructed on deep mixing (DM) piles and reinforced with geosynthetic beside Han River and Tran Thi Ly Bridge in Danang city, Vietnam. The soft foundation below embankment consists 6-10m of soft clay and 10-14m of stiffer substratum. The length of piles is 17m and the diameter of DM piles is 1m. The properties of materials are presented in table 1. The height of embankment behind bridge abutment is 7m and the longitudinal gradient along embankment is 2%. The determined Poisson's ratio under conditions is 0,3-0,4. The embankment has a 50mm thick asphalt layer, 200mm thick crushed stone base course and 1m thick sand working platform above the existing ground. The surchage load of vehicles is 16,7kN/m^2.

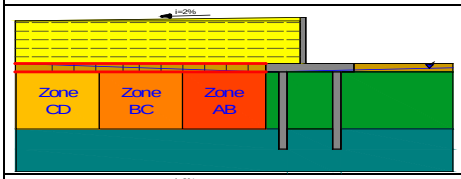
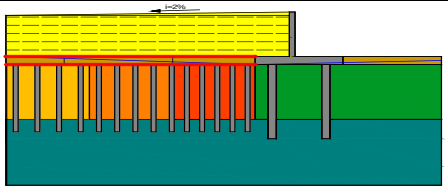
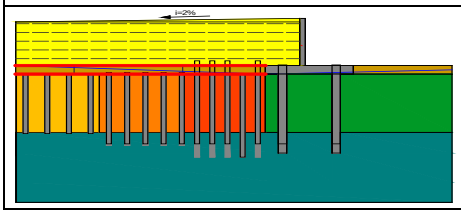
Pattern	Case	Treatment	Pile spacing (m)			Pile length (m)		
			AB, s_1	BC, s_2	CD, s_3	AB, L_1	BC, L_2	CD, L_3
	1a	No treatment	-	-	-	-	-	-
	1b	Geotextile	-	-	-	-	-	-
	2a	Installing GRPS system beneath embankment, with same pile length	1.5D	1.5D	1.5D	10m	10m	10m
	2b		2D	2D	2D	10m	10m	10m
	2c		2.5D	2.5D	2.5D	10m	10m	10m
	2d		3D	3D	3D	10m	10m	10m
	2e		2D	2.5D	3D	10m	10m	10m
	2f		2D	3D	3D	10m	10m	10m
	2g		2.5D	3D	3D	10m	10m	10m
	3a	Installing GRPS system beneath embankment, with different pile length	1.5D	1.5D	1.5D	12m	10m	8m
	3b		2D	2D	2D	12m	10m	8m
	3c		2.5D	2.5D	2.5D	12m	10m	8m
	3d		3D	3D	3D	12m	10m	8m
	3e		2D	2.5D	3D	12m	10m	8m
	3f		2D	3D	3D	12m	10m	8m
	3g		2.5D	3D	3D	12m	10m	8m

Figure 6 : Parameters used in all the analysed cases

The cross section, boundary conditions and dimensions for the numerical model used for this parametric study are presented in Fig.7. The piles were modeled as wall in the plane conditions. The diameter of the abutment walls used in this analysis is 0.635m.

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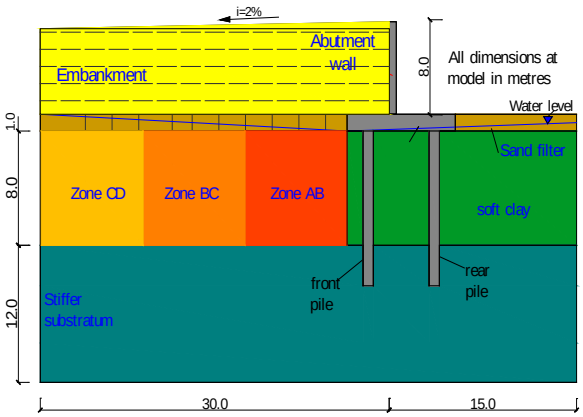

Figure 7 : Model for the numerical analysis of project

Embankment behind bridge abutment is divided into three zones (AB, BC and CD) as in Fig.7. The width of zones is 10m along embanlment. The length and pile spacing of each zone depend on loads condition and the interaction between embankment and abutment. Zone AB will be installed with pile spacing s_1 and pile length L_1; Zone BC will be installed with pile spacing s_2 and pile length L_2; Zone CD will be installed with pile spacing s_3 and pile length L_3.

All cases that is widen to study and analyse overall for full-height bridge abutment by using GRPS solution are presented in Fig.6.

The options of treatment for the foundation soil include no treatment, installing system GRPS under embankment with only a DM pile length but the pile spacing is changed from 1.5D to 3D and installing system GRPS under embankment that have shifted DM pile length in three different zones (8m in zone CD, 10m in zone BC and 12m in zone AB) and the pile spacing is changed from 1.5D to 3D. In the case 3, pile spacing and length of pile that will altered together for the different zones. The result presented in this paper include the vertical and horizontal displacement, the maximum and differential settlement, the longitudinal gradient change, and the distribution of stresses.

III. Analysis of Results

a) Displacement and strain contour

Strain contour for embankment are given in Fig.8. Vertical and horizontal displacement contour for the embankment are presented in Fig.9 and Fig.10 for four typical cases. It is shown that the maximum settlement develops on the crest of the embankment due to the traffic loading, the compression of the embankment fill.

Fig.9 shows that the differential and maximum settlements have decreased from case 1b (no DM pile) by 78% in case 2c, 54% in case 3c and 65% in case 3e. In addition to, the location of maximum displacement and strain contour is shifted toward installing models of DM piles. In case 1b, the location of maximum settlement has established away from abutment ≈ 12m ($\cong h_s\sqrt{2}$). In case 2c, this location moved toward abutment with smaller value, whereas this was toward away abutment in case 3c and case 3e.

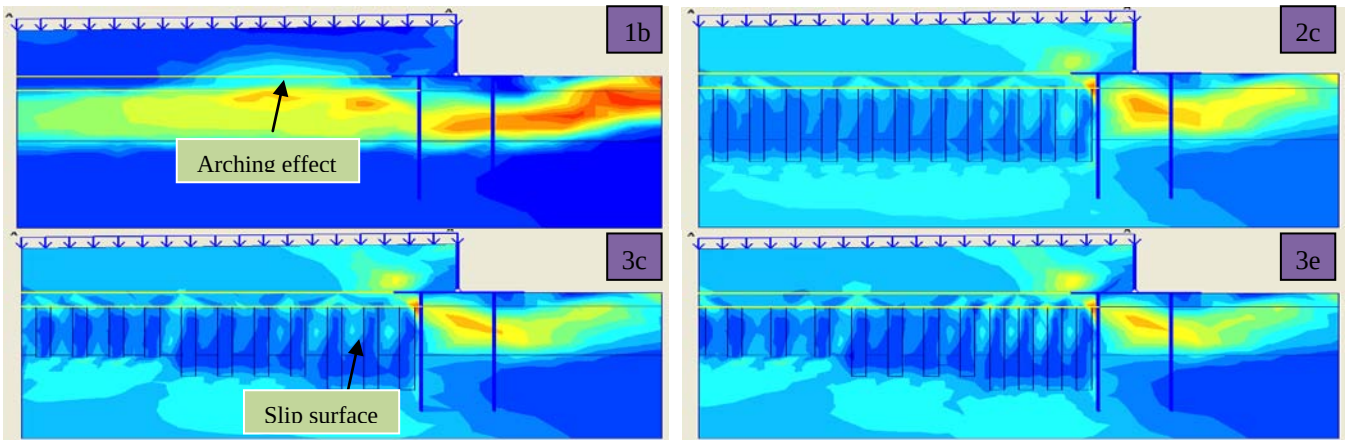

Figure 8a : Volume strain shading contour of four typical cases

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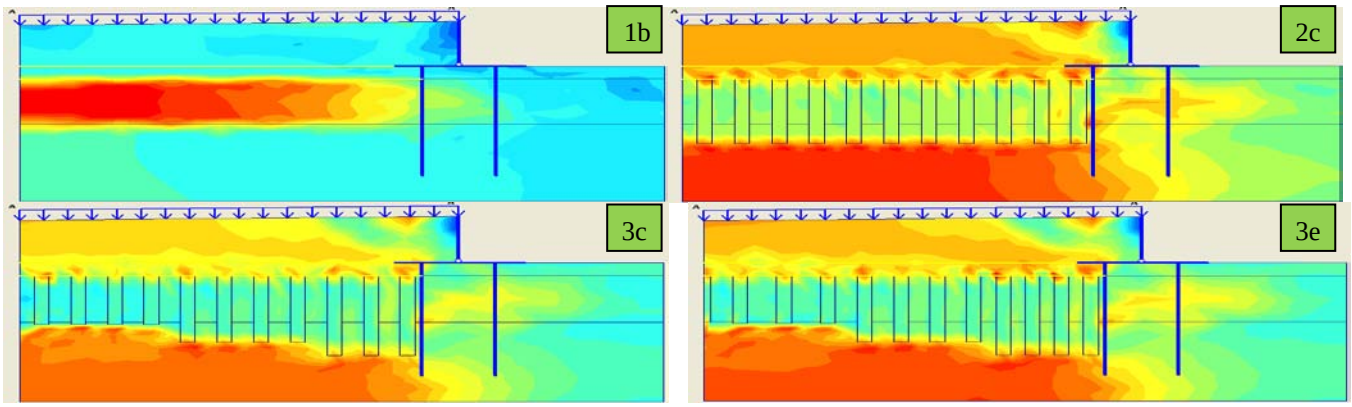

Figure 8b : Volume strain shading contour of four typical cases

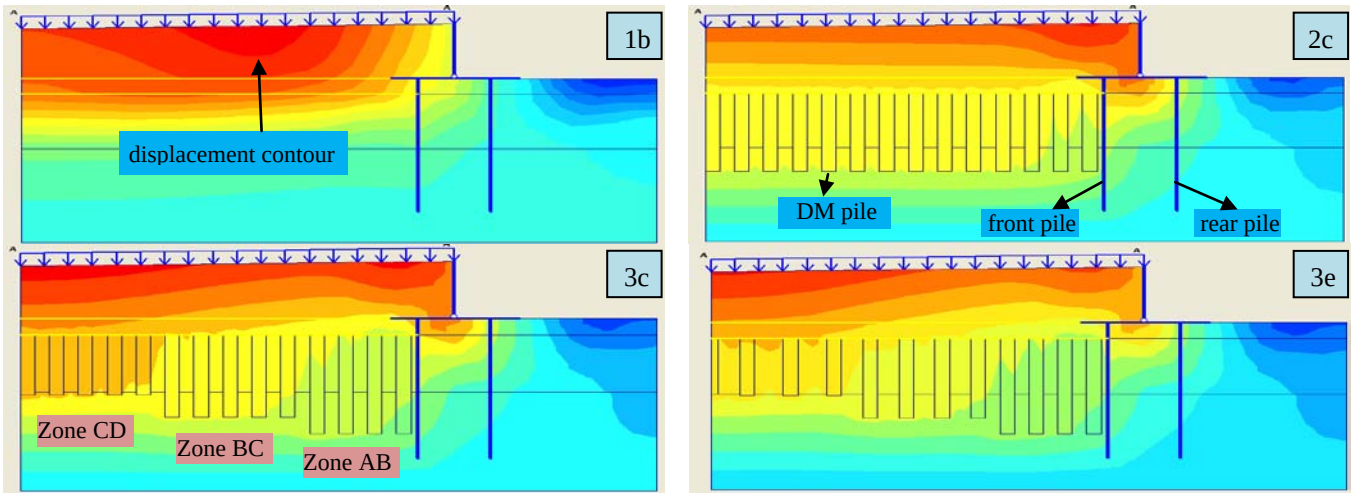

Figure 9 : Vertical displacement contour of four typical cases

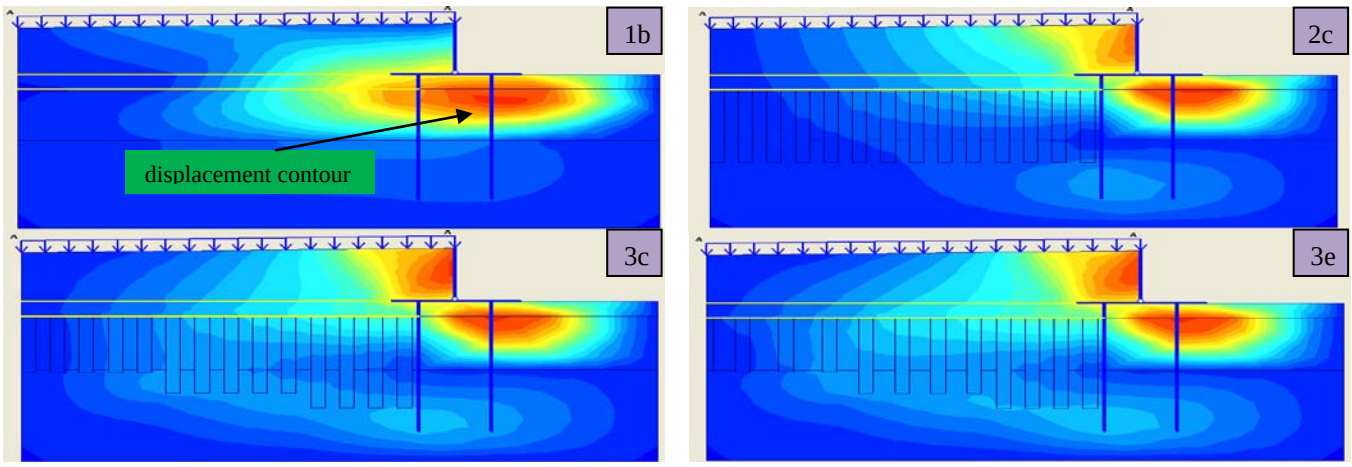

Figure 10 : Horizontal displacement contour of four typical cases

Fig.10 shows horizontal displacement contour, and is is shown that the location of mobilisation appeared at the edge of pile cap and real pile. Therefore, the real pile endured a greater lateral pressure from embankment than front pile). So it is necessarily to consider to design of real pile that has higher strength than front pile to avoid shear and bending failures. As can be seen in Fig. 10 that in the cases has installing of DM piles (2c,3c,3e), the horizontal displacement contour was narrower approximately 63% on both area and value than case 1b(no DM pile). However, the difference between these cases include (2c,3c,3e) is insignificantly with only $\leq$15%. Clearly, the use of the DM piles not only reduces the maximum settlement but also pushes the location of the maximum settlement towards away abutment. In other words, the soft soil under the embankment plays an important role in the maximum settlement, but the length of DM piles less influence to the location of the maximum settlement.

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The magnitude of the arching effect become more dominant in the long term, as consolidation settlement advances and causing reduction horizontal stress.

The reason for this is because stiffness of soft soil impact to arching effect. It is obviously that lateral loading due to arching must be considered, in order to perform a realistic design for this problem.

b) Displacement and bending moment of wall

The abutment wall is a critical element of superstructure. The variations of displacement of abutment wall for different cases are given in Fig.11. As case 1a is compared with case 1b and case 2a in Fig.11a, the use of DM piles not only decreases the displacement of wall to approximately 67% (120mm and 40mm). With case without piles DM(case1a, 1b), horizontal displacement of wall was greatly at pile cap and might be cause of failure of abutment wall.

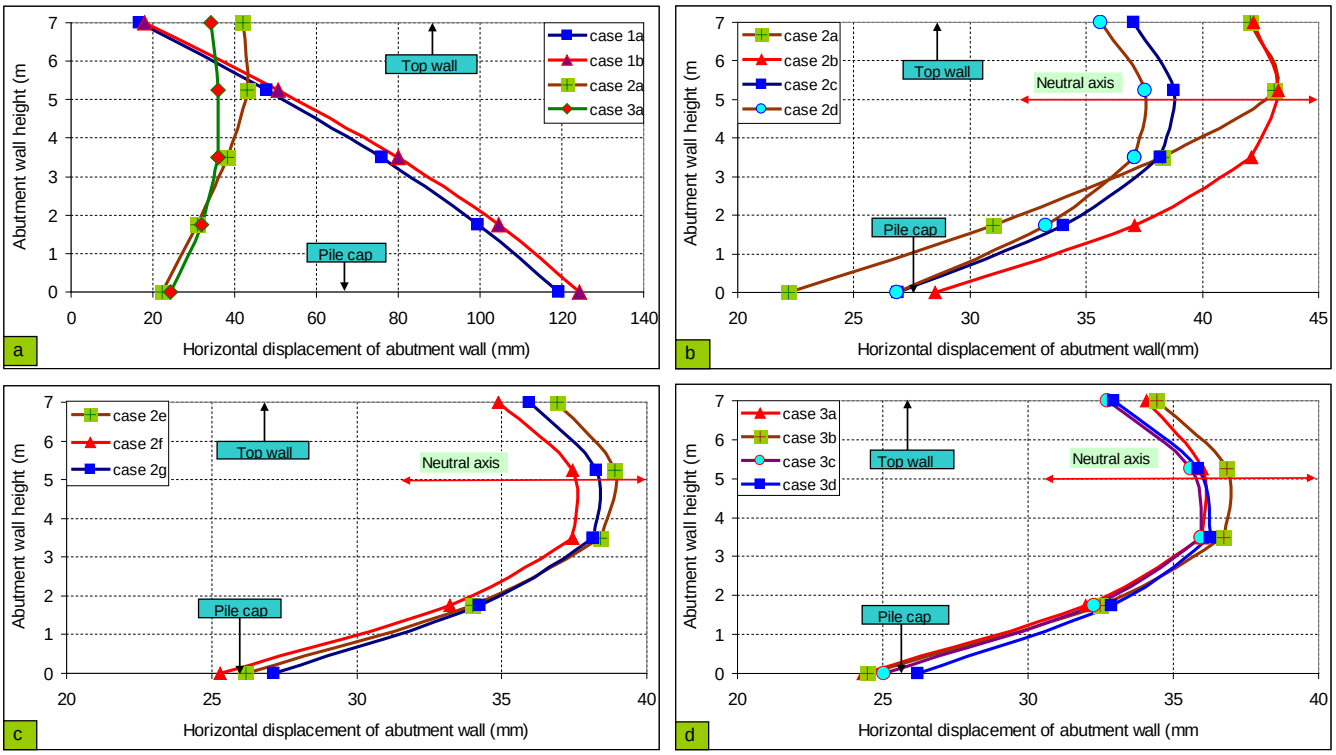
Fig.11b shows the effect of DM pile spacing. Case 2c and case 2d with spacing is 2D and 2.5D respectively have horizontal movement less than case 2a(1.5D) and case 2b(2D) about 16.5%, but the magnitude of differences between case 2c and case 2d is not significantly, the range of 2-4%.

Fig.11c shows comparison among case 2e, case 2f and case 2g. As can be seen that case 2f has smallest displacement, following is case 2g and 2e but three cases are closely.

Fig. 11d and Fig.11e show the influence of changing DM pile length based on support region (case 3). Generally, all cases have the good match, the maximum displacement value averaged out at about 36.2mm.

With an identical pile spacing, abutment wall dispalcement value of case 3a and case 3b are lesser ≈18% compared to case 2a and case 2b as in Fig.11f.

Case 3(c,d,e,g) with varying pile length from 12m in zone AB to 10m in zone BC and 8m in zone CD. Additionally, varying spacing from 2D in zone AB to 2,5D in zone BC and 3D in zone CD reduces maximum displacement of abutment wall as compared with case2(a,d,e,g). Case 3c and 3e had the least movement among all the cases as presented in Fig.11(g,h).



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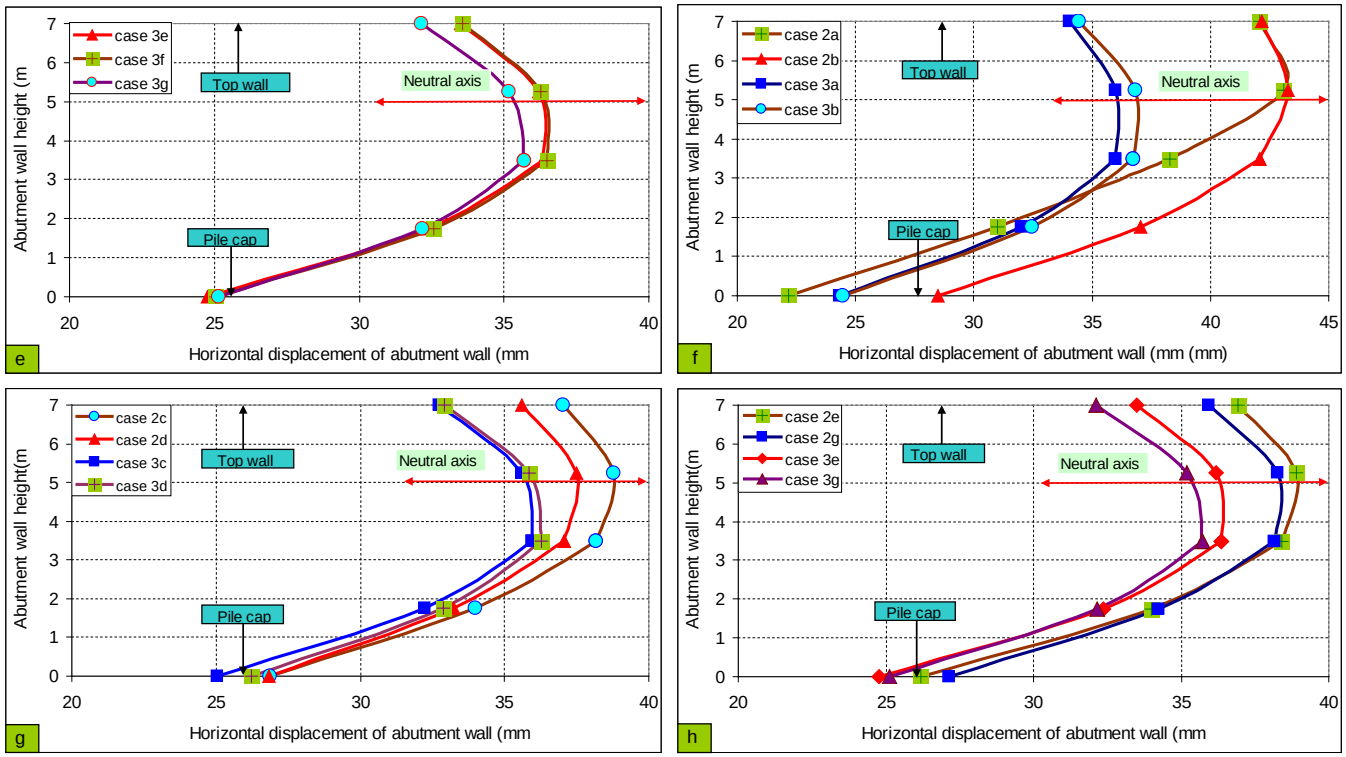

Figure 11 : Horizontal displacement of abutment wall

The bending moment of abutment wall is presented in Figure 12. Abutment wall deformations as a funtion of the global the rotation of pile group and the pile cap translation. However, the rotational deformation of the pile group in the numerical analysis, was almost zero and only translational movement of the abutment wall was observed.

Fig.12a shows displacement between case1(a,b) with case2a and case 3a. It is clearly that almost the gap of cases is quite narrow. However, The location of maximum bending moment moved up above in case 2 and case 3 which have support of GRPS system.

The results for bending moment of abutment wall in cases 2 are given in Fig.12(b,c). It is particularly to see that the position of maximum bending moment in all cases were at 2m away from pile cap(tip wall), except case 2a(at 3.5m). The absence of bending moment mobilised in the upper part of the abutment wall reveals the influence of the aforementioned arching onto the pile cap, due to the settlement and shear stress transfer.

Fig.12(c,d) show the comparision bending moment of wall among cases when have change length and spacing of piles DM. It is obviously that bending moment value in case 3 is smaller a little than case 2 (≈2-3%). It also quite similar to the results in cases 2. Case 3c and case 3d have the smallest value among all the cases. Aslo, all the cases 2 were compared to cases 3 as in Fig.12(e,f,g,h). It is evidently to confirm that all cases 2 and cases 3 were similarly, the differences is insignificantly with only range of 1-4%.

The results about displacement and bending moment of abutment wall showed that the arching mechanism has a significant effect in the long-term, when the lateral loading due is more dominant than that due to the shear sress transfer along the soft soil-embankment interface. Initially, the lateral stresses form an arch onto the front face of the pile cap and increase rapidly near the pile cap, still with considerable vertical load transfer onto the top pf soft clay layer below. The magnitude of the arching effect become more dominant in the long term, as consolidation settlement advances and causing reduction horizontal stress. The results also confirm that the thick of soft clayer, strength pameters of clayer impact strongly to the arching effect.

As the results were analysed that using geosynthetic reinforced pile supported system reduced lateral loading affect onto abutment wall. Especially, cases (3c,3d,3g) have smallest displecement value of abutment wall. Changing the length of piles DM based on different regions gave a better effect. In the distance away from wall should be examined to install longer length of pile DM and decrease gradually as toward away abutment

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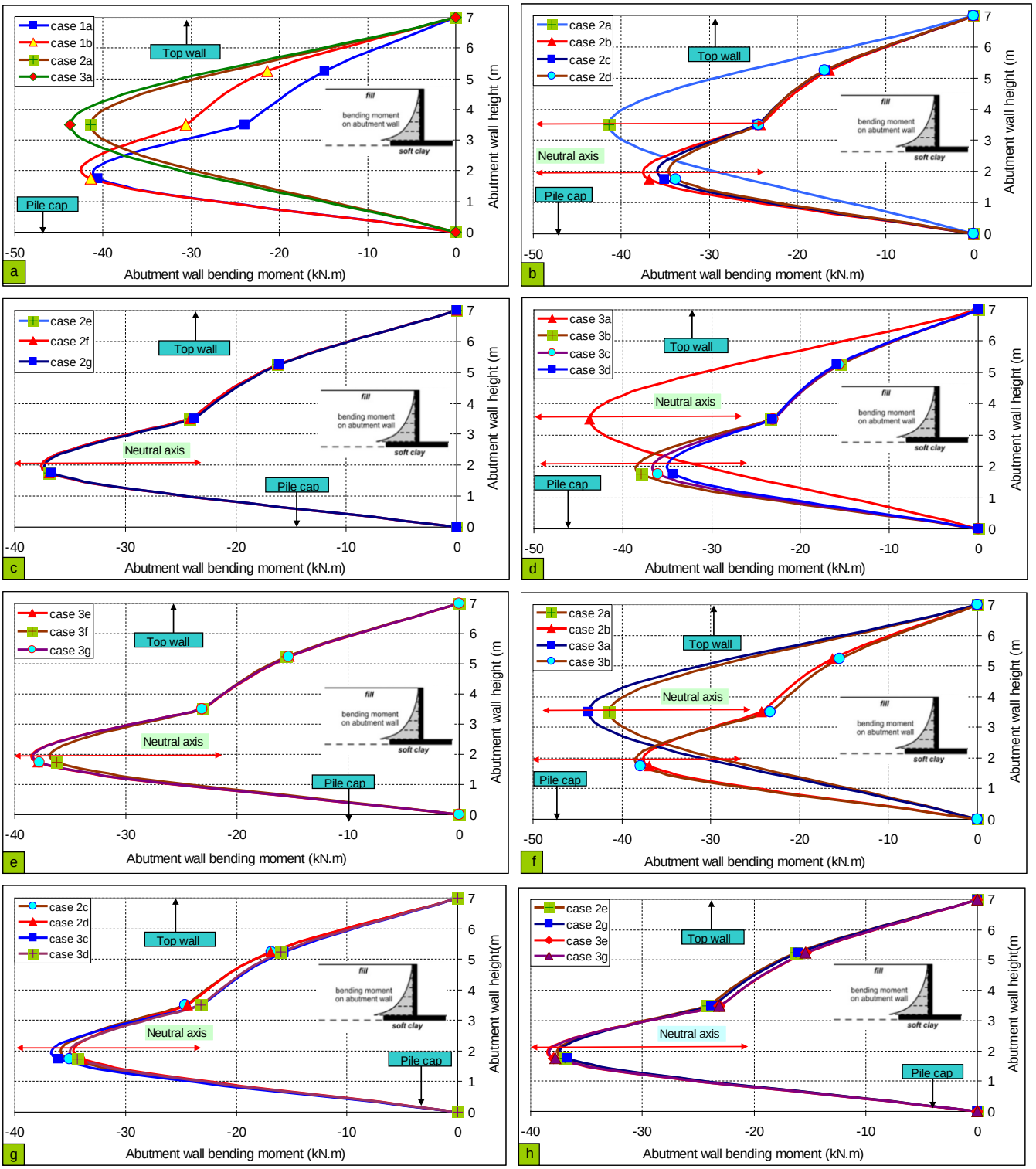

Figure 12 : The bending moment on abutment wall

c) Strain of embankment

Fig.13 presents normal and shear strain of some typical cases for embankment behind bridge abutment. The results show that the strain area and the degree of strain in case 1a is higher significantly(≈61%) than cases where use GRPS solution. Additionally, the maximum strain location is at nearly with the position $\sqrt{2}$ h_s from away abutment wall. As can be seen in Fig.13b, the degree of strain in case 3c is much smaller (≈49%) than case 2c, this has confirmed that the length of DM pile has strongly influenced to the increase of strain of embankment. For the shear strain, Fig.13f shows that shear strain in case 2c is significant smaller than case 3c. A similar comparison also was taken beween case 2a with case 3a and case 3b as in Fig.13(e,g,h). Evidently, the length of DM piles has

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strongly impacted to the stranfer of shear stress from embankment on pile cap.

It is also particularly to notice that all cases 2 as compared to cases 3 nearly give to a similar result, which show the shear strain in cases 3 are much higher than cases 2. Similarly. The shear strain differences at position of pile cap and at the ground between pile is significantly among all the cases 3. Such as in Fig.13e, the shear strain of case 3c is approximately 2.5 times highe than case 1 and case 2a. It also can see case 3c and case 3e have shear strain larger 73% than case 2c, case 2e. However, all cases 3 have a goot match in shear strain result. Evidently, changing the length of pile DM contributed greatly to this differences.

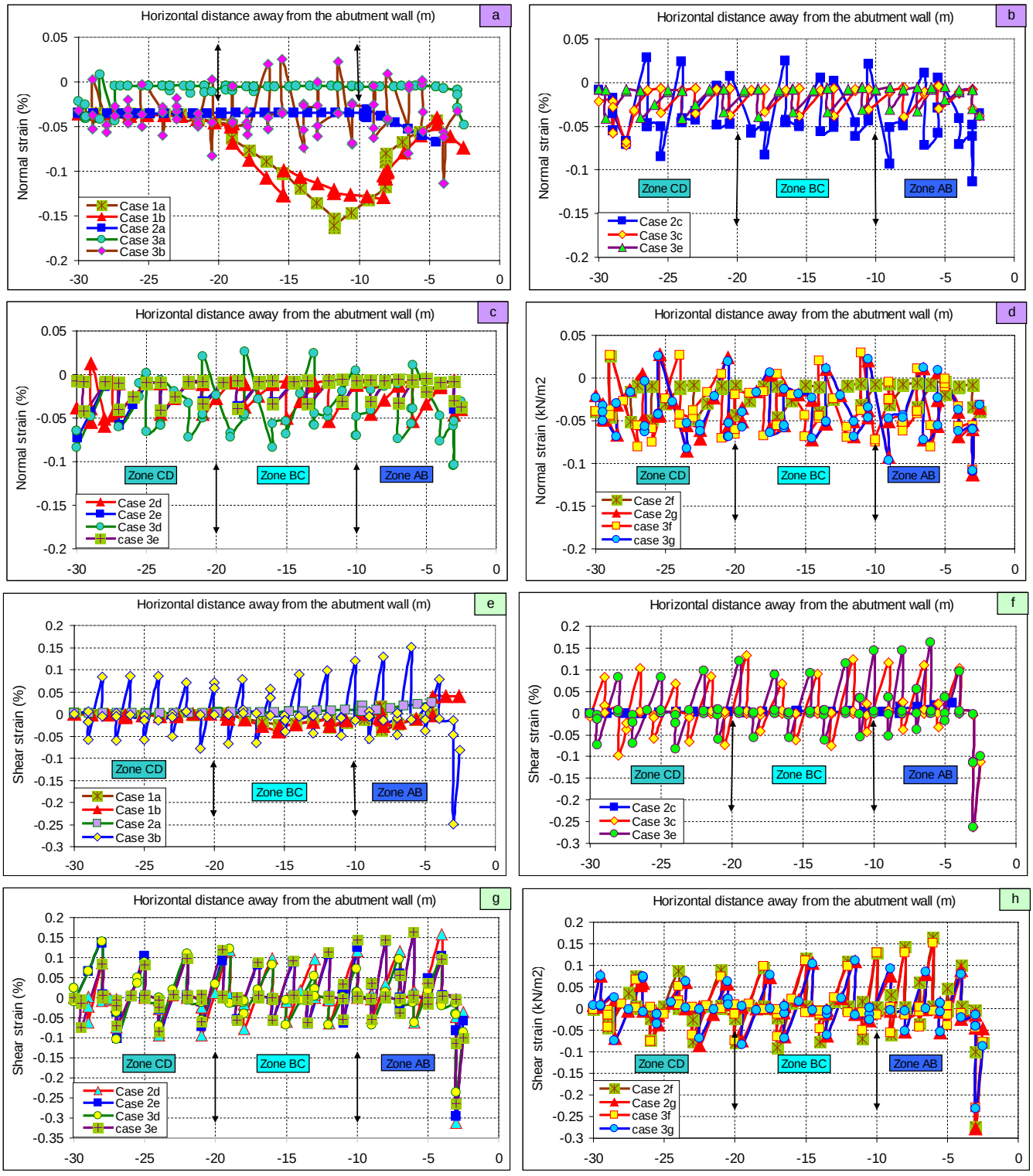

Figure 13 : Normal and shear strain at the base of embankment behind bridge abutment

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d) Settlement profile

The settlement at the base of embakment is presented in Fig.14. As case 1a is compared with case 1b and case 2a in Fig.14a, the use of DM piles not only reduces the maximum settlement from 20cm (Case 1a) to 5cm (Case 2a-decreasingly 80%), but also help the settlement of embankment is less difference along all embankment ($\approx 5cm$).

Fig.14b shows the impact of pile spacing when all zones (AB, BC, CD) are installed by the identical pile length. The avarage settlement of embankment in case 2b is approximately 5.45cm compared to case 2a ($\approx$5.18cm), case 2c($\approx$4.9cm), and case 2d($\approx$5.5cm). Differential settlement in case 2(a,b,c) is also smaller than case 2d as comparison in table 2. Hence, the settlement in Case 2c (s=2,5D) is lowest and distribution settlement is relatively equal as case 2(a,b). This is result of arching effects and group pile effect.

Fig.14c shows the influence of DM pile spacing when all zones AB, BC, CD are supported by various spacing. The avarage settlement of embankment in cases 2e, 2f, 2g is similarly with approximately 4.7cm for zone AB and approximately 5.0cm for zones BC, CD. However, the differential settlement in case 2f and case 2g is higher significantly ($\approx$10%) than case 2e for area of zone BC and CD. In addition to, the use of DM piles shifted the location of maximum settlement toward away abutment than case 1a and case 1b.

Another analysis was performed for case 2 by changing the length of pile for zones (AB, BC, CD) likely in Fig.14d and Fig.14e. The avarage settlement and differential settlement in case 3d is clearly higher greatly ($\approx$19%) than case 3(a,b,c). The settlement results also has trend decreasingly at position nealy abutment, the difference of settlement between zone AB with BC and CD is aprroximately 30% .

Due to the influence of the strength and length of soft soil under the embankment to various zones(AB, BC, and CD) is differently as discussed above. So, the piles installed under the embankment is shifted pile spacing and length of piles for each zone that was compared and analysed in Fig.14f, Fig.14g, Fig.14h. As case 2(a,b) is compared with case 3(a,b) shown that the settlement in zone AB and CD of case 2(a,b) largely reduce (21.2%) than case 3(a,b).

Fig.14g shows results for comparison of cases have changing pile spacing from 2,5D to 3D and the length of piles has decreased gradually follow supporting zones. With case 3c (s=2,5D), distribution of settlement only slightly increase than case 2c and 2d. The results of comparision also presented similarly for case 2(e,f,g) with case 3(e,f,g) in Fig.14h. And the longitudinal gradient change is defined as distortion (i.e., differnetial settlement/distance) of pavement is relatively small with 0,22%, at in safety limitation ($\leq$ 1.5%)(Ling. et.al).

Differential settlement ratio S_d (%), that is defined as ratio between settlement on DM pile and settlement of soft ground, as well as longitudinal gradient change, g_e, for all cases presented in bảng 2. As can be seen that GRPS solution has significantly reduced settlement of embankment (5,5cm-treatment and 25,1cm-untreatment). Also, GRPS solution help decreasing longtitudoinal gradient change by settlement of embankment, as case 1a with ge =1,89% over limited value (1.5%), but avarage value ge in other cases only 0,11%. Case 2c and case 3c show the best suitable results include all factors such as displacement, differential settlement, longitudial gradient change.

It is obvously to see that the cause of this is because of the wall displacement is often significantly affected by the stiffness and displacement of the embankment behind the abutment by arching effects and pile group effects. Arching effect increases the stress on the pile DM concentration leads to lower displacement of soft ground, arching effects will decrease as the pile sapcing is the greater. The pile group effect occurs because phenomena ovelap stress lead to increased displacement of the soft ground, pile group effects also decrease as the distance increases piles. With case 3c, the case of the impact of arching effects tend to be greater than the impact of the pile group effect as the cause of the smallest value of the wall displacement.

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Table 2 : Settlement, differential settlement, longitudinal gradient change of embankment

Case	1a	1b	2a	2b	2c	2d	2e	2f	2g	3a	3b	3c	3d	3e	3f	3g
Settlement at at crest , cm	28.8	29.0	8.8	9.1	8.9	8.8	8.8	8.8	8.9	8.6	8.6	9.1	9.95	9.0	9.1	9.2
Settlement at Base, cm	25.1	25.1	5.2	5.5	5.6	5.5	6.5	5.5	5.5	5.8	5.7	6.0	6.8	6.0	6.4	6.3
Settlement of Fill, cm	3.7	4.1	3.6	3.6	3.3	3.3	2.3	3.3	4.4	2.8	2.9	3.1	3.2	3.0	2.7	2.9
Differential settlement, %	0	0	0.1	0.5	3.0	9.2	14.2	10	12.8	0.8	1.2	5.8	13.3	8.2	8.5	8.8
Gradient change g_e, %	1.89	1.45	0.06	0.13	0.06	0.1	0.1	0.1	0.1	0.1	0.11	0.12	0.16	0.12	0.13	0.14

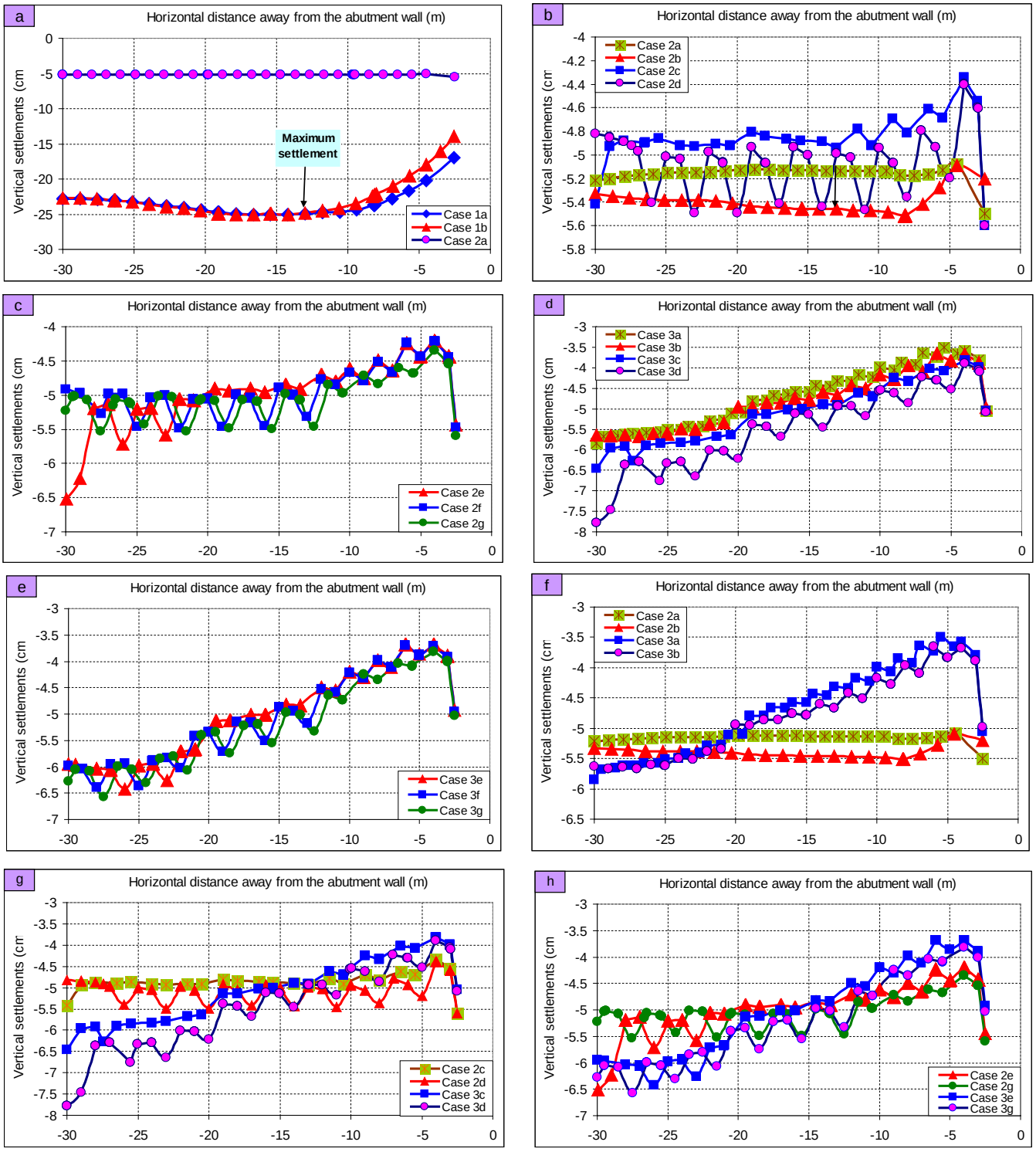

Figure 14 : Settlement profile at the base of embankment behind bridge abutment

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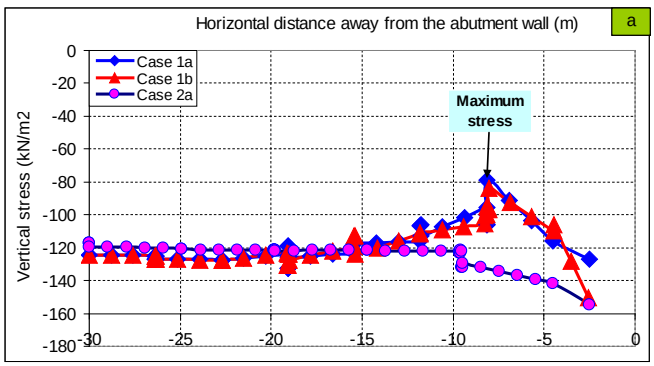
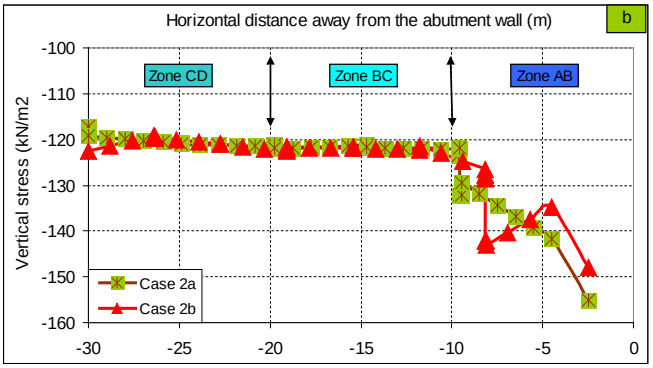
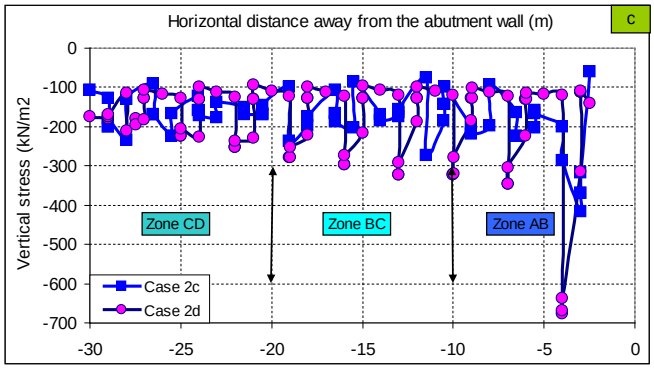
e) Vertical stress distribution

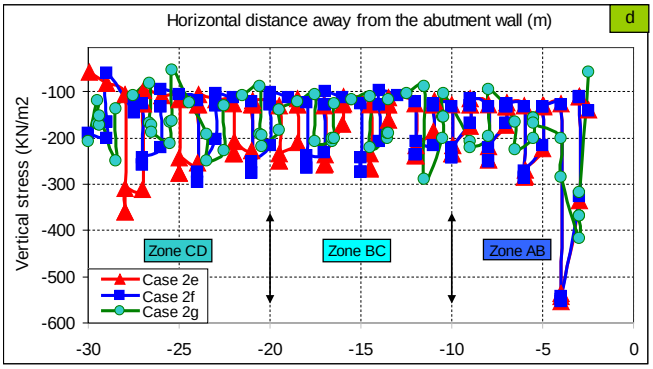
Eight typical cases for distribution of stress at the base of embankment are presented in Fig.15. As compared with case 2a, Fig.15a shows that there are a good agreement about distribution of stress along embankment in cases(1a,1b,2a). But, for zone AB, stress has increasingly steadily in case 2a rather than the reduction in case 1. Fig.15b shows the comparision between case 2a and 2b, and most stress shifted in zone AB with the difference only from 3% to 5%. This had indicated distribution of stress were impacted greatly by arching effects. Simultaneously, the results also shows that the interaction area of embankment and bridge abutment is suitable with value $\sqrt{2}\,h_s$ (h_s-the depth of soft clay), nearly only in zone AB.

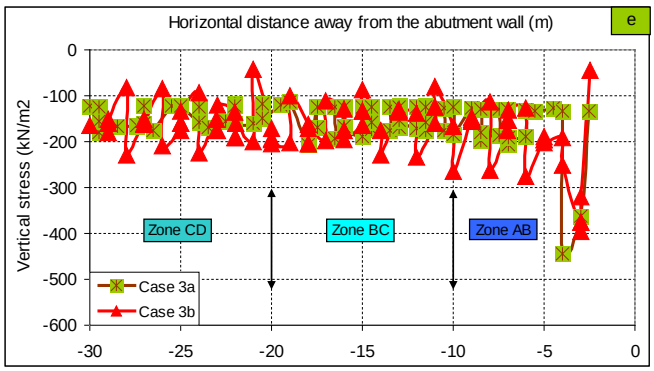
Fig.15c and Fig.15d shows influence of pile spacing DM to distribution of stress for other cases. The maximum value of stress appeared suddenly at the edge of pile cap ($\approx 550 \div 700 kN/m^2$) when has the change of pile spacing (2D÷3D). Thus, this position might be destroyed higher significantly than other locations. Fig.15e and Fig.15f show comparision on distribution of stress between cases 3(a,b,c,d). The distribution of stress on DM pile cap in case 3b is higher approximately 17% than case 3a and also quite similarly with case 3c and 3d in zone AB. Fig.15g shows that stress value is not differently much between case 3a and 3g, but much higher ($\approx 32\%$) compared to case 3a and 3b. Besides, stress concentration ratiowas analysed from all cases has remained about 1 5 and less depend on the change of DM pile length.

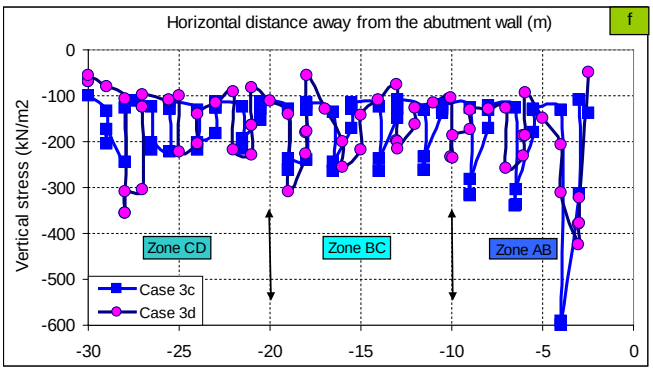












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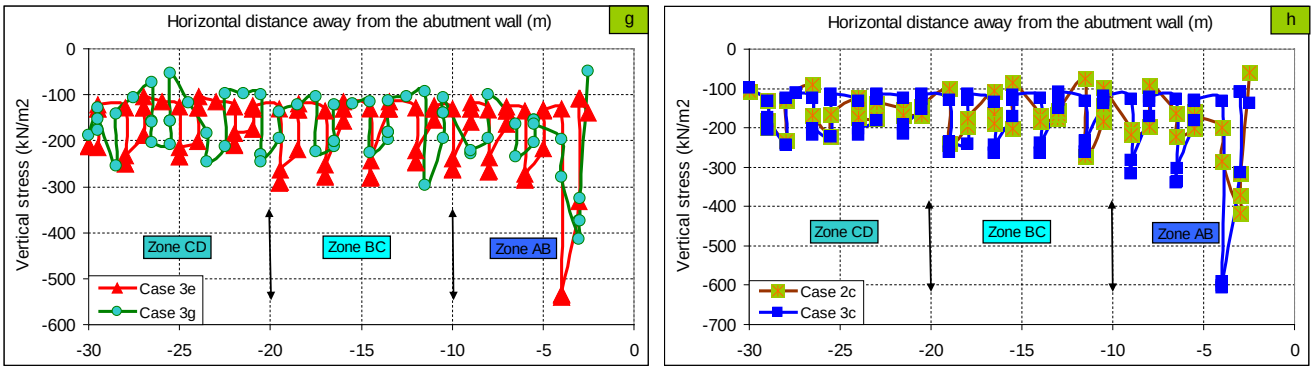

Figure 15 : Vertical stress distribution at the base of embankment behind bridge abutment

IV. Conclusion

A commercially available FE software and soil model were used to compare and discuss the results obtained. The development of strain contour, vertical and horizontal movements of the embankment and soft clayer, the displacement and bending moment of abutment wall, the deformation of embankment, the settlement and stress distribution were analysed, compared and discussed. Additionally, mechanism pertaining to bridge abutment constructed on piled foundation through soft soil have mostly been investigated using numerical analyses presented in this paper. The findings are summerised based on Fe numerical software as follows:

Numerical findings revealed that arching effect and pile group effect have a significant effect on the lateral loading of the abutment wall in long-term.

The arching effect increases the stress on the pile DM concentration leads to lower displacement of soft ground, arching effects will decrease as the pile sapcing is the greater. The pile group effect occurs because phenomena ovelap stress lead to increased displacement of the soft ground, pile group effects also decrease as the distance increases piles. With case 3c, the case of the impact of arching effects tend to be more dominant than the impact of the pile group effect lead to the smallest value of the wall displacement.

The abutment wall is a critical member of the structure system, and FE analysis shown that the displacement of wall was being impacted significant by the stiffness and the thick of soft clayer.

It is necessarily to use GRPS system for support embankment behind abutment. This can reduce settlement, displacement, strain and failure risks of abutment. The best performance might obtain by changing length and spacing of pile DM based on different regions

Deformation zone by interaction between embankment and bridge abutment mainly happen during domain approximately $\sqrt{2}$ h_s away from abutment wall. Depth of clay layer (h_s) and variation of c_u with depth are factors that influenced significantly.

The reduction of displacement, differential settlement and deformation can be achieved by installing DM piles. The best performance can be obtained by optimizing the pile spacing under embankment from 2D to 2,5D.

Installing DM piles with a spacing is 2,5D and shift the length of DM piles based on supporting zone might help embankment get the reduction of differential settlement and longitudinal gradient change as well as get a good aggrement with the distribution of stress. longitudinal gradient change should be controlled to be avoid possible failure (≤1,5%).

In the deformation zone behind abutment(AB and BC), stress distributed and focused extremely large at the location of edge of pile cap with cases has treated by GRPS and at the location $\sqrt{2}$ h_s - untreatment cases.

The stress concentration ratio for the GRPS systems ranged from 1 to 5, and nearly less influence to the length of DM piles. But, the shear stress transfer on pile cap depend significant on the length of DM piles.

Foundation piles can provide shear resistance to the shear stress induced by embankment. It is necessarily to install DM piles with larger length in zone $\sqrt{2}$ h_s from abutment to avoid possible failure or dmage of roadways and bridge abutment.

References Références Referencias

1. Jie Han, Sadik Oztopraka, Robert L. (2007), Numerical analysis of foundation columns to support widening of embankment. Computer and geotechnics 34, Elsevier Ltd. pp 435-448.
2. M.K Kelesoglu, S.M Springman. (2011), Analytical and 3D numerical modelling of full-height bridge abutment. Computer and geotechnics 38, Elsevier Ltd. pp 934-948.
3. E.A. Ellis. (1996), Soil-structure interaction of piled bridge abutments constructed on soft clay. Ground Engineering, University of Cambridge. pp 42-44.
4. CA. Jones, DI Stewart, CJ Danilewicz. (2008), Bridge distress caused by approach embankment settlement. geotechnics Engineering, Elsevier Ltd. pp 63-74.

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5. De Beer EE. (1972), Piles subjected to static lateral loads. Proceedings of 9th European conference on soilmechanics and foundation engineering, Tokyo, 1972. pp. 1–14.
6. Tschebotarioff GP. (1973), Foundations, retaining and earth structures. 2nd ed. New York: McGraw-Hill; 1973. p. 365–414.
7. Brinkgreve, R.B.J and Vermeer, P.A. (1998), Plaxis - Finite Element Code for Soil and rock Analysis - Version 7, A.A. Balkema Publishers, Netherlands.

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