

DOI: 10.47094/COBRAMSEG2024/354

The Effect Of An Eccentric Blow In The High Strain Dynamic

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ABSTRACT: The High Strain Dynamic Pile Test (HSDPT) has been used on piles to detect damage along the shaft and to determine the pile capacity. The Beta Method is commonly used to identify the magnitude of the pile damage. A broken pile may not support a low-energy blow applied to the pile top (Murakami et at, the pile damage. A broken pile may not support a low-energy blow applied to the pile top (Murakami et at, ABSTRACT: The High Strain Dynamic Pile Test (HSDPT) has been used on piles to detect damage along
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the pile damage. particularly for detecting pile damage (Murakami et al., 2022a, 2022b, 2023, 2024a, 2024b). This paper
presents a case study in which poor data quality indicated false damage on 30 cm-square precast concrete piles. Furthermore, the set per blow was zero, and the force signals demonstrated an eccentric blow, with piles. Furthermore, the set per blow was zero, and the force signals demonstrated an eccentric blow, with negative force values before the 2L/c time in one of the pair of sensors, indicating that this bending on the pile may have resulted in this "false pile damage." This paper shows that the pile testing engineer may evaluate if the collected data is of good quality. If not, an investigation must be done to identify the cause of the bad-quality data. Otherwise, the outcome of the HSDPT will not be reliable and may indicate false pile damage on the pile shaft. the bad-quality data. Otherwise, the outcome of the HSDPT will not be reliable and may indicate false pile
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lon longo do fuste e determinar a capacidade da estaca. O Método Beta é comumente usado para identificar a
magnitude do dano na estaca. Uma estaca danificada pode não resistir a um impacto de baixa energia aplicado no topo da estaca (Murakami et al., 2020). Além disso, dados dinâmicos coletados com qualidade são fundamentais para um diagnóstico confiável das estacas, particularmente para detectar danos (Murakami et al., 2022a, 2022b, 2023, 2024a, 2024b). Este artigo apresenta um estudo de caso no qual a baixa qualidade et al., 2022a, 2022b, 2023, 2024a, 2024b). Este artigo apresenta um estudo de caso no qual a baixa qualidade
dos dados indicou falsos danos em estacas pré-fabricadas de concreto de 30 cm de lado. Ademais, a nega por golpe foi zero, e os sinais de força demonstraram um golpe excêntrico, com valores de força negativos antes do tempo 2L/c em um dos pares dos sensores, indicando que esta flexão na estaca pode ter resultado neste "falso dano na estaca". Este artigo mostra que o engenheiro responsável pelo ensaio da estaca pode avaliar se os dados coletados são de boa qualidade. Caso contrário, uma investigação deve ser realizada para identificar a causa dos sinais de baixa qualidade. Do contr falsos danos no fuste da estaca. longo do fuste e determinar a capacidade da estaca. O Método Beta é comumente usado para identificar a
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a causa dos sinais de baixa qualidade. Do contrário, o resultado do ECD não será confiável e poderá indicar
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PALAVRAS CHAVE: Ensaio de Carregamento Dinâmico (ECD), Método Beta, Falso dano na estaca, Qualidade dos sinais, Estacas pré moldadas

1 **INTRODUCTION**

The High Strain Dynamic Pile Test (HSDPT) (NBR 13208, ASTM D4945) has been used on piles to detect damage along the shaft and to determine the pile capacity. The Beta Method is commonly used to identify the magnitude of the pile damage. detect damage along the shaft and to determine the pile capacity. The Beta Method is commonly used to identify the magnitude of the pile damage.
In the HSDPT, if the velocity increases sharply relative to the force at any

detect damage along the shaft and to determine the pile capacity. The Beta Method is commonly used to identify the magnitude of the pile damage.
In the HSDPT, if the velocity increases sharply relative to the force at any and velocity measurement on a broken pile (Rausche and Goble,

Figure 1 1. Example of a force and velocity measurement on a broken pile (Rausche and Goble, 1979)

The pile data collected in the HSDPT are analyzed through a Signal (Case Pile Wave Analysis Program) is a software used to perform Signal-Matching Analysis (Pile Dynamics, Inc, 2006). The pile data collected in the HSDPT are analyzed through a Signal-Matching Method. The CAPWAP (Case Pile Wave Analysis Program) is a software used to perform Signal-Matching Analysis (Pile Dynamics, Inc. 2006).
In the fi Example of a force and velocity measurement on a broken pile (Rausche and
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Wave Analysis Program) is a software used to perform Signal 1. Example of a force and velocity measurement on a broken pile (Rausche and Goble, 1979)
pile data collected in the HSDPT are analyzed through a Signal-Matching Method. The CAPWAP

Analysis models the pile nalysis models the pile Analysis models the pile-soil system, adjusting the pile impedance along the pile length.
integrity are suggested as a function of the β values, according to Rausche and Globe (197
Table 1. Pile description as a functi he Pile Driving Analyzer (PDA) calculates the β value. Further, a spile-soil system, adjusting the pile impedance along the pile length. C
ed as a function of the β values, according to Rausche and Globe (1979): soil system, adjusting the pile impedance along the pile length. Categories of pile

β (%)	Description
100	Uniform pile
$80 < \beta < 100$	Slight damage
$60 < \beta < 80$	Damage
B<60	Pile broken

1. Pile description as a function of

A broken pile may not support a low-energy blow applied to the pile top (Murakami et at, 2020). A broken pile may not support a low-energy blow applied to the pile top (Murakami et at, 2020).
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pile damage (Murakami et particularly for

Murakami et al. (2022b) showed a case study in which a root pile was considered broken based on the impedance reduction calculated by the CAPWAP analysis. However, poor impedance reduction calculated by the CAPWAP analysis. However, poor-quality collected data was observed, and the dynamic test was performed again. The second test, with good-quality collected data, confirmed that the pile was still functional. On both tests, the match quality number was acceptable. confirmed that the pile was still functional. On both tests, the match quality number was acceptable.
Furthermore, the authors concluded that the match quality number in a CAPWAP analysis is not the only parameter to be analyzed as a quality parameter of the tested piles, being fundamental to quality assurance of the collected data. integrity are suggested as a function of the β values, according to Rausche and Globe (1979):
 $\frac{Table 1. Pile description as a function of β values.
 $\frac{10}{100}$ Decretion
 $\frac{100}{100}$ Uniform pile
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Damage
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Decre$ detecting pile damage (Murakami et a
Murakami et al. (2022b) showe
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observed, and the dynamic test was Murakami et al. (2022b) showed a case study in which a root pile was considered broken based on the impedance reduction calculated by the CAPWAP analysis. However, poor-quality collected data was observed, and the dynamic that the pile was still functional. On both tests, the match quality number was ace, the authors concluded that the match quality number in a CAPWAP analysis is not be analyzed as a quality parameter of the tested piles, b On both tests, the match
match quality number in a
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2 OBJECTIVES

This paper aims to present the effect of an eccentric blow in the high-strain dynamic pile test. It is shown in a Case Study that an eccentric blow applied at the pile top (pile E10) may cause bad-quality data,

indicating false pile damage on the pile shaft. This Case Study shows the importance of good quality data in indicating false pile damage on the pile shaft. This Case Study shows the importance of good-quality data in
the Dynamic test. In addition, the collected signals with bad quality (negative force values at the beginning
of the Dynamic test. In addition, the collected signals with bad quality (negative force values at the beginning
of the strike) shown in this paper are one of the collected signal types that Murakami (2024a) suggests that a CAPWAP analysis cannot be performed. strike) shown in this paper are one of the collected signal types that Murakami (2024a) suggests that a

VAP analysis cannot be performed.
 METHODOLOGY

The results obtained in the field through the CASE Method are shown

3 METHODOLOGY

signals from the blow with the highest energy level. Different force and velocity signals collected by the Pile Driving Analyzer (PDA) for the same pile with the same drop height of 40 cm are shown. Moreover, the HSDPT was performed in a 30 cm-square precast concrete pile for a design load of 70 tons. the shown in this paper are one of the colle

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3 **METHODOLOGY**

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Drivi heat energy level. Different force and velocity signals collected by the Pilame pile with the same drop height of 40 cm are shown. Moreover, th square precast concrete pile for a design load of 70 tons. 40 cm are shown. Moreover, the od-quality data in

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In addition, the bad E10). Further, these results are compared with another pile (E92) with good-quality data, close to pile E10. The results of the bad-quality data are entirely different from the good ones. HSDPT was performed in a 30 cm-square precast concrete pile for a design lost In addition, the bad-quality and good data are compared in the same E10). Further, these results are compared with another pile (E92) with good med in a 30 cm-square precast concrete pile for a design load of 70 tons.
the bad-quality and good data are compared in the same pile tested by the HSDPT (pile . Different force and velocity signals collected by the same drop height of 40 cm are shown. Moreove oncrete pile for a design load of 70 tons. The compared in the same pile tested by the HSDPT ther pile (E92) with good-qu and good data are compared in the same pile tested by the HSDPT (pile npared with another pile (E92) with good-quality data, close to pile E10.

Moreover, the pile damage determined by the Case Method demonstrated low Beta values for the bad-Moreover, the pile damage determined by the Case Method demonstrated low Beta values for the bad-
quality data, indicating that the pile would be considered broken. However, the good-quality data indicated that the pile was not broken but had slight damage. Inter, these results are compared with another pile
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4 CASE STUDY

The project site was in Cubatão, SP, Brazil, and the 30 cm-square precast concrete piles were driven by a 5-ton hydraulic hammer up to 32m depth. The soil profile indicated a thick, soft clay layer up to 28m depth, followed by a sandy layer up to 38m depth. The 5 depth, followed by a sandy layer up to 38m depth. The 5-ton hydraulic hammer applied four blows with a drop height of 40cm, and the β values were between 52% and 90%, indicating severe pile damage (broken pile). These drop height of 40cm, and the β values were between 52% and 90%, indicating severe pile damage (broken pile). These magnitudes of the β values mean that the pile would not be able to support the loads from the structures, according to Table 1. Nonetheless, it will be shown in this paper that false pile damage. that the pile was not broken but had slight damage.

4 CASE STUDY

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quality data, indicating that the pile wou ulic hammer up to 32m depth. The soil profile indicated a thick, soft clay layer up to 28m
by a sandy layer up to 38m depth. The 5-ton hydraulic hammer applied four blows with a that the pile would not be able to support the loads from the it will be shown in this paper that bad-quality data caused this a drop height of 40 cm (Blow numbers between 4 and 7), the (broken

For those four blows on pile E10 with a drop height of 40 cm (Blow numbers between 4 and 7), the RMX (maximum static resistance) was between 1 set per blow was zero, and the force signals demonstrated an eccentric blow, indicating that this bending on set per blow was zero, and the force signals demonstrated an eccentric blow, indicating that this bending or
the pile may have resulted in this "false pile damage." Normally, a broken pile may not support a low-energy
blow blow applied to the pile top (Murakami et at, 2020). Once the pile set was zero, it would be an indication that the pile would not be broken. w applied to the pile top (Murakami et at, 2020). Once the pile set was zero, it would be an indication that pile would not be broken.
The two worst collected data were observed on blow numbers 5 and 6 (BN 5 and 6). Figure set per blow was zero, and the force signals demonstrated an eccentric blow, indicating that this bending on
the pile may have resulted in this "false pile damage." Normally, a broken pile may not support a low-energy
blow false pile damage.
For those four blows on pile E10 with a drop height of 40 cm (Blow numbers between 4 an RMX (maximum static resistance) was between 107 tons and 132 tons, as shown in Table 2. How set per blow was zero, For those four blows on pile E10 with a drop height of 40 cm (Blow numbers between 4 and 7), the (maximum static resistance) was between 107 tons and 132 tons, as shown in Table 2. However, the low-energy

values at the beginning of the strike before the 2l/c period caused by an eccentric blow. This eccentric blow caused a bad proportionality between force and velocity signa and velocity) of 0.9, as shown in Table 2. Further, this bending on the pile indicated false pile damage (β of and velocity) of 0.9, as shown in Table 2. Further, this bending on the pile indicated false pile damage (β of 79.0 at 1.0m and 52 at 6.8m, as shown in Table 2) once the β values are calculated on force and velocity 79.0 at 1.0m and 52 at 6.8m, as shown in Table 2) once the β va collected signals. For precast concrete piles, a good collected signal Figure 3 shows the pair of force signals on BN 6. The sensor the pair of force signals collected on pile E10 (BN 5). It was observed that sensor F3 measured negative values at the beginning of the strike before the $2l/c$ period caused by an eccentric blow. This eccentric blow cause is the resulted in this "false
applied to the pile top (Murakami
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The two worst collected data we
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d a bad proportionality betw set per blow was zero, and the force signals demonstrated an eccentric blow, indicating that this bending or
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ed signals. For precast concrete piles, a good collected signal normally indicates an FVP of 1.0.
Figure 3 shows the pair of force signals on BN 6. The sensor F3 is still negative at the beginning of the strike before the 2L/c period. This eccentric blow caused a bad proportionality between force and velocity signals, with a FVP of 0.5, as shown in Table 2. Further, this bending on the pile indicated false pile damage (β of 79.0 at 6.6m and 90 at 18.3m, as shown in table 2) once the β values are calculated on force and signals, with a FVP of 0.5, as shown in Table 2. Further, this bending on the pile indicated false pile (β of 79.0 at 6.6m and 90 at 18.3m, as shown in table 2) once the β values are calculated on f velocity collect velocity collected signals. For precast concrete piles, a good collected signal normally indicates an FVP of 1.0. Although the Beta values on BN 6 were higher than the ones observed on BN 5, it is expected that a CAPWAP analysis would indicate to the force signal before the 2L/c time. (Goble et al., 1977; Murakami and Cabette, 2023). force signal before the 2L/c time. This fact would indicate that damage on the pile had weakened it et al., 1977; Murakami and Cabette, 2023).
The pile E10 was slightly inclined, which made it harder to collect good-qualit CAPWAP analysis would indicate more severe damage on BN 6 once the velocity increased sharply relative
to the force signal before the 2L/c time. This fact would indicate that damage on the pile had weakened it
(Goble et al *X*. Congresso Brasileiro de Mecânica os Solos e Engenheiro de Mecânica das Rochas

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de 2024 – of 79.0 at 6.6m and 90 at 18.3m, as shown in table 2) once the β values are calculated on f
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Although the Beta values on Congress Dealth and Mechanica dos Solos e Congresso Congresso Mechanica dos Solos e Mechanica do Solos e Mechanica do Solos e Mecânica Center (1919) Powers in this pape dealth and this Congress Mechanica Center (1919) Powe shows the pair of force signals on BN 6. The sensor F3 is still negative at the beginning of the e 2L/c period. This eccentric blow caused a bad proportionality between force and velocity FVP of 0.5, as shown in Table 2. F This eccentric blow caused a bad proportionality between force and velocity ted signals. For precast concrete piles, a good collected signal nothe Beta values on BN 6 were higher than the ones observed on lysis would indicate more severe damage on BN 6 once the velocit gnal before the 2L/c time. T between 62% and 90%, including the density of the testing engineer of environmental and signals with bad quality (negative force of good-quality data in digitals with bad quality (negative force values at the beginning th ow caused a bad propor
Further, this bending on
in in table 2) once the β extractive positions, a good collected signal normally indicates an FVP of BN 6 were higher than the ones observed on BN 5, it is expected that a more severe damage on BN 6 once the velocity increased sharply relative indicating the latteration inter the beta 11 in Cose show the input random included pairs of the of with bad pairs of the of with the of with the of with the signature force of the collected again by the distinction (i.e. of force signals on BN 6. The sensor F3 is still negative at the beginning of the
This eccentric blow caused a bad proportionality between force and velocity
shown in Table 2. Further, this bending on the pile indicated f If this pile term is a standard between 73% and 90%, the showled between 1980s and 10% of the should be included by the showled between 7), properties the should be included by the should be the should be the should be the force and velocity pile damage indicates an FVP of ality data indicated
ay layer up to 28m
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6). F

The pile E10 was slightly inclined, which made it harder to collect good-quality data (Murakami, 2024a). In this case, the hammer should be adjusted with the same inclination of the pile. Then, during those 2024a). In this case, the hammer should be adjusted with the same inclination of the pile. Then, during those
four blows with the same drop height (BN between 4 and 7), the pile testing engineer tried to properly adjust

the pile driving machine in order to collect good-quality data. Further, the pile had been appropriately adjusted on blow number 7 (figure 3) with no indication of negative values at the had been appropriately adjusted on blow number 7 (figure 3) with no indication of negative values at the beginning of the strike on sensor F3. An additional blow of 60 cm drop height (BN 8) was applied at the pile the pile driving machine in order to collect good-quality data. Further, the pile-driving machine's hammer
had been appropriately adjusted on blow number 7 (figure 3) with no indication of negative values at the
beginning slight damage on the pile, with two compression slacks $(0.10 \text{mm with an efficiency of } 0.10 \text{ at } 12.11 \text{m and}$ slight damage on the pile, with two compression slacks (0.10mm with an eff
0.25mm with an efficiency of 0.20 at 17.15m) and one tension slack (1 tf with
In addition, with a blow of 60 cm, the RMX was 192 tons, as shown in In addition, with a blow of 60 cm, the RMX was 192 tons, as shown in Tabl
Table 2. Case Method results for pile E10 tension slack $(1 \text{ if with } a \text{ ms}, \text{ as shown in Table 2})$. of 0.20 at 17.15m) and one tension slack $(1 \text{ ft with an efficiency of } 1.0 \text{ at } 1.0 \text{ m})$. machine's hammer
gative values at the
s applied at the pile
WAP demonstrated
0.10 at 12.11m and
cy of 1.0 at 1.0 m).

Where: RMX = maximum static resistance; β = Beta values; EMX = maximum transferred energy; FVP = proportionality between force and velocity.

Figure 3. Collected data on pile E10 with a drop height of 40cm

Figure 4. Collected data on pile E10 with a drop height of 40 cm (Blow number 7)

Figures 5 and 6 show the force signals for piles E10 (60 cm drop height) and E92 (80 cm drop height), Figures 5 and 6 show the force signals for piles E10 (60 cm drop height) and E92 (80 cm drop height), respectively. The shape of force and velocity on both collected signals are qualitatively close, with no negative force values at the beginning of the strike before the 2L/c time. The pile E92 showed slight damage through the Case Method (along the pile shaft. h the Case Method (β of 78 at 31.6m). However, the CAPWAP analysis showed no signs of damage the pile shaft.
Likewise, the signals with good-quality data (figures 5 and 6) are different from the bad-quality data Figures 5 and 6 show the force signals for piles E10 (60 cm drop height) and E92 (80 cm drop height), respectively. The shape of force and velocity on both collected signals are qualitatively close, with no negative force signs of damage

through the Case Method (β of 78 at 31.6m). However, the CAPWAP analysis showed no signs of damage along the pile shaft.
Likewise, the signals with good-quality data (figures 5 and 6) are different from the bad-quality Likewise, the signals with good-quality data (figures 5 and 6) are different from the bad-quality data
from figures 2 to 4. This would explain the reason for detecting false pile damage on bad-quality signals
(figures 2 to to be analyzed on the HSDPT for the quality of the test; the quality of the collected data the quality assurance of the deep foundations to be analyzed on the HSDPT for the quality of the test; the quality of the collected data is fundamental for
the quality assurance of the deep foundations.
Ensuring high-quality collected data is fundamental for reliable from figures 2 to 4. This would explain the reason for detecting false pile damage on bad-quality (figures 2 to 4). As Murakami (2024a, 2024b) observed, the match quality number is not the only pa to be analyzed on the HSD es 2 to 4). As Murakami (2024a, 2024b) observed, the match quality number is not the only parameter analyzed on the HSDPT for the quality of the test; the quality of the collected data is fundamental for reliable HSDPT res 2024b) observed, the match quality number is not the only parameter to be analyzed on the HSDPT for the quality of the test; the quality of the collected data is fundamental for

Ensuring high-quality collected data is fundamental for reliable HSDPT results and deep foundation quality assurance, as the match quality number alone is not sufficient for assessing test quality (Murakami, 2024a, 2024b).

Figure 6. Collected data on pile E92 with a drop height of 80cm

This paper demonstrated that the pile testing engineer must evaluate the collected-data quality; if inadequate, an investigation is necessary to identify the cause. Failure to ensure high-quality data may yield inadequate, an investigation is necessary to identify the cause. Failure to ensure high-quality data may yield
unreliable HSDPT results, potentially leading to the misinterpretation of pile integrity, as highlighted by Murakami et al. (2020, 2022, 2023, 2024a, 2024b). ible HSDPT results, potentially leading to the misinterpretation of pile integrity, as highlighted by
ami et al. (2020, 2022, 2023, 2024a, 2024b).
CONCLUSIONS
This paper aims to present the effect of an eccentric blow in This paper demonstrated that the pile

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CONCLUSIONS

This paper aims to present the effect of

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5 CONCLUSIONS

unreliable HSDPT results, potentially leading to the misinterpretation of pile integrity, as highlighted
Murakami et al. (2020, 2022, 2023, 2024a, 2024b).
CONCLUSIONS
This paper aims to present the effect of an eccentric

In addition, a comparison between the bad-quality data and the good one in the same pile tested by the shown in a Case Study that an eccentric blow applied at the pile top (pile E10) may cause bad-quality
In addition, a comparison between the bad-quality data and the good one in the same pile tested
Dynamic Load Test was ma data. The results of the bad-quality data are entirely different from the good one, and the bad one indicated false pile damage on the pile shaft. This Case Study shows the importance of good Dynamic test. testing engineer must evaluate the collected-data quality
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of an eccentric blow in the high-stra Figure 6. Collected data on pile E92 with a drop height of 80cm
This paper demonstrated that the pile testing engineer must evaluate the collected-data quality; if
andequate, an investigation is necessary to identify the c data. The results of the bad-quality data are entirely different from the good one, and the base false pile damage on the pile shaft. This Case Study shows the importance of good-quad Dynamic test.
This paper demonstrated Figure 6. Collected data on pile F92 with a drop height of 80cm

inadequate, an investigation is necessary to identify the cause. Failure to ensure high-quality data m

unreliable HSDPT results, potentially leading to the In addition, a comparison between the bad-quality data and the good one in the same pile tested by the mic Load Test was made. Further, these results are compared with another pile (E92) with good-quality The results of th another pile (E92) with good-quality quality data in the ted-data quality; if
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This paper demonstrated that the pile testing engineer must evaluate the col an investigation must be done to identify the cause of the bad-quality data. Otherwise, the outcome of the False pile damage on the pile shaft. This Case Study shows the importance Dynamic test.

This paper demonstrated that the pile testing engineer must evaluate the

an investigation must be done to identify the cause of the al. (2020, 2022, 2023, 2024a, 2024b). 2024b). data. The results of the bad-quality data are entirely different from the good one, a false pile damage on the pile shaft. This Case Study shows the importance of Dynamic test.

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estigation must be done to id This paper demonstrated that the pile testing engineer must evaluate the collected-data quality. If not, an investigation must be done to identify the cause of the bad-quality data. Otherwise, the outcome of the HSDPT will e cause of the bad-quality data. Otherwise, the outcome of the false pile damage on the pile shaft, as observed by Murakami et lected-data quality. If not,

20, 2022, 2023, 2024a, 2024b).
In this case study, the bad-quality data resulted from the misalignment of the pile driving hammer. The pile was slightly inclined, and in this case, the hammer should be adjusted with the same inclination of the pile was slightly inclined, and in this case, the hammer should be adjusted with the same inc
pile. After several adjustments, the hammer was correctly aligned, yielding good-quality data. damage on the pile shaft,
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tly aligned, yielding good In this case study, the bad-quality data resulted from the misalignment of the pile drivi-
pile was slightly inclined, and in this case, the hammer should be adjusted with the same in
pile. After several adjustments, the h from the misalignment of the pile driving hammer. The inclination of the

fter several adjustments, the hammer was correctly aligned, yielding good-quality data.
Furthermore, after proper hammer alignment, the negative force values before 2L/c, initially indicative Furthermore, after proper hammer alignment, the negative force values before 2L/c, initially indicative of severe pile damage, were no longer observed. This correction in the readings confirmed that the initial of severe pile damage, were no longer observed. This correction in the readings confirmed that the initial diagnosis was inaccurate, highlighting the critical influence of proper equipment setup on data quality and accurate pile integrity assessment.

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