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PROJECT TITLE

SONG HAU 1 THERMAL POWER PLANT (2X600MW)

OWNER

PETROVIETNAM

VIETNAM OIL AND GAS GROUP (PVN)

OWNER'S CONSULTANT

FICHTNER GmbH & Co. KG

PETROVIETNAM ENGINEERING

FICHTNER GmbH & Co. KG — PV ENGINEERING

EPC CONTRACTOR

LILAMA

VIETNAM MACHINERY INSTALLATION CORPORATION (LILAMA)

EPC CONTRACTOR'S CONSULTANT

TEPSCO

TOKYO ELECTRIC POWER SERVICES COMPANY LIMITED -TEPSCO

SUB-CONTRACTOR

PETROVIETNAM PTSC

Petrovietnam Technical Services Corporation

CMB

Construction Consultation JS Co For Maritime Building

	DATE	NAME	SIGN	DOCUMENT TITLE
PREPARED	20.7.2016	P.V.BA	Vba	**In - situ Pile Testing Procedure For Oil Jetty**
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DOCUMENT NO. SH1-PTSC-P0UZR-C-C13-PRO-0201 | REV. A

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I. PILE TESTING PROCEDURE FOR OIL JETTY:

The test procedure will be reviewed on finalisation of the Oil Jetty detail design.

The test procedure will be reviewed after pile testing results are received.

I.1. List of Codes and Standards:

No.	Standards	Codes
1	Foundation of small-section piles. Design standard	TCXD 189 - 96
2	Pile foundation. Design standard	TCVN 10304:2014
3	Pile driving and pressing. Construction and acceptance	TCVN 9394:2012
4	Standard Test Method for High-Strain Dynamic Testing of Pile	ASTM D4945-00

I.2. Purposes of the Test:

- Pile test may be done in the following stages: Exploratory design and inspection for construction quality. In this stage of detailed design, soil conditions of the site location have been already investigated completely and the vicinity has been already constructed with similar jetty works, with consideration of construction structures, pile test is selected to be done in the stage of inspection for construction quality only.

- Purposes of the test :

+ To check bearing capacity of piles under calculated load in design of foundation;

+ To check pile lowering capacity to the defined depth and also to evaluate on soil identity relatively under resistance force when lowering pile;

+ To define the relation between relocation of pile in soil and load;

+ Comply with regulations and standards.

+ Verify pile behaviour to applied loads (vertical & or raking)

+ Design validation.

+ Stresses in the pile.

+ Pile integrity.

+ Hammer performace.

+ Pile bearing capacity.

+ Any other relevant information.

+ Appraisal of the test results and subsequent design revisions and value engineering to be carried out.

- Pile test procedure is divided into stages for the following purposes:

+ Stage 1: To lower pile onto soil, to monitor its refusal and PDA test in order to define bearing capacity at the time of stage 1.

+ Stage 2 (After the "stop" time of 7 days): To define actual bearing capacity of pile according to subsoil, then to decide the pile length.

+ Stage 3: This stage is only executed in case that pile testing procedure in stage 2 does not reach the designed refusal (Actual refusal is higher than designed refusal). Purpose of this stage is the same with the one of stage 2.

I.3. Content of the test:

- Methods of pile test on site are based on the following factors:

+ Purposes of the test.

+ Importance and characteristics of construction work:

Grade of construction: Construction work with the height H < 20m, in accordance with Design standards for sea port works 22 TCN 207-92, construction in grade III. Based on the Engineering design, the construction work was selected as construction in grade II.

Construction work has structure of soft, high pile platform, its bearing capacity is under pile groups which are hardly connected together and it is not almost affected by horizontal slide of subsoil.

Construction work is located on river (offshore), so it is not feasible to execute the statics load test, therefore, it is necessary to consider and select the proper method of pile test so as to assure the technical economic factor and also to satisfy the time schedule of construction. Based on the actual time schedule of construction at present, it is able to apply the method of dynamic test on site in combination with dynamic test with high deformation (PDA method with consideration of elastic refusal and residual refusal).

+ Accuracy of calculation model for pile foundation structure: In the design document, the jetty structure is calculated in 3D model for the whole of jetty segment. Results of internal force show that the accuracy of calculation model is high, the calculation results show that the construction satisfies the prevailing regulations of bearing capacity, transposition, etc...

+ Soil conditions of construction site: The soil investigation results show that the stratum in construction site has quite simple structure and quite identical. There are following basic layers downwards:

<u>*Layer 1a:*</u> Very soft organic silty CLAY. This layer is distributed at borehole TK07, from existing ground level to 14.7m deep (Ele.=-16.38m). Main composition of soil is caly, silt with some organic, it is greenish dark - gray in color.

<u>*Layer 1:*</u> Stiff lean CLAY/ fat CLAY (CL/CH). This layer is distributed in all the site, except borehole TK07, from existing ground level with large thickness. Characteristic of distribution and thickness of layer given in table below:

Description		Borehole No.							
		TK01	TK02	TK03	TK04	TK05	TK06	TK07	TK08
Top (m)	Elevation	-12.98	-12.75	-12.85	-13.35	-13.41	-12.90	-	-10.39
	Depth	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
Bottom (m)	Elevation	-28.58	-27.75	-25.85	-22.35	-24.41	-21.90	-	-21.39
	Depth	15.6	15.0	13.0	9.0	11.0	9.0	-	11
Thickness (m)		15.6	15.0	13.0	9.0	11.0	9.0	-	11

Main composition of soil is clay, silt; it is brown grayish yellowish in color.

Layer 2: Stiff fat CLAY (CL).

This layer is distributed in all the site (undistributed at borehole TK01, TK03 and TK07), located below layer 1 with thin thickness. Characteristic of distribution and thickness of layer given in table below:

Description		Borehole No.							
		TK01	TK02	TK03	TK04	TK05	TK06	TK07	TK08
Top (m)	Elevation	-	-27.75	-	-22.35	-24.41	-21.90	-	-21.39
	Depth	-	15.0	-	9.0	11.0	9.0	-	11.0
Bottom (m)	Elevation	-	-31.75	-	-30.55	-30.71	-27.90	-	-27.39
	Depth	-	19.0	-	17.2	17.3	15.0	-	17.0
Thickness (m)		-	4.0	-	8.2	6.3	6.0	-	6.0

Main composition of soil is clay, silt with many sand; it is brownish grayish in color.

This layer some lenses below:

- Lens 2a: Medium dense clayey sand (SC)

This lens is only distributed at borehole TK01, from 15.6 (Ele. = -28.58m) to 19m (Elv. = - 31.98m), thickness is of 3.4m. Main composition of soil is sand with some clay, silt; it is greenish brown in color.

- Lens 2b: Stiff sandy lean CLAY (CL): This lens is only distributed at borehole TK06, from 15.0m (Ele. = -27.90m) to 17.0m deep (Ele. = -29.90m), thickness is of 2.0m. Main composion of soil is sand with some clay, silt; it is greenish brown in color.

- Lens 2c: Very stiff lean CLAY with sand (CL): This lens is only distributed at borehole TK03, TK05 and TK06, from 13.0/17.3m (Ele. = -25.85m/-30.71m) to 17.0m/21.0m deep (Ele. = -29.85m/-33.90m), thickness is change from 1.7m to 4.0m, average is of 3.2m. Main composion of soil is clay, silt with some sands; it is yellowsish brownish grey in color.

Layer 3: Stiff lean CLAY with sand (CL):

This layer is distributed in all the site, located below layer 2 with large thickness. Characteristic of distribution and thickness of layer given in table below:

Description		Borehole No.							
		TK01	TK02	TK03	TK04	TK05	TK06	TK07	TK08
Top (m)	Elevation	-31.98	-31.75	-29.85	-30.55	-32.41	-33.90	-26.68	-27.39
	Depth	19.0	19.0	17.0	17.2	19.0	21.0	27.0	17.0
Bottom (m)	Elevation	-53.98	-41.75	-53.85	-56.35	-56.31	-57.90	-42.68	-45.39
	Depth	41.0	29.0	41.0	43.0	43.0	45.0	41.0	35.0
Thickness (m)		22	10.0	24.0	25.8	22.0	24.0	14.0	18.0

Main composition of soil is clay, silt with some sand; it is brownish gray in color.

This layer has some lenses below:

- Lens 3a: Very stiff sandy lean CLAY (CL): This lens is only distributed at borehole TK03 and TK05, from 21.0m/27.0m (Ele. = -34.41m/-39.85m) to 23.0m/37.0m deep (Ele. = -36.41m/-49.85m), thickness is change from 2.0m to 10.0m. Main composion of soil is clay, silt with meny sands; it is brownish grey in color.

- Lens 3b: Medium dense silty clayey SAND (SC-SM). This lens is only distributed at borehole TK02, from 29m (Ele. = -41.75m) to 31m (Ele. -43.75m), thickness is of 2.0m. Main composion of soil is sand with some clay and silt; it is brownish grey in color.

- Lens 3c: Stiff fat CLAY with sand (CH). This lens is only distributed at borehole TK02, from 31m (Ele. = -43.75m) to 33m (Ele. -45.75m), thickness is of 2.0m. Main composion of soil is clay, silt with some sands; it is brownish grey in color.

Layer 4: Very stiff lean CLAY (CL).

This layer is distributed in all the site, located below layer 3 with medium thickness. Characteristic of distribution and thickness of layer given in table below:

Description		Borehole No.							
		TK01	TK02	TK03	TK04	TK05	TK06	TK07	TK08
Top (m)	Elevation	-53.98	-	-53.85	-56.35	-56.31	-57.90	-42.68	-45.39
	Depth	41.0	-	41.0	43.0	43.0	45	41.0	35.0
Bottom (m)	Elevation	-59.98	-	-57.85	-62.65	-63.31	-59.90	-50.68	-59.39
	Depth	47.0	-	45.0	49.3	49.9	47.0	49.0	49.0

Description	Borehole No.							
	TK01	TK02	TK03	TK04	TK05	TK06	TK07	TK08
Thickness (m)	6.0	-	4.0	6.3	6.9	2.0	8.0	14.0

Main composition of soil is clay, silt with some sand; it is brownish gray in color.

- Lens 4a: stiff lean CLAY (CL): This lens is only distributed at borehole TK07, from 49.0m (Ele. = -50.68m) to more than 50.0m deep (end of drilling). Main composion of soil is clay, silt with meny sands; it is brownish grey in color.

Layer 5: Dense to very dense silty SAND (SM).

This layer is distributed in all the site, except borehole TK07, located below layer 4 to the end of drilling (50.0m). Characteristic of distribution and thickness of layer given in table below:

Description		Borehole No.							
		TK01	TK02	TK03	TK04	TK05	TK06	TK07	TK08
Top (m)	Elevation	-59.98	-59.75	-57.85	-62.65	-63.31	-61.90	-	-59.39
	Depth	47.0	47.0	45.0	49.3	49.9	49.0	-	49.0
Bottom (m)	Elevation	-62.98	-62.75	-57.85	-63.65	-63.41	-62.90	-	-59.39
	Depth	50.0	50.0	50.0	50.0	50.0	50.0	-	50.0
Thickness (m)		3.0	3.0	5.0	0.7	0.1	1.0	-	1.0

Main composition of soil is sand with some silt; it is brownish gray in color.

Standard penetration test (SPT) and laboratory testing result of each layer are summarized in table below:

No.	Description	Symbol	Unit	Layer 1 (CL)	Layer 1a (OH)	Layer 2 (CL)	Layer 2a (SC)	Layer 2b (CL)
1	*Number of sample*		Sample	27	5	9	1	1
2	*Consistency/ density of soil*			Stiff	Very soft	Stiff	Medium dense	Stiff
3	*SPT test – N-value*			11	2	12	11	10
	N_{min} - N_{max}			7-14	1-3	9-15	-	-
4	*Particle size distribution*							

No.	Description	Symbol	Unit	Layer 1 (CL)	Layer 1a (OH)	Layer 2 (CL)	Layer 2a (SC)	Layer 2b (CL)
	- Clay	C	%	30.3	34.9	29.9	13.3	18.9
	- Silt	M	%	59.9	55.9	59.2	33.3	43.0
	- Sand	S	%	9.8	9.2	11.0	53.3	38.1
	- Gravel	G	%	0.0	0.0	0.0	0.0	0.0
5	*Physical properties*							
	- Limit liquid	LL	%	43.8	64.1	55.7	33.0	48.1
	- Plastic limit	PL	%	21.6	32.9	30.1	19.2	26.0
	- Plasticity index	PI	%	22.1	31.2	25.7	13.8	22.1
	- Liquidity index	LI		0.35	1.03	0.40	0.24	0.37
	- Water content	W	%	29.33	65.76	40.27	22.48	34.12
	- Specific gravity	GS		2.70	2.61	2.69	2.68	2.69
	- Wet density	γ_w	kN/m^3	18.7	15.1	17.2	18.8	18.1
	- Dry density	γ_d	kN/m^3	14.5	9.2	12.2	15.4	13.5
	- Submerged density	γ'	kN/m^3	8.7	5.1	7.2	8.8	8.1
	- Void ratio	e_o		0.827	1.831	1.156	0.710	0.950
	- Porosity	N	%	45.3	64.0	53.6	41.5	48.7
	- Degree of saturation	S_R	%	95.6	93.9	93.6	84.9	96.6
6	*Quick direct shear test*							
	- Cohesion	C	kg/cm^2	0.212	0.077	0.218	0.171	0.206
	- Internal friction angle	Φ	deg.	14°42’	3°21’	11°57’	16°55’	13°17’

No.	Description	Symbol	Unit	Layer 1 (CL)	Layer 1a (OH)	Layer 2 (CL)	Layer 2a (SC)	Layer 2b (CL)
7	*Compression test (Oedometer)*							
	- Compression index	$a_{1.0-2.0}$	cm^2/kg	0.029	0.330	0.033	0.029	0.032
	- Deformation modulus	$E_{1.0-2.0}$	kg/cm^2	144.4	4.8	117.2	147.2	108.4

No.	Description	Symbol	Unit	Layer 2c (CL)	Layer 3 (SC)	Layer 3a (CL)	Layer 3b (CL)	Layer 3c (CL)
1	*Number of sample*		Sample	5	50	4	1	
2	*Consistency/ density of soil*			Very Stiff	Stiff	Very Stiff	Medium dense	Stiff
3	*SPT test – N-value*			20	12	20	10	14
	N_{min} - N_{max}			15-36	9-19	15-27	-	-
4	*Particle size distribution*							
	- Clay	C	%	17.9	21.1	20.9	8.0	35.1
	- Silt	M	%	53.5	59.2	46.4	17.1	49.3
	- Sand	S	%	28.6	19.4	32.6	74.9	15.6
	- Gravel	G	%	0.0	0.3	0.0	0.0	0.0
5	*Physical properties*							
	- Limit liquid	LL	%	43.4	41.9	41.5	23.8	55.3
	- Plastic limit	PL	%	23.9	22.4	24.3	17.2	26.6
	- Plasticity index	PI	%	19.5	19.5	17.2	6.6	28.7

No.	Description	Symbol	Unit	Layer 2c (CL)	Layer 3 (SC)	Layer 3a (CL)	Layer 3b (CL)	Layer 3c (CL)
	- Liquidity index	LI		0.13	0.34	0.19	0.37	0.29
	- Water content	W	%	26.68	28.99	27.63	19.65	34.78
	- Specific gravity	GS		2.70	2.69	2.69	2.67	2.7
	- Wet density	γ_w	kN/m^3	19.2	18.6	19.0	18.6	18.1
	- Dry density	γ_d	kN/m^3	15.2	14.5	14.9	15.6	13.5
	- Submerged density	γ'	kN/m^3	9.2	8.6	9.0	8.6	8.1
	- Void ratio	e_o		0.746	0.828	0.778	0.681	0.967
	- Porosity	N	%	42.7	45.3	43.7	40.5	49.2
	- Degree of saturation	S_R	%	96.4	94.3	95.6	77.0	97.1
6	*Quick direct shear test*							
	- Cohesion	C	kg/cm^2	0.300	0.206	0.307	0.104	0.200
	- Internal friction angle	Φ	deg.	17°48’	14°54’	17°24’	23°14’	15°25’
7	*Compression test (Oedometer)*							
	- Compression index	$a_{1.0\text{-}2.0}$	cm^2/kg	0.020	0.029	0.023	0.024	0.030
	- Deformation modulus	$E_{1.0\text{-}2.0}$	kg/cm^2	207.6	145	190.1	180.5	145.7

No.	Description	Symbol	Unit	Layer 4 (CL)	Layer 4a (CL)	Layer 5 (SM)	Layer 5a (SM)
1	*Number of sample*		Sample	19	1	10	6
2	*Consistency/ density of soil*			Very stiff	Stiff	Dense to very dense	Medium dense
3	*SPT test – N-value (blows/30cm)*		Blow	19	14	>30	27
	N_{min} - N_{max}			15-25	-	-	23-29
4	*Particle size distribution*						
	- Clay	C	%	23.9	17.9	2.0	3.2
	- Silt	M	%	65.0	72.9	20.8	19.4
	- Sand	S	%	11.1	9.4	76.9	76.9
	- Gravel	G	%	0.0	0.0	0.3	0.5
5	*Physical properties*						
	- Limit liquid	LL	%	43.6	38.0	-	-
	- Plastic limit	PL	%	22.2	21.5	-	-
	- Plasticity index	PI	%	21.4	16.5	-	-
	- Liquidity index	LI		0.17	0.39	-	-
	- Water content	W	%	25.84	27.86	16.27	18.03
	- Specific gravity	GS		2.7	2.71	2.66	2.66
	- Wet density	γ_w	kN/m^3	19.2	19.0	-	-
	- Dry density	γ_d	kN/m^3	15.3	14.9	-	-
	- Submerged density	γ'	kN/m^3	9.2	9.0	-	-
	- Void ratio	e_o		0.735	0.786	-	-
	- Porosity	N	%	42.4	44.0	-	-
	- Degree of saturation	S_R	%	94.9	96.0	-	-

No.	Description	Symbol	Unit	Layer 4 (CL)	Layer 4a (CL)	Layer 5 (SM)	Layer 5a (SM)
6	*Quick direct shear test*						
	- Cohesion	C	kg/cm^2	0.308	0.203	-	-
	- Internal friction angle	Φ	deg.	17°24'	16°42'	-	-
7	*Compression test (Oedometer)*						
	- Compression index	$a_{1.0\text{-}2.0}$	cm^2/kg	0.020	0.036	-	-
	- Deformation modulus	$E_{1.0\text{-}2.0}$	kg/cm^2	212.7	120.6	-	-
8	*Tests on non-cohesive soils*						
	- Maximum void ratio of sand	e_{max}				0.967	0.967
	- Minimum void ratio of sand	e_{min}				0.705	0.700
	- Naturally sloping angle of sand in dry condition	α_{dry}	Deg.			36°46'	35°24'
	- Naturally sloping angle of sand in saturated condition	α_{sat}	Deg.			32°30'	32°48'

- With reference of appendix D of Vietnamese standard TCVN 10304-2014 "Pile foundation - Design standard", with consideration of test purposes, accuracy of calculation model, soil conditions as mentioned above, method of pile test on site is selected in accordance with the method of dynamic test on site in combination with PDA method.

I.4. Number of tested piles:

- Further to articles 1-7 of standard 20TCN 88 - 82: "Piles - Method for site testing" and with reference of appendix D of Standard TCVN 10304-2014, number of tested piles for inspection of construction are defined in accordance with the technical task within the following limits:

+ In case of testing by live load (impulse and vibration), number of tested piles shall be 1% of total number of piles on site, but not less than 5 piles.

+ In case of testing by dead load, number of tested piles shall be 1% of total number of piles on site, but not less than 2 piles.

- With consideration of soil conditions on site, based on number of tested piles as per regulations, scale and structural characteristics of construction work, and based on number of piles for technology platform of 20 piles D700; number of piles for approach bridge of 27 piles D700; number of piles for abutment of 09 piles D700; number of piles for berthing dolphin of 20 piles D800 (02 dolphin); number of piles for mooring dolphin of 16 piles D800 (02 dolphin); number of piles for trestle of 08 piles D700 (04 dolphin), number of tested piles are decided as follows:
+ Technology platform shall be tested with 01 pile, approach bridge shall be tested with 01 pile, abutment shall be tested with 01 pile, each berthing dolphin shall be tested with 01 pile and each mooring dolphin shall be tested with 01 pile.
+ Test method: Dynamic test on site in combination with Test Method for High-Strain Dynamic Testing of Piles (PDA).
- For favorable conditions of pile test, because the site location is affected by tidal levels and with consideration of provision for pile test in the next phase (if necessary), length of tested piles shall be longer 2m than the length of designed piles.

I.5. Dimensions, positions and co-ordinates of tested piles:

Table 1. Coordinates of tested piles for Segment 1
(as per the supposed VN2000 co-ordinates system)

Positions	Piles	Dimensions	VN 2000 co-ordinates		Level (Hon Dau datum)
			X(m)	Y(m)	
Technology platform	**B-3**	D700-480mm, L = 33m	1,100,726.181	595,209.255	+4.00
Approach bridge	**I-7**	D700-480mm, L = 33m	1,100,704.672	595,185.463	+4.40
Abutment	**MC2-2**	D700-480mm, L = 33m	1,100,680.916	595,172.905	+3.05
Berthing dolphin TV1&TV2	**V3-3**	D800-560mm, L = 33m	1,100,716.164	595,221.737	+3.75
	V8-3	D800-560mm, L = 33m	1,100,736.733	595,197.224	+3.75
Mooring dolphin TN1&TN2	**N3-4**	D800-560mm, L = 33m	1,100,679.053	595,240.528	+3.75
	N8-4	D800-560mm, L = 33m	1,100,748.795	595,157.412	+3.75

Notes:
- Length of tested piles is longer 2m than length of designed piles for favorable conditions of pile test.

- Levels of pile heads which are mentioned in the table are levels at completion of driving tested piles in stage 1, higher 2m than levels of designed pile heads.

- Levels stated in table 1 are the levels for pile test on site. After completion of pile test, piles shall be cut off their surplus parts, and then their head levels are:

+ At Technology platform (B-3): +2.00m (Hon Dau Datum).

+ At Approach bridge (I-7): +2.4m (Hon Dau Datum).

+ At abutment (MC2-2): +1.05m (Hon Dau Datum).

+ At Berthing dolphin (V3-3&V8-3): +1.75m (Hon Dau Datum).

+ At Mooring dolphin (N3-4&N8-4): +1.75m (Hon Dau Datum).

- Allowable declination of pile shaft on the layout during pile driving process must comply with table 11 of Standard TCVN 9394:2012.

(Details of tested pile positions are seen in Drawing SH1-PTSC-P0UZR-C-C13-DFN-0213 and SH1-PTSC-P0UZR-C-C13-DFN-0234*).*

I.6. Design of pile test by method of live load:

I.6.1. Design of pile test:

I.6.1.1. Hammer for driving tested piles:

<> Hammer type is used with the following specifications:

- Weight of the impulsive part:	4,500 kg.
- Weight of entire hammer:	10,500 kg.
- Maximum impulsive energy of 01 blow:	13,500 kg.m.

I.6.1.2. Settlement recording device:

- Settlement of pile is recorded by theodolite and scale paper (in mm) which is pressed onto pile shaft, the fixed point and settlement of pile are defined from the theodolite, etc...

- Height of hammer blow is recorded by steel ruler which is welded fixedly onto hammer body, the ruler is scaled at interval of 10cm, each hammer blow shall be monitored and recorded.

I.6.2. Procedure of driving tested piles:

I.6.2.1. Pile driving for stage 1:

- Tested piles shall be driven to design level, refer to <u>Table 1.</u>

- During the pile driving process, number of blows and height of hammer blow in average are recorded per 1m of penetrated pile length in average. For the last 1m of pile, number of blows and height of hammer blow in average must be recorded every 10cm of penetrated pile length.

I.6.2.2. Pile driving for stage 2:

After tested piles are driven for stage 1, the piles shall be in "stop" within 07 days at least in order wait for:

- Exessive pore water pressure to be dissipated.

- Setting up of shaft resistace of pile surface.

Then tested piles shall be driven for stage 2 as per the following sequence:

- To drive a non-explosive blow (to get the hammer close to pile head).
- To drive 05 explosive blows, to record settlement of the pile and height of hammer blow every driving blow.
- To drive 30 explosive blows which are divided into 03 stages, 10 blows per each, to record settlement of the pile and height of hammer blow every 10 blows.

I.6.3. Designed refusal e(mm):

<> The following designed refusal is calculated with specifications of the selected hammer. Before tested piles are driven, the contractor should provide specifications of the used hammer for driving tested piles so as to design and calculate the refusal.

$$e = \frac{n.F.Q.H}{P.(P+nF)} x \frac{Q_n + \varepsilon^2 (q+q_1)}{Q_n + q + q_1}$$

Where:

- n: Factor of striking n = 150 T/m^2.
- F: Area of pile tip
  + Pile of Technology platform D = 700 - 480mm: F = 0.385 m^2 (pile tip to be covered).
  + Pile of approach bridge D = 700 - 480mm: F = 0.385 m^2 (pile tip to be covered).
  + Pile of abutment D = 700 - 480mm: F = 0.385 m^2 (pile tip to be covered).
  + Pile of Berthing dolphin D = 800 - 560mm : F = 0.503 m^2 (pile tip to be covered).
  + Pile of Mooring dolphin D800 - 560mm: F = 0.503 m^2 (pile tip to be covered).
- Q: Weight of striking part of hammer: Q = 4.5T.
- Q_n: Total weight of hammer : Q_n = 10.5T.
- ε^2: Factor of striking recovery ε^2 = 0.2.
- H: Actual height of hammer blow H = 2.4 ~ 2.8m.
- P: Calculated internal force of pile P = (P_{tc}. k_n. n. n_c. m_d + q).K_{tc} (T)
- P_{tc}: Internal force inside pile, calculated with standard load
  + Pile of Technology platform: P_{tc} = 58.46 T.
  + Pile of approach bridge: P_{tc} = 50.78T.
  + Pile of abutment: P_{tc} = 49.40T.
  + Pile of berthing dolphil: P_{tc} = 66.31T.
  + Pile of mooring dolphil: P_{tc} = 40.76T.
- k_n: Factor of load combination: k_n = 1.00.
- n_c: Factor of load combination: n_c = 1.00.
- n: Overload factor: n = 1.25.

- m_d: Sub factor of working conditions: m_d = 1.05.
- K_{tc}: Factor of safety of subsoil in case of dynamic test:
  + For pile of Technology platform: K_{tc} = 1.55.
  + For pile of approach bridge: K_{tc} = 1.4.
  + For pile of abutment: K_{tc} = 1.65.
  + For pile of berthing dolphil: K_{tc} = 1.65.
  + For pile of mooring dolphil: K_{tc} = 1.65.
- q_1: weight of pile cap and pile cushion q_1 = 0.5T.
- q: Selt - weight of pile.
  + For technology platform D = 700 - 480mm, L = 33m: q = 16.82 T.
  + For approach bridge D = 700 - 480mm, L = 33m: q = 16.82 T.
  + For abutment D = 700 - 480mm, L = 33m: q = 16.82 T.
  + For berthing dolphil D = 800 - 560mm, L = 33m: q = 21.15 T.
  + For mooring dolphil D = 800 - 560mm, L = 33m: q = 21.15T.

<> To substitute figures into the above mentioned formula, the designed refusal is calculated as follows:

Item	Type of Pile	Actual height of hammer blow H(m)	Designed refusal e_{tk} (mm)
Technology platform	D700-480mm, L = 33m	2.4	10.65
		2.5	11.09
		2.6	11.53
		2.7	11.98
		2.8	12.42
Approach bridge	D700-480mm, L = 33m	2.4	15.34
		2.5	15.98
		2.6	16.62
		2.7	17.26
		2.8	17.89
Abutment	D700-480mm, L = 33m	2.4	12.07
		2.5	12.57
		2.6	13.07
		2.7	13.58
		2.8	14.08

Item	Type of Pile	Actual height of hammer blow H(m)	Designed refusal e_{tk} (mm)
Berthing dolphil	D800-560mm, L = 33m	2.4	8.29
		2.5	8.63
		2.6	8.98
		2.7	9.32
		2.8	9.67
Mooring dolphil	D800-560mm, L = 33m	2.4	15.36
		2.5	16
		2.6	16.64
		2.7	17.28
		2.8	17.92

I.6.4. Treatment of pile test results by method of live load:

- During the test process, it is necessary to record in accordance with the notes of appendix 2, appendix 4 in Standard TCXD 88-1982.
- Chart of pile test results by live load shall be drawn in chart of relation between number of blows K and average refusal e at the depth *l* (chart No.1 in standard TCXD 88 - 1982).

I.7. Design of pile test by method of high deformation PDA:

(This shall be done at the same time with dynamic test process)

I.7.1. Equipment for pile test:

I.7.1.1. Hammer for driving tested piles (similar to dynamic test):

I.7.1.2. Load test metering device:

Load test device in uniform includes:

- Metering device for pre-stress, acceleration.
- 2 measuring heads for acceleration, 2 measuring heads for pre-stress and cable system.
- Computers with CAPWAP software for processing.

I.7.2. Testing process:

- Before driving a tested pile, the pile is installed the measuring heads, a pair of acceleration measuring heads or a pair of pre-stress measuring heads are fixed on 2 opposite sides of the pile at position distant about 1m from the pile head.

- <> Pile driving for stage 1: This is executed as mentioned in item *I.6.2.1*. When a pile is driven to the level which is 1m higher than level of pile head as stated in table 1, installation of equipment for PDA test shall be done.

- Each hammer blow is recorded by the metering device, including:

  + Refusal of pile corresponding to each blow (SET).

  + Striking energy of hammer transmitting to pile (EMX).

  + Bearing capacity of pile at its correlative position (RMX).

  + Maximum tensile - compress stress appearing in pile concrete (CSX-TSX).

  + Original form of pile during the driving process (BETA).

- Data processing: upon completion of pile driving for stage 1, data shall be analyzed by CAPWAP software to provide the following data:

  + Total bearing capacity P_1 of pile at existing level corresponding to the driving process for stage 1, of which P_1 is divided into 02 parts: lateral friction and pile tip resistance.

  + Refusal e_1 correlative with bearing capacity P_1.

  + Compatibility of hammer, original form of pile.

<> Pile driving for stage 2: This is executed as mentioned in item *I.6.2.2.*

- Testting process (data measuring, recording, etc...) is similar with stage 1.

- Data processing: upon completion of pile driving for stage 1, data shall be analyzed by CAPWAP software to provide the following data:

  + Total bearing capacity P_2 of pile at existing level corresponding to the driving process for stage 2, of which P_2 is divided into 02 parts: lateral friction and pile tip resistance.

  + Refusal e_2 correlative with bearing capacity P_2.

  + Compatibility of hammer, original form of pile.

- Data of site work shall be analyzed by specialized software.

<> Reporting on pile test results by PDA method.

I.8. Regulations during the pile test process:

- All tested piles shall be used later, therefore, their quality must be checked for acceptance before they are driven for test on straightness of central line, dimensions of piles, etc… (as stated in design document). Testing position must be defined accurately, and after completion of pile test, the contractor must have methods to keep the tested piles in safe condition.

- If the contractor does not have the above mentioned hammer type for pile test, he must provide the designer his type and specifications of hammer (which are verified for its quality by competent relevant authority), but he must assure that energy of the used hammer type shall not less than the energy as required in item *I.6.1.1* for pile test.

When driving piles, height of hammer blows, refusal of piles, ground levels at pile driving positions must be measured accurately. (*Method statement of load test method is referred to the document SH1-PTSC-P0UZR-C-C13-TPD-0003)*

- During the test pile driving in stage 1, the following cases may occur:

+ Case 1: When level of pile head meets the level stated in table 1, then stage 2 is continued to be executed after the "stop" time of 7 days.

+ Case 2: When level of pile head is higher than the level stated in table 1 but the pile cannot be driven more (Pile refusal is smaller than designed refusal), then the contractor shall report to SH1PP for solution on site.

- When driving piles for stage 2, if the refusal of pile is higher than the designed refusal ($e_{tt} > e_{tk}$), the tested pile shall be driven 1 ~ 2m more (additional driven length shall be decided by Design consultant on site), height of hammer blow and refusal shall be recorded every 10cm of additional driven length of the pile. The pile shall be in "stop" within 07 days at least, then pile test for stage 3 shall be executed, the pile testing process shall be similar with stage 2.

- During the pile test process, there should be a close co-ordination between SH1PP, the contractor and the design consultant.

I.9. Form of data record for pile test :

- The form of data record for pile test shall be in accordance with Appendix 2 of standard TCXD 88 :1982: Piles - Methods of field test (Refer to attached form below).

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II. APPENDIX 1: FORM OF DATA RECORD FOR PILE TEST ON SITE BY METHOD OF LIVE LOAD

Name of Company:..
Address: ....
Project:...
Work item: ....
Data record of pile test on site by method of live load :
Characteristics of pile:..
Data of pile No. ....
Pile type :...
Material of pile:...
Date of pile manufacture:.................................
Date of pile driving:...................................
Section (diameter) of pile at its tip and head:............................cm
Length of pile (excluding its tip).....................................m
Weight of pile:..kg
Certificate of pile manufacturer:...
Characteristics of driving machine and hammer:
+ Driving machine:...
+ Driving hammer (type):....................................

Driving depth (m)	Number of blows per 1m or 10cm of driving depth	Height of hammer lifting of the striking part (cm)	Average refusal (cm)	Number of driven blows	Remark

Total weight of hammer:.. tons
Weight of striking part of hammer:.......................................tons
Energy of hammer:...kgm
Number of hammer blows in 01 minute (as per Certificate)...........
Weight of pile head cushion:..........................
Cushion at pile head:...........................
Measuring method of pile transposition:.......................
Pile conditions after being driven:............................
Elevation:
c) Pile part above the ground:..............................m
d) Ground surrounding the pile: ....m
e) Pile tip:...
Depth of pile driving:...
Water temperature: ....
State of pile head after being driven: ....
Air temperature (°C)
Continued driving process

Date	"stop" time (day)	Number of hammer blows	Refusal (cm)	Average refusal per 01 blow (cm)

Measuring method of pile transposition (Refusal is measured by straight ruler):
Air temperature:... °C.
Water temperature (in case of testing in lake)...................°C.
Person in charge of test (chief of field test) ....
Authorized representative of pile driving company:.................

III. APPENDIX 2: FORM OF REPORT ON PILE TESTING RESULTS
1. BASES FOR THE REPORT:
2. PILE TESTING PROCESS:
2.1. Number, position, dimension of test piles:

Number, position, dimension of test piles are seen in table 1 below:

Number, position, dimension of test piles

Structure	Pile name	Dimension	Co-ordinates		Level (Hon Dau Datum)
			X(cm)	Y(cm)	

Note: Level of test pile head is 2m higher than level of popular pile head, but its tip level is equivalent to level of popular pile tip.

2.2. Pile test by dynamic load:

2.2.1. Pile test by dynamic load:

1. Equipment for pile test:

a. Hammer for test pile driving:

b. Equipment for recording:

- Recording for the height of hammer blow: to steel ruler which is welded fixedly onto hammer body, the ruler is scaled at interval of 10cm, each hammer blow shall be monitored and recorded.
- Settlement of pile is recorded by theodolite and scale paper (in mm) which is pressed onto pile head, the fixed point and settlement of pile are defined from the theodolite.

2. Pile testting results:

a. Pile testing results of stage 1:

Pile testing results of stage 1

No.	Pile name	Date of driving	Number of final blows	Settlement (cm)	Refusal (mm)	Level of pile head (m)	Average height of hammer blow (m)	Position
1								
2								

b. Pile testing results of stage 2:

- After piles are in "stop" of 7 days at least, it is to continue to drive test piles for stage 2.

Pile testing results of stage 2

No	Pile name	Date of driving	Number of calculated blows	Settlement (mm)	Actual refusal (mm)	Calculated refusal e_{tt}(mm)	Level of pile head after being driven (m)	Height of hammer blow (m)	Type of driving hammer
1									
2									

2.2. Pile test by Test Method of High-Strain Pile Dynamic Analysis (PDA):

a.Hammer for test pile driving:

b. Equipment for pile test - Testing process:

- Schedule of pile test by PDA method:

Schedule of pile test by PDA method

No.	Pile name	Date of the second dynamic load test	Dated of PDA test	Time difference	Remarks
1					
2					

3. CALCULATION OF PILE BEARING CAPACITY ACCORDING TO TESTING RESULTS:

3.1. Calculation of pile bearing capacity according to dynamic load test results:

- For a pile under dynamic load test, its confined bearing capacity is defined by the following formula:

$$P_{gh} = \frac{n.F.M}{2}\left[\sqrt{1+\frac{4.Q.H}{n.F.e}x\frac{Q_n+\varepsilon^2(q+q_1)}{Q_n+q+q_1}}-1\right] \qquad (1)$$

Where:

n : Factor of striking;

F : Area of pile tip;

M : Factor is taken as 1 (striking hammer);

e : refusal of each pile;

Q : Weight of striking part of hammer;

Q_n : Total weight of hammer;

H : Actual height of hammer blow;

ε : Factor of striking recovery;

q : Self-weight of pile;

q_1 : weight of pile cap and pile cushion;

Bearing capacity according to pile testing results of stage 2

Pile name	Dynamic load test results P_{gh1} (T)	Penetrated pile length (m)	P_{gh1}/1m (T/m)	P_{tc} (T)	P_{yc} (T)	Rate P_{gh1}/P_{yc}	Length of test pile (m)	Conclusion

3.2. Calculation of pile bearing capacity according to PDA test results:

Calculation results of pile bearing capacity according to PDA test results

Pile name	PDA test results P_{gh2} (T)	Penetrated pile length (m)	P_{gh2}/1m (T/m)	P_{tc} (T)	P_{yc} (T)	Rate P_{gh2}/P_{yc}	Length of test pile (m)	Conclusion

4. CALCULATION OF PILE LENGTH:

4.1. Comments on pile testing process:

4.1.1. Dimension, position and number of test piles:

4.1.2. Pile testing results:

4.2. Soil conditions:

4.3. Principle of calculation for pile length:

Based on the pile testing results from dynamic load test and PDA test, the confined bearing capacity of pile Pgh is calculated, compared with the calculated bearing capacity of pile Ptt for conclusion of pile length.

$$K_{tc}.P_{tt} \leq P_{gh}$$

- Ktc: Factor of safety of subsoil during pile test on site is defined subject to number of piles in the foundation.
- Confined bearing capacity of pile (Pgh) follows dynamic load test and PDA test.
- Calculated bearing capacity of pile (internal force of pile) Ptt is obtained from the calculation results responding to the standard loads.

$$P_{tt} = P_{tc}.n_1.n_2.n_3 + q$$

Where:

P_{tc}: Internal force of pile, to be calculated with standard load

n_1: Factor of load combination

n_2: Overload factor

n_3: Sub factor of working conditions

q : Self-weight of pile.

5. DETERMINATION OF POPULAR PILE LENGTH FOR DRIVING ON A LARGE SCALE:

5.1. Major bases for determination of popular pile length:

- Results of on-site test pile driving.
- Topographic & bathymetric, soil conditions.
- Working chart of piles, general structures of jetty and pile base as well as conditions of sliding stability of overall construction.
- The technical, economic elements of construction are assured.

5.2. Determination of popular pile length:

5.3. Regulations in popular pile driving process: