PROCEEDINGS OF THE SIXTH INTERNATIONAL CONFERENCE ON THE APPLICATION OF STRESS-WAVE THEORY TO PILES / SÃO PAULO / BRAZIL/ 11 – 13 SEPTEMBER 2000

Application of Stress-Wave Theory to Piles

Quality Assurance on Land and Offshore Piling

Edited by

Sussumu Niyama
Institute for Technological Research – IPT, São Paulo, Brazil

Jorge Beim
PDI Engenharia, Rio de Janeiro, Brazil

Sonic Integrity test of piles-integrity effected by basement excavation in Bangkok soft clay

N. Thasnanipan, A.W. Maung, P. Tangseng & Z. Z. Aye
Seafco Company Limited Bangkok, Thailand

A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 2000

Sonic integrity test of piles-integrity effected by basement excavation in Bangkok Soft Clay

N. Thasnanipan, A. W. Maung, P. Tanseng & Z. Z. Aye
Seafco Company Limited, Bangkok, Thailand

ABSTRACT: Modern buildings in Bangkok nowadays are designed with basement facility and different elevation of pile foundation which require excavation works in the immediate vicinity of the constructed bored piles. Adverse effects on piles from adjacent excavation works in terms of excessive movement of piles and pile damages have been observed in some projects. Assessment of bored pile damages using sonic integrity test is focused in this paper with demonstration of test results from three case histories. Method of remedial works for damaged piles and additional testing for pile capacity justification where available are also briefly discussed. Stress induced in piles due to the soil movement caused by excavation works is also examined with the aid of computerized finite element program. Location of cracks detected by sonic integrity tests is correlated with the analyzed bending moment in pile, which exceeds the cracking moment capacity of pile.

1 INTRODUCTION

Due to the prevailing condition of subsoil (existence of considerably weak stratum at top part) piles are commonly used for foundation of buildings and structures in Bangkok. Deep-seated large diameter bored piles of over 35 m depth with 0.8 –1.8m in diameter have been mainly used for heavy structures such as high rise buildings, elevated expressways, flyovers or overpass bridges and more recently for underground subway stations of the first Bangkok MRTA system. As a part of pre-planned quality assurance regime and retrospective investigation, integrity of the piles are tested to obtain the information with regard to the potential deficiencies of the constructed piles which may have formed during actual pile construction process or may have been attributed by other activities after construction of the piles. Designs of the modern buildings in Bangkok frequently call for the basement facility and for the different elevation of pile foundation, which require excavation work mainly in top soft clay layer. In some projects, adverse effect from excavation works adjacent to constructed piles has been observed. This paper presents the assessment of bored pile damages which were induced by adjacent excavation using sonic integrity testing method.

2 GENERAL DESCRIPTION OF BANGKOK SUBSOIL

Bangkok subsoil consisted of alternating clay and sand layers of Quaternary deposits extending down to about 550m depth where bedrock generally exists (Balasubramanium, 1991). Made-Ground consists predominantly of Fill-Materials, Clayey Sand or Silty Clay with some cement block rubble and rock fragments, is commonly found up to 4m depth. Soft to very soft, highly compressible dark gray marine clay lies beneath Made-Ground and in some areas it lies under weathered crust layers of 2m thick. Depending on the location, this layer is extended up to 12-18m. About 2m thick Medium Clay layer can be observed between Soft Clay and underlying Stiff Clay. Generally Stiff Clay layer occurs directly underneath Medium Clay and its depth goes up to 22m. Below Stiff Clay layer, First Sand layer 5-8m in thickness can be found. This First Sand layer, however, is absent in some areas. Stiff to Hard Clay layer underlies First Sand and it is found to be about 5m thick. Second Sand layer generally occurs at depths between 45 to 65m. The Generalized Fence Diagram of Subsoil covering the central area of Bangkok is illustrated in Figure 1.

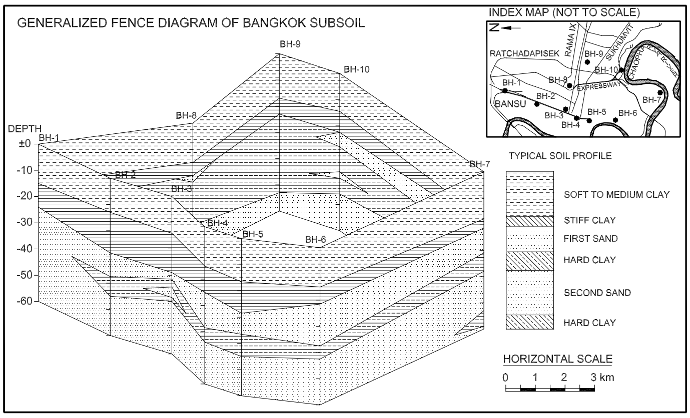

Figure 1. Generalized fence diagram of Bangkok subsoil

3 BORED PILE CONSTRUCTION IN BANGKOK

In Bangkok, bored piles are constructed mainly by two methods, dry and wet process. Dry process is applied commonly for small piles of diameter 0.35 to 0.60m with relatively shorter lengths. In dry process, a pile is bored to the required depth within impermeable layers (usually up to 25m) by either rotary or percussion method whilst temporary casing (about 15m in length) is installed in soft clay layer for protection of soil caving. After installing reinforcement cage, concrete is poured into the borehole under dry condition. Tripod method, shell with drop weight is also commonly used in dry process.

Wet process method as its name implies makes the pile under wet condition by using drilling slurry (bentonite or polymer). Temporary casing of 14-15m in length is also used as a support in soft clay layer and soil inside the casing is normally excavated by auger applying rotary drilling method. Drilling is continued with the bucket under the slurry from the top of sand layer to the final depth. Tremie concreting is necessary for pile installed under wet process. Bored piles constructed by wet process are generally of large diameter (0.8m to 1.8m diameter) deep-seated (30m to over 60m) and are normally founded in either first or second sand layer. Bored piles having compressive cylindrical strength of concrete in a range of 240-280 ksc (24-28 MPa) with reinforcement ranging 0.5% to1.2% of pile sectional area, are commonly used in Bangkok.

4 SONIC INTEGRITY TESTING IN BANGKOK

Sonic integrity test is widely used for integrity testing of both driven and bored piles in Bangkok. It is employed as a part of quality control and or as a retrospective investigation when some problem becomes apparent. For a quality control regime, the number required for integrity testing depends upon the technical requirement of the particular projects ranging from minimum 10% to maximum 100% of total constructed bored piles. A sonic integrity tester with built-in computer having high quality signal acquisition system and computer programs developed by TNO, PDI, IFCO etc. are commonly used for pile integrity testing.

5 OVERVIEW OF EXCAVATION INDUCED PILE DAMAGE IN BANGKOK

In general, pile defects are caused at two stages, during the pile construction process and after construction of the piles (post-pile-construction).

Thasnanipan et al. (1998b) reported that integrity of 285 bored piles (3.3 % of 8,689) were found to be of doubtful quality according to an assessment on the results of sonic integrity test with the additional information obtained from the pile construction records of bored piles in Bangkok subsoil. The results of the findings are summarized below.

Table 1. Summary of pile assessment on 8,689 bored piles (Thasnanipan et al. 1998b)

Type of Defect	Causes	%
Poor concrete at pile top (0-3m)	Cutoff level near the ground or inadequate overcast	0.1
Size reduction	Insufficient casing length or soft clay layer variation in thickness	1.0
Cracks/discontinuities	Excavation works for pile trimming and construction activities	2.2

As can be seen in the above table, higher percentage of defects is caused by post-pile-construction activities and more commonly by movement of surrounding soils induced by excavation works in the vicinity of the piles.

Modern buildings in Bangkok frequently require the excavation works for basement facility and for the use of different elevations of pile foundation. Excavation works are mainly carried out by using cut slope, sheet pile wall, diaphragm wall and secant pile wall. Since most of the bored piles are designed mainly to carry an axial load, lateral and tensile force which may impose on pile during basement excavation are sometimes not considered or overlooked. The lateral displacement of ground caused by excavation naturally induced an additional lateral force and bending moment in the pile. Once the induced bending moment exceeds the cracking moment capacity, piles are subject to be cracked. Unexpected tensile force acting upon the pile due to an excessive heave or uplift force induced by excavation can also cause cracking of pile. In Bangkok, pile cracks caused by external forces are normally found to be at the level where Soft and Medium to

Stiff Clay boundary is present. Figure 2 illustrates the typical features of external forces, which cause a crack in the piles. Pile damage associated with sheet pile wall excavation is presented in this paper.

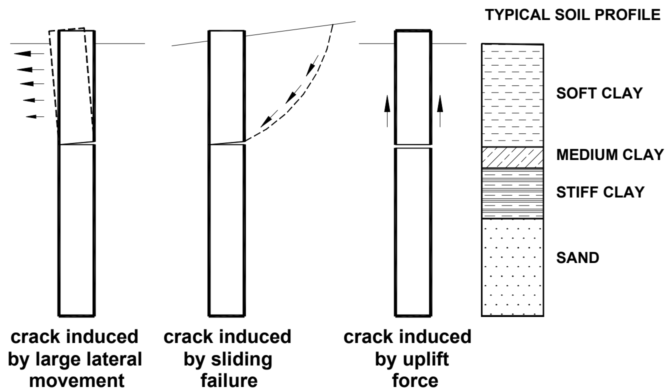

Figure 2. Typical features of external forces causing pile cracks in Bangkok subsoil

6 APPLICATION OF SONIC INTEGRITY TEST IN PILE-INTEGRITY CHECKING

Sonic integrity test is simple, rapid, efficient and cost effective in examination of the pile integrity. It is reasonably reliable for the integrity testing of the pile especially for the upper part where potential of damage is higher as far as defect caused by the external effects (lateral displacement of soft clay due to adjacent excavation works, unexpected force from improper pile head trimming) is concerned.

6.1 Basic principles of sonic integrity test

Sonic integrity testing also called as low-strain integrity testing examines the response of a pile to a light external impulse force. Either time-domain or frequency-domain can be used in analysis of measured data by sonic integrity test. In Bangkok, time-domain method is mainly applied in interpretation of test data.

Sonic integrity test is undertaken by striking the head of the pile with a light hand-held hammer and recording the response of the pile to this impulse blow by means of a sensor or accelerometer placed in good contact with the pile head. Stress wave theory is a basic principle of this low-strain integrity testing. The hammer blow induces a compressive stress-wave into the pile, which propagates axially along the pile shaft and reflects back toward the pile head at a change of impedance within the pile. In the case where pile impedance variation occurs due to changes in pile cross sectional area or properties of pile materials or presence of discontinuities, part or whole of down ward wave reflects at the impedance variations and returns to the pile head before the first reflection from the pile toe.

Basically, following formulae are used in analysis of sonic integrity test.

$$L = c\,T/2 \qquad (1)$$

where, L is a length from pile head to reflected surface, c is a velocity of stress wave and T is a travel time of the wave for length L.

From this formula, length L, can be computed from the travel time of reflected wave and the wave velocity of concrete which may be estimated from concrete strength of piles or from the reference pile of known length.

$$z = E\,A/c \qquad (2)$$
$$E = \rho\,c^2 \qquad (3)$$

where, z is an impedance of pile, E is Young Modulus of pile material, A is cross-sectional area of pile, c is the propagation velocity of the stress wave and ρ is density of pile.

From Equations (2) and (3)

$$z = \rho\,c\,A \qquad (4)$$

As can be seen from Equation (4), the change in pile impedance could be due to variation in pile cross-sectional area or in concrete quality.

6.2 Interpretation of sonic integrity test

In general the typical pile features detectable by sonic integrity test includes;

- Pile size variation
- Pile toe reflection (for pile length verification)
- Pile material variation
- Soil influence
- Discontinuity and/or cracks

The typical sonic integrity signals of above features have been reviewed and presented by Thasnanipan et al. (1998a). As some features have a similar pattern to each other, it is always important to check and compare the test data of pile in question with those of other piles within the same job site to establish "site signature". In some cases correlations should be made with similar projects where damaged piles were investigated with firmed evidence (coring or excavation to detect damage level). Interpretation should also be made with sound knowledge of pile construction technique, subsoil condition and other factors (problem encountered during and post pile construction) which may influence the sonic test signals. Pile construction records are also useful in interpretation of piles with detected anomaly. Conclusion should be made after careful and thorough review of test results in conjunction with other available information. Further investigation (if applicable excavate down to level of detected crack for visual inspection) may require before final conclusion is made.

As a main focus of this paper, the typical features associated with the pile damage (discontinuity/cracks) detected by sonic integrity test is discussed in detail with the data obtained from three cases as presented in the following sections.

6.3 Pile damage assessment

From the results of sonic integrity test, degree of damage or level of crack may be assessed. The assessment of crack generally involved – setting of amplification in the same range for all piles and comparison of input impulse, amplitude of anomaly and intensity of reflection from the anomaly (i.e. multiple reflection). Additional information obtained from further investigation as described in above section is also used in pile damage assessment.

7 CASE STUDIES

7.1 Case I – Sheet pile excavation supported by soil berm

7.1.1 Subsoil condition

A 12m thick soft clay layer occurs beneath fill material and weathered crust of 1.0 to 2.5m thick. Unconfined shear strength (Su) of soft clay layer ranges $1t/m^2$ at top and $2.5t/m^2$ at bottom whereas the natural water content is about 60-80%. Medium clay layer of 1 to 2m in thickness, having shear strength of $2.5t/m^2$ to $3.5t/m^2$ underlies soft clay layer. Below medium clay, at the depth between 18 to 27m, stiff clay with traces of fine sand having SPT N value of 15 to 37 is observed. Thick layer of fine sand interbedded with clayey sand occurs underneath stiff clay layer.

7.1.2 Pile foundation

Pile foundation of eight high rise buildings in this project comprises 904 cast-in-place bored piles of diameter 1.0m and 1.5m, founded at 59m below ground level. Pile tips are embedded in dense sand layer and the entire length of piles are reinforced with steel reinforcement of 0.72% of pile sectional area for the top part and reduced gradually to 0.23% for the bottom section. To support the underground water tanks, 88 pre-cast concrete piles (I-30cm) having 21m length were also driven down to stiff clay layer.

7.1.3 Excavation method and observed failure

Excavation was initially carried out by using sheet pile (Type FSP III) with soil berm support or slope. Before reaching to –8.1m maximum depth of excavation, sheet pile failure and associate severe lateral movement as well as settlement of ground including tension cracks of more than 300mm in width were observed at some locations. Minor damages were also investigated at the adjacent properties. Temporary raking struts were immediately installed in response to these excessive ground movements caused by sheet pile failure. A typical scheme showing excavation works of Case I is presented in Figure 3.

Figure 3. A picture showing slope excavation with sheet pile support – Case I

7.1.4 Sonic integrity test and pile damage assessment

More than 50% of piles were tested with sonic integrity test. Test results were thoroughly reviewed and "site signature", most common features of the majority of piles, is established. It is to be noted that test signals from piles of less potential for damage (least effect from excavation) are selected in establishment of "site signature" or reference signal of good piles. Based on the "site signature" of good piles, defect piles were identified and assessed. Table 2 shows the summary of pile damage assessment by sonic integrity test.

Table 2. Summary of pile damage assessment by sonic integrity test – Case I

Pile Dia. (m)	No. of piles with defect			Defect depth below ground level (m)
	Least prominent crack	Less prominent crack	Prominent crack	
1.0	4	8	7	6.0 – 13.8
1.2	-	10	2	6.1 – 7.6
1.5	-	1	-	9.9

The typical sonic integrity test results of undamaged pile and damaged pile classified as least prominent crack, less prominent crack and prominent crack are shown in Figure 4. Majority of piles with crack detected were located in the periphery of the excavation zone. Piles, particularly with prominent cracks, were observed to be deviated from their original location up to 600mm towards excavation.

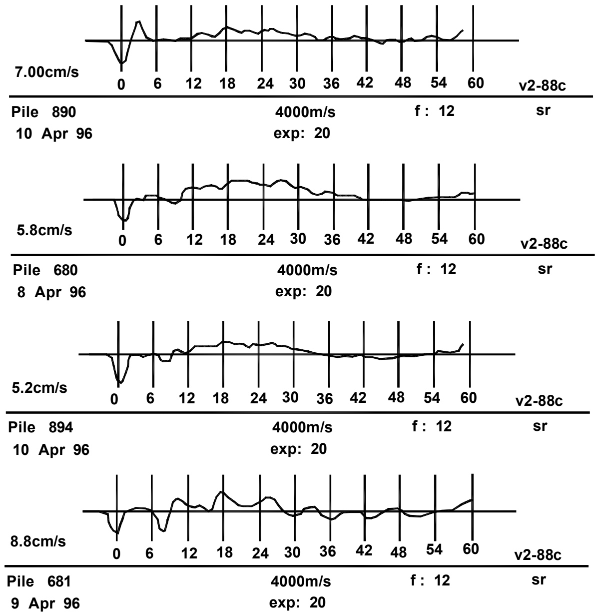

Figure 4. Seismic test results of good pile, pile with least prominent, less prominent and prominent crack (top to bottom in order) – Case I

7.1.5 Remedial measures and pile capacity justification

Bored piles with cracks were cored to the depth below the crack and grouted with non-shrink cement. Sonic integrity test was conducted few days after rectifying the pile. Sonic integrity signals of the defected pile tested before and after the remedial work is presented in Figure 5. After the rectification works, high strain dynamic load test was performed on two piles with large horizontal deviation and suspected prominent cracks. The dynamic test results indicate that tested piles could be capable of carrying the design load with factor of safety higher than 1.5.

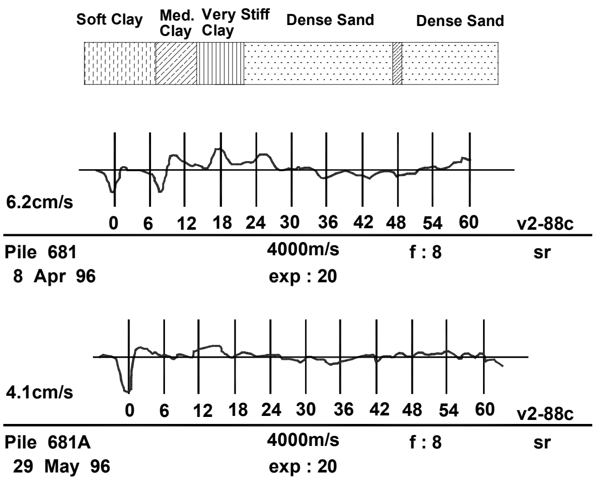

Figure 5. Sonic integrity test results on defected pile before and after remedial work – Case I

7.2 Case II – Pile damage caused by sheet pile excavation with one level temporary support

7.2.1 Subsoil condition

Soft Clay layer extends to 15m below ground surface with undrained shear strength increases from 1t/m^2 at the top and 2t/m^2 at the bottom. Medium Clay layer of 2 to 3m in thickness is found between Soft Clay and the underlying Stiff Clay. Stiff Clay layer occurs up to depth 42m with the SPT ‘N’ values ranges between 14 and 40.

7.2.2 Pile foundation

402 bored piles of diameter 1m and 1.5m, founded at 55m below ground, being embedded in dense sand layer were used as foundation in this project. Reinforcement steel bars of 0.5% pile cross sectional area were provided for the entire length of bored piles.

7.2.3 Excavation method and observed failure

Sheet pile wall of 14m in length with 1 level bracing was utilized for maximum 8m excavation. Though the design required for installation of struts at 1m below ground level, the actual excavation was carried out up to 3m depth without installing the temporary struts causing sheet piles deflected in large magnitude.

7.2.4 Sonic integrity tests and pile damage assessment

Sonic integrity test was performed for all piles after trimming to the designed cutoff level. It is evident that piles with crack detected by sonic integrity test were mostly located in the vicinity of the excavation boundary.

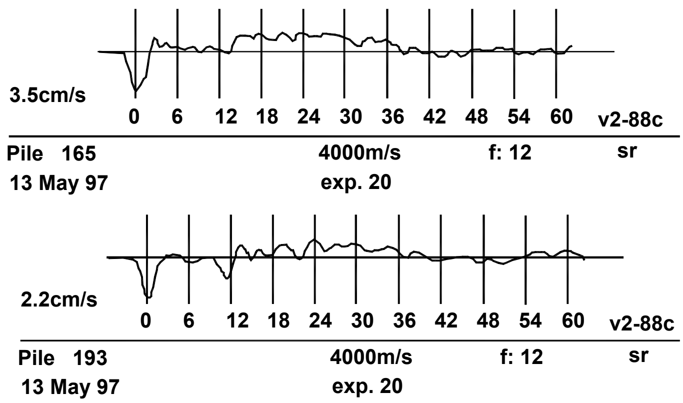

Figure 6. Sonic integrity test results of good pile and pile with prominent crack – Case II

A summary of the number of damaged piles and their degree of damage assessed are presented in Table 3.

Table 3. Summary of pile damage assessment by sonic integrity test – Case II

Pile Dia. (m)	No. of piles with defect			Defect depth below ground level (m)
	Least prominent crack	Less prominent crack	Prominent crack	
1.0	-	-	5	7.5 - 9.4
1.5	-	-	14	8.4 - 21.0

7.2.5 Remedial measures

Damaged piles were cored to the level below the defected crack and grouting was performed.

7.3 Case III – Pile damage caused by sheet pile excavation with two level temporary support

7.3.1 Subsoil condition

Underneath the top 2m of weathered crust, Soft Clay layer can be observed up to 15m below the ground surface. Medium Clay layer underlies Soft Clay with the thickness of 2m. Undrained shear strength of Soft Clay ranges between 1t/m^2 and 3t/m^2 whereas it is about 50t/m^2 in Medium Clay. Beneath Medium Clay, Stiff Clay layer is found up to 25m where the boundary of Hard Clay is investigated. Within Stiff Clay stratum softer zone of Medium Clay is identified at the depth between 19 and 21m characterized by reduction in SPT values which appear consistent with increases in moisture content.

7.3.2 Pile foundation

A total of 143 bored piles of 0.6m diameter were installed with pile tip at about 26m below the ground to support a residential apartment. Dry process was employed to construct the piles. Cut-off level of bored piles ranges from 0.85m to 5.95m depth. Entire lengths of all piles are fully reinforced with steel bars grade SD40 of 0.35% of pile sectional area.

7.3.3 Excavation method and observed failure

Temporary retaining wall using FSP III sheet pile type of 14m in length with two level bracing placed at 1m and 3.5m below ground level was employed for 6m depth excavation. A part of pile layout within excavation area showing sheet pile wall and bracing system is illustrated in Figure 7. No major failure in terms of large tension cracks and ground settlement was observed at the surface adjacent to the excavation though some excessive sheet pile deflection was visually inspected at few locations. Hence, it was not expected by the visual inspection at site that excavation work has effected the integrity of piles.

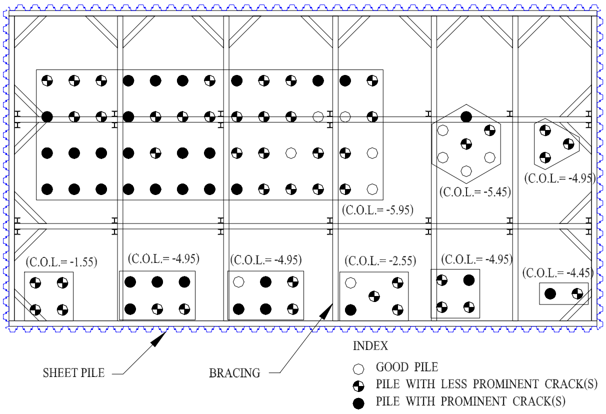

Figure 7. Layout plan showing part of bored piles, sheet pile wall and bracing system – Case III

7.3.4 Sonic integrity tests and pile damage assessment

Though sonic integrity test was employed as a part of quality control regime in the original plan, it was eventually applied for a retrospective investigation after encountering many piles with defect. Hence all piles were undergone sonic integrity test. According to the test results, 84% of piles located within the excavation zone were identified to be with crack. Sonic integrity test results of good pile, pile with less prominent crack, and pile with prominent crack are illustrated in Figure 8. As can be seen in Figure 8, for pile with prominent crack, a distinct and sharp reflection is evident at depth about 5.5m below pile top. Repetition of reflection at multiples of this depth can also be observed for this pile. These features are comparatively not distinct for the pile with less prominent crack. An excessive basal heave, insufficient reinforcement to resist the tensile stress and relatively small pile size are considered to be the main reasons causing the cracks in this case. Table 4 shows a summary of pile damage assessment by sonic integrity test.

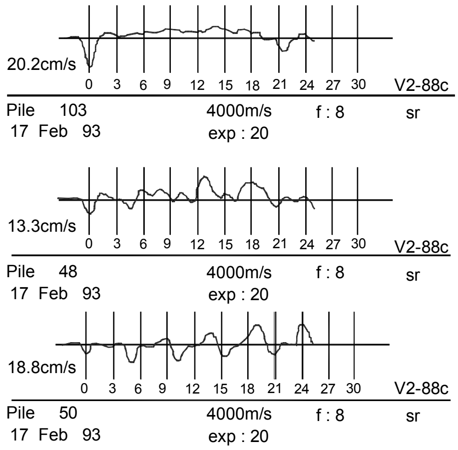

Figure 8. Case III - Seismic test results of good pile, pile with less prominent and prominent crack (top to bottom in order)

Table 4. Summary of pile damage assessment by sonic integrity test – Case III

Pile Dia. (m)	No. of piles with defect			Defect depth below ground level (m)
	Least prominent crack	Less prominent crack	Prominent crack	
0.60	-	38	33	5.5 – 13.8

7.3.5 *Remedial measures and pile capacity justification*

Coring was carried out up to the depth below the detected crack to verify the pile damage and then it was grouted with non-shrink cement. To justify the capacity of damage piles, high strain dynamic load test was carried out on 25 piles in which 24 piles with detected cracks and 1 pile without crack detection. Summary of dynamic load test is presented in Table 5.

Table 5. Summary of dynamic load test results of damaged piles – Case III

Mobilized capacity / Design ultimate capacity of 240 ton	No. of pile
Less than 50%	1
Less than 10%	2
More than 100%	22

8 FINITE ELEMENT ANALYSIS WITH COMPUTER MODEL SIMULATION

Finite element analysis was carried out using two-dimensional modeling. With the aid of PLAXIS computer program staged excavation was simulated and pile/soil movements as well as bending stress induced in the piles were examined for above presented projects. Model profile of Case III used in FEM analyses is presented in Figure 9.

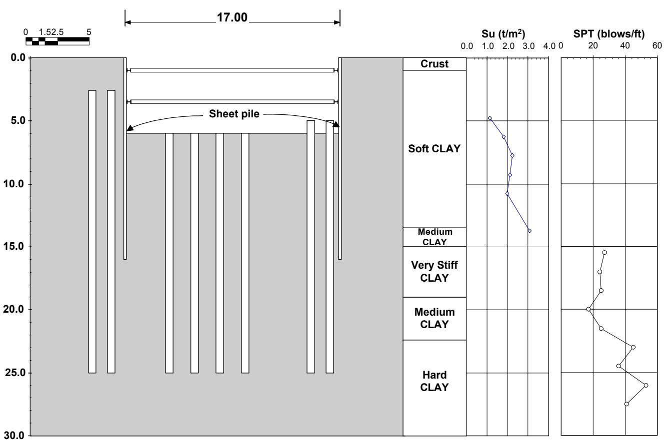

Figure 9. Finite element model profile of Case III

Stiffness of foundation piles per linear meter (*E.∑I per* pile spacing in row) was used as a parameter for plate elements, where *E* and *I* is Young Modulus and moment of inertia of pile respectively. The soil between piles in a row is ignored. Mohr-Coulomb constitutive model is adopted using undrained soil parameters derived from soil investigation at site and associated lab test results.

9 CORRELATION BETWEEN RESULTS FROM FINITE ELEMENT AND SONIC INTEGRITY TEST

The analysis results indicate that bending moment in piles induced by excessive ground movement due to excavation works are higher than that of cracking capacity of pile in all cases. Table 6 presents the summary of the analyses.

Table 6. Moment capacity of piles and induced moment in piles due to excavation simulated by finite element method

Case	Pile size (m)	Rebar (%)	Cracking moment (t.m)	Ultimate moment (Whitney) (t.m)	Moment by FEM model (t.m)
I	1.0	0.75	30	79	149.7
II	1.5	0.50	102	188	117.2
					255.7*
III	0.60	0.35	6.5	9.2	13.3

Note: (*) moment in pile located outside of sheet pile wall within the active side of soil mass.

As can be seen in Table 7, the crack location in pile indicated by sonic integrity test is generally consistent with the location of computed bending moment, which exceeds the cracking moment capacity of piles for all three cases.

Table 7. Locations of crack and computed bending moments in piles in the vicinity of excavation boundary

Case	Integrity test depth of crack in piles near excavation boundary (m)	Depth of maximum bending moment by FEM (m)	Depth of bending moment exceeding pile's cracking moment from FEM (m)
I	12.7 & 13.7	18.0	11.0 & 13.0
II	12.7 &13.7	15.0	12.8 & 14.5
III	11.5 & 12.0	15.5	13.0 & 14.0

It is evident that detected cracks are located near or at the depths where boundary of Soft and Medium or Stiff Clay is present.

In case III, FEM analysis results suggest that piles are subject to some degrees of basal heave as illustrated in Figure 10. This is found to be caused by inadequate embedded length of sheet pile. As can be seen in Figure 11, the results also show that bending moment induced by excavation exceeds the ultimate moment capacity of pile . Sonic integrity test results of some piles indicate the presence of more than one crack at some depths, suggesting piles would have experienced both bending and tensile stress due to the excavation.

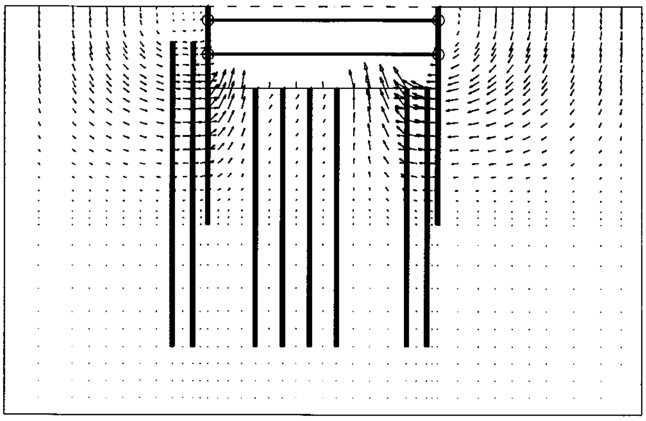

Figure 10. Finite element analysis results showing large degree of basal heave caused by excavation with inadequate sheet pile embedded length - Case III

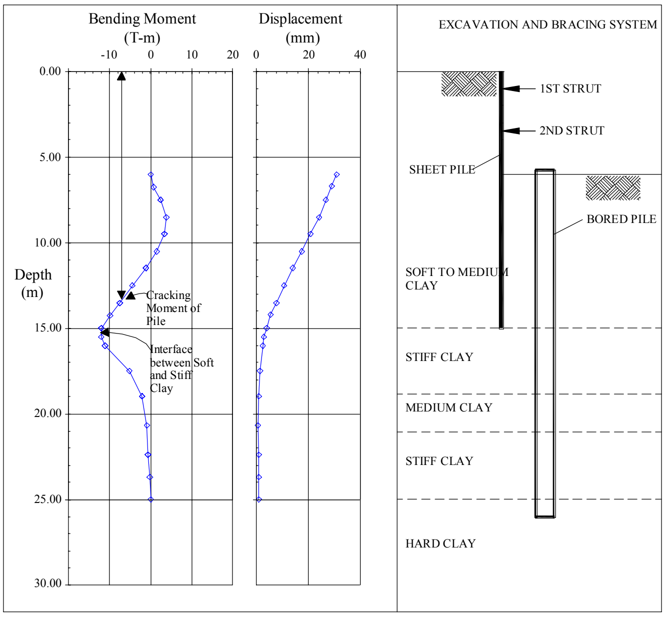

Figure 11. Computed bending moment and deflection of pile located closest to sheet pile - Case III

10 CONCLUSIONS

With the demonstration of three case studies, effectiveness of sonic integrity test in pile damage assessment in Bangkok is presented in this paper. This research study also proves that external forces due to both lateral and uplift movement of the ground induced by adjacent excavation can cause considerable damage to constructed bored piles.

Observation of actual construction works on sites suggests that over excavation prior to installation of support and inadequate retaining system are the main causes leading to excessive ground movement, a primary reason of pile damage. Excavation contractors should be well aware of the consequences of excessive soil movement induced by improper construction practice.

The designer of the foundation should also be aware of the potential problem on site and should take the actual construction practice into consideration in the design. For instance, if piles are expected to experience the excessive tensile or bending stress from the most practical excavation method, sufficient reinforcement should be provided in the design at the first place. The foundation designer should closely be involved in the design of the retaining system and construction control on site during the excavation period so that any possible negative effect can be minimized if not entirely avoided.

REFERENCES

Balasubramanium, A.S. 1991*, Inaugural Lecture on Contributions in Geotechnical Engineering, Soil Mechanics and Foundation Engineering*, AIT, Bangkok, March 1991

Turner, M. J. 1997. *Integrity Testing in Piling Practice*, CIRIA Report No. 144, Construction Industry Research and Association, London.

Thasnanipan, T., Maung, A. W. and Tanseng, P. 1998a. Damages to Piles associated with Excavation Works in Bangkok Soft Clay, 6th *International Conference on Problems of Pile Foundations Building,* Ufa, Russia. September 14-18, 1998. pp. 91-98

Thasnanipan, T., Maung, A. W. and Baskaran, G. 1998b. Sonic Integrity Test on Piles Founded in Bangkok Subsoil – Signal Characteristics and Their Interpretations, 4th *International Conference on Case Histories in Geotechnical Engineering*, St. Louis, Missouri. March 9-12, 1998. pp. 1086-1092.