An Alternative to enhance the reliability of Wave Equation Analysis of Piles

[1], Myung-Whan Lee,   [1], Hun-Sung Hong,   [2], Chun-Whan Cho,
[1], Sung-Hoi Kim,   [1], Young-Suk Jun

1) ( )   , Piletech Consulting Engineers (02) 3402-2361
2)   ( ), (02) 2145-6584

SYNOPSIS : The bearing capacity of piles driven in soils of set-up tendency increases with time. Though WEAP(Wave Equation Analysis of Pile Driving) is an excellent tool for evaluating the driveability of driven pile, it has some limitations to predict reliable bearing capacity of pile. It is because the existing method can not take into account time dependent soil properties. The set-up effect should be accounted for to obtain a reliable bearing capacity by WEAP. Unfortunately, there are no sufficient methods to take the set-up effect into cosideration in wave equation analysis. This paper suggests an alternative to consider time effect in order to improve the reliability of wave equation analysis.

Key words : WEAP, set-up, damping, quake, driven pile

1.

Smith(1960)   (Wave Equation Analysis of Pile Driving, WEAP)
        (at EOID)   .   WEAP
                        (Restrike)   .
                                                            WEAP
                            WEAP
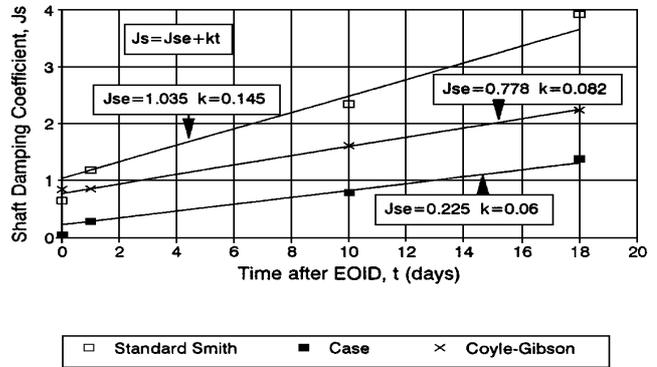   .

        WEAP
            .   WEAP
                ,
            ,   (quake, damping)   .
        WEAP   .
                Hunt (1988), York (1994)   WEAP
        WEAP   .   Rausche (1996)

WEAP

(set value)

. WEAP

.

WEAP

. WEAP

'   '

.

Svinkin(1998)   WEAP

damping   WEAP

damping

(1   ).

Svinkin

WEAP

damping

'

Svinkin

WEAP

. WEAP

.

WEAP

.

(quake, damping)   .

WEAP   '

.

set-up   .

610 mm Square Prestressed Concrete Pile
(305 mm Diameter of Hollow Center)

Js=Jse+kt

Jse=1.035 k=0.145

Jse=0.778 k=0.082

Jse=0.225 k=0.06

□ Standard Smith   ■ Case   × Coyle-Gibson

FIG. 3. Shaft Damping-Time Relationship

1.

quake   .

2.

(set-up factor :   /   ),
(quake, damping)   26

.   2

46   .

CAPWAP(Case Pile Wave
Analysis Program)

.

Davisson   , (
)/   .

(   )
.   .

(S),   (C),   (SM),   (SG)   4   ,
(S),   (C),   (SM)   3   .

CAPWAP   signal matching

        ,   signal matching   (match quality)

                                                  CAPWAP

WEAP   .

        WEAP   6   WEAP   .

        4   24   .

        WEAP   WEAP   (EMX),

        (FMX)   10%   m   (blows per meter, BPM)

                                                  . EMX   FMX   EMX

                        .   (,   ,   ,   )   CAPWAP

                .

                WEAP   WEAP

                                        (probability density function)   .
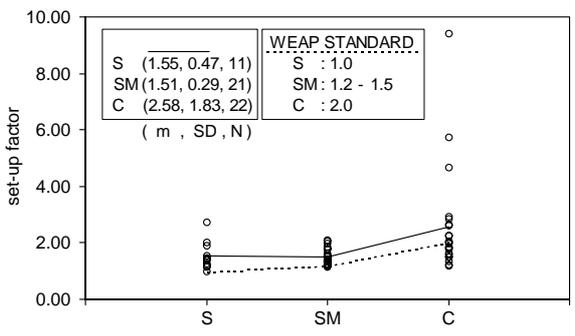
                                                      0

                        (log normal probability density function)   .

3.

                2   ,   (set-up factor)

                            .   m   , SD   , N   .

                                                                                                          1.5,

            1.5,   2.5   .   WEAP   FHWA(1996)

(1   )

                                                                .

그림 2.   set-up factor

1.

	( )
Clay	2.0
Silt - Clay	1.0
Silt	1.5
Sand - Clay	1.5
Sand - Silt	1.2
Fine Sand	1.2
Sand	1.0
Sand - Gravel	1.0

                                set-up

                                                .

                                set-up   .

3. quake

4. damping

3   quake

quake   3   ,

.   quake

2.0±0.2(mm)   WEAP   , 2.5 mm   .

4   damping   .

. damping

damping   0.65±0.1(s/m)   damping

WEAP   .   WEAP

.   damping

.   ,   2

(   )

damping   .

2.

	(VMX)	(EMX)		
	0.94	0.89	1.69	3.26
	0.19	0.19	0.87	4.80
( )	43	43	43	43

5. quake

6. damping

5	quake	·	·	5

quake	·

'

·	5	quake

quake	·

quake	Davisson

·

3	quake

·	3

·	WEAP

Davisson	quake	,	D/120(D	)	(	D/52,	D/94)	,

·

quake	·

quake	SM

,	SM

·

3.	quake

		(EOID)			(Restrike)			( )
			(r²)				(r²)	( )
	C	$\dfrac{D}{25}$	0.53	10.31	$\dfrac{D}{80}$	0.64	2.07	7
	S	$\dfrac{D}{51}$	0.52	7.06	$\dfrac{D}{72}$	0.45	9.53	9
	SM	$\dfrac{D}{62}$	0.21	5.40	$\dfrac{D}{87}$	0.34	3.59	21
	SG	$\dfrac{D}{71}$	0.54	7.36	$\dfrac{D}{177}$	0.61	3.17	9
		$\dfrac{D}{52}$	0.28	7.64	$\dfrac{D}{94}$	0.39	5.10	46
		$\dfrac{D}{58}$	0.10	3.83	$\dfrac{D}{102}$	0.54	4.07	23
		$\dfrac{D}{47}$	0.34	10.14	$\dfrac{D}{88}$	0.32	6.03	23

quake	quake	,

quake	plugging

·

6	damping	·	·

damping

·	,	2

damping

·	damping

·

damping	0.25±0.02(s/m)

WEAP	(0.5 s/m)	,	damping	WEAP

·

4.

WEAP

WEAP

4.   .

	(EOID)				(Restrike)				set-up factor
	quake (mm)	damping (s/m)	quake (mm)	damping (s/m)	quake (mm)	damping (s/m)	quake (mm)	damping (s/m)	
	2.0 (2.54)	0.65 (0.65)	D/25 (D/120)	0.25 (0.5)	2.0	0.65	D/80	0.5	2.0 (2.0)
	2.0 (2.54)	0.65 (0.16)	D/50 (D/120)	0.25 (0.5)	2.0	0.65	D/70	0.5	1.3 (1.0)
	2.0	0.65	D/70	0.25	2.0	0.65	D/180	0.5	-
	2.0	0.65	D/60	0.25	2.0	0.65	D/90	0.5	1.5
			1.2				1.2		

) ( )   WEAP

(,
,   )   .

4

.

4   set-up factor

.

WEAP   (Restrike)   .
(
)   .
,
.

5   WEAP   .   5
WEAP   .
WEAP   (FMX)   (EMX)
.

7   10   WEAP   5
.   7   8   ,
WEAP   .   9
10

,

.   .

5. (CAPWAP) WEAP

	ER	ES	RR	RS	ER	ES	RR	RS	ER	ES	RR	RS
1	0.90	1.19	1.00	1.00	1.12	1.10	1.11	1.11	0.94	1.04	0.93	0.88
2	1.01	1.21	0.98	1.11	0.97	0.93	1.10	1.05	1.04	1.12	0.89	0.98
3	1.00	1.24	1.20	1.36	1.05	0.97	0.91	0.91	1.04	1.13	0.99	1.11
4	1.02	1.27	1.27	1.51	0.95	0.91	0.91	0.92	1.04	1.16	0.94	1.11
1	0.99	1.19	1.09	1.26	1.05	1.04	0.94	0.92	1.01	1.11	1.00	1.09
2	0.99	1.15	1.17	1.51	1.05	1.05	0.92	0.92	0.98	1.08	0.98	1.11
3	0.96	1.16	1.10	1.37	1.07	1.07	0.90	0.90	1.00	1.11	0.99	1.10
4	0.96	1.12	1.09	1.25	1.09	1.11	1.06	1.06	0.94	1.10	0.97	1.10
1	1.02	1.27	1.03	1.14	1.01	0.97	0.99	0.98	0.98	1.06	1.02	1.15
2	0.96	1.22	1.00	1.10	1.02	0.97	1.01	0.99	1.05	1.14	0.99	1.14
3	1.04	1.10	1.01	1.06	1.00	1.00	1.10	1.08	0.95	1.07	0.93	1.12
4	1.03	1.23	0.97	1.00	0.98	0.95	1.04	1.04	1.11	1.16	1.00	1.17
1	1.13	1.13	1.07	1.06	0.94	0.94	0.99	0.99	1.08	1.05	1.06	1.06
2	1.09	1.09	1.11	1.11	0.95	0.95	0.96	0.96	1.05	1.02	1.00	0.99
3	1.07	1.06	1.03	1.01	0.97	0.97	1.02	1.02	1.03	0.94	0.91	0.87
4	1.03	1.15	1.08	1.08	0.94	0.93	1.01	1.01	1.03	0.98	0.92	0.90
1	1.00	0.96	1.08	1.00	0.93	0.93	0.92	0.94	1.28	1.48	1.18	1.48
2	1.05	1.00	1.07	0.99	0.99	0.99	0.92	0.97	1.13	1.35	1.12	1.40
3	1.06	1.00	1.10	1.00	1.02	1.03	0.91	0.95	0.99	1.15	1.04	1.24
4	0.98	0.96	1.00	0.94	1.06	1.07	1.02	1.09	1.04	1.42	0.96	1.17
1	1.02	1.02	1.10	1.14	0.93	0.94	0.91	0.92	1.14	1.39	0.99	0.96
2	1.01	1.18	0.99	1.08	1.01	0.93	0.99	0.97	0.96	1.18	1.04	1.05
3	1.11	1.11	1.09	1.09	1.01	1.02	1.00	1.00	0.94	1.08	0.84	0.84
4	1.02	1.13	1.26	1.31	1.02	0.97	0.96	0.93	0.93	1.19	0.98	0.99
	1.02	1.13	1.08	1.15	1.01	0.99	0.98	0.98	1.03	1.15	0.99	1.08
	0.05	0.09	0.08	0.16	0.05	0.06	0.06	0.06	0.08	0.13	0.07	0.15

) ES, RS :
ER, RR :

7. WEAP
( )

8. WEAP
( )

10
8
6
4
2
0

(,)
━ ER (1.02, 0.05)
── ES (1.13, 0.09)

0   0.5   1   1.5   2
(/)

10
8
6
4
2
0

(,)
━ RR (1.01, 0.05)
── RS (0.99, 0.06)

0   0.5   1   1.5   2
(/)

9.   (FMX)
   WEAP   (   )

10.   (EMX)
   WEAP   (   )

5.

                                                   WEAP
                    .   46
                                      WEAP

            .
   WEAP   (damping, quake)   .
                          WEAP
      ,   WEAP
   .
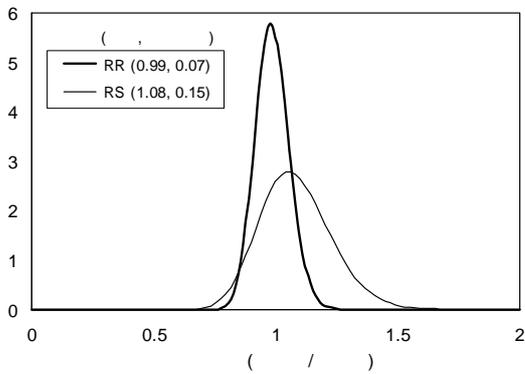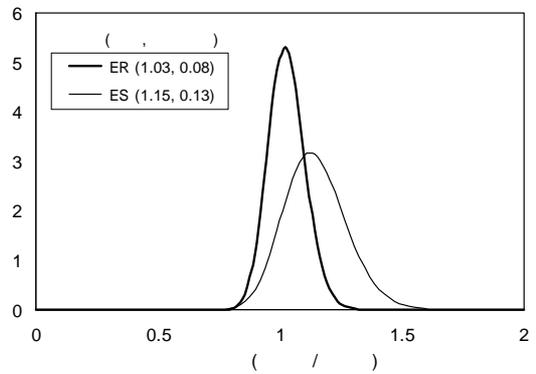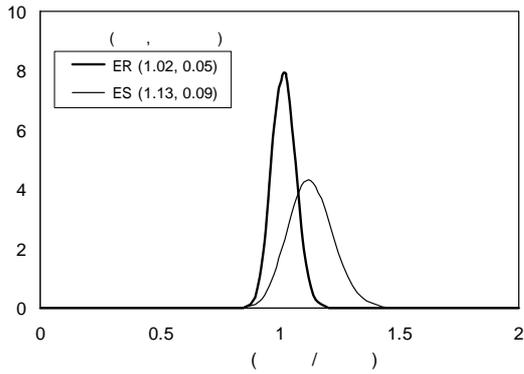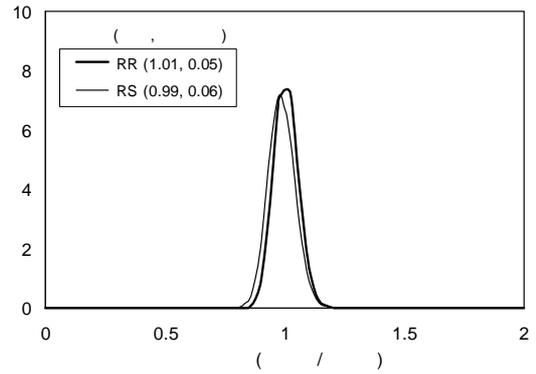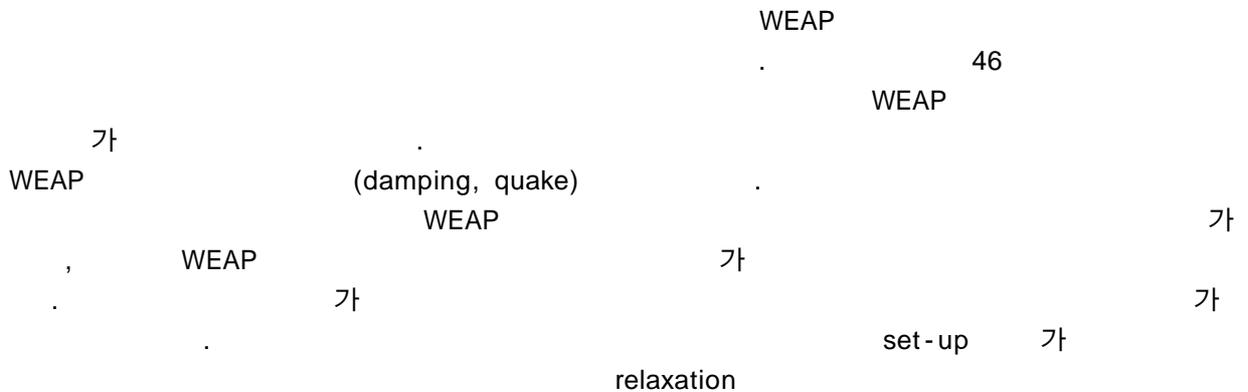
      .   set- up
                              relaxation
   .

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