

3º WORKSHOP

BRASIL - 2013

DATA: 18 DE OUTUBRO 2013

HORÁRIO: 8H 30 ÀS 18H

LOCAL: CLARION HOTEL
(BELO HORIZONTE)



CRAVAÇÃO COM MARTELO HIDRÁULICO

CONCEITOS DE CRAVABILIDADE E AVALIAÇÃO DO DESEMPENHO DE SISTEMAS DE CRAVAÇÃO



ASSOCIAÇÃO BRASILEIRA DE MECÂNICA DOS SOLOS E ENGENHARIA GEOTÉCNICA

NÚCLEO REGIONAL DE MINAS GERAIS - NRMG

PATROCÍNIO:



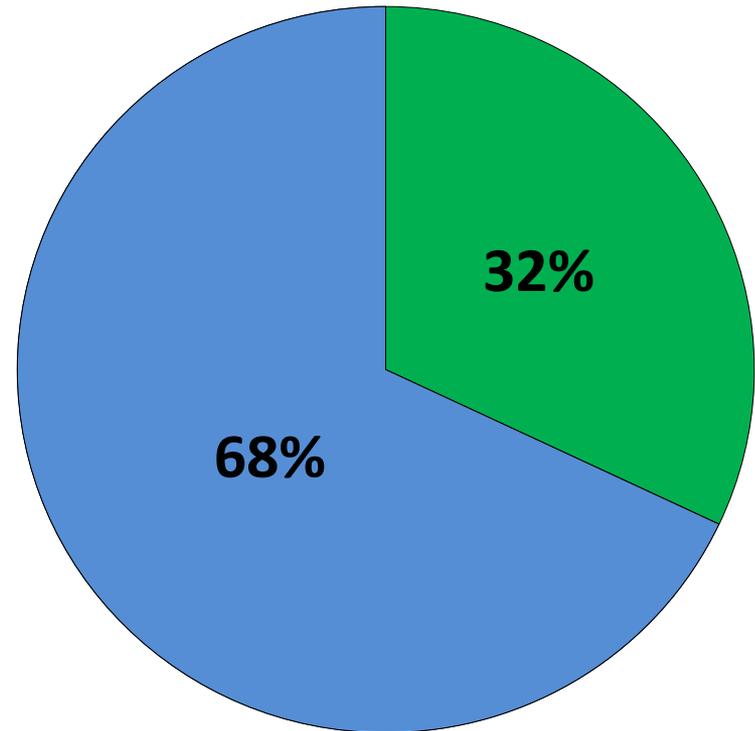
APOIO



DFI 2006 – 10TH INTERNATIONAL CONFERENCE ON PILING AND DEEP FOUNDATIONS - AMSTERDAM

MERCADO MUNDIAL DE ESTACAS

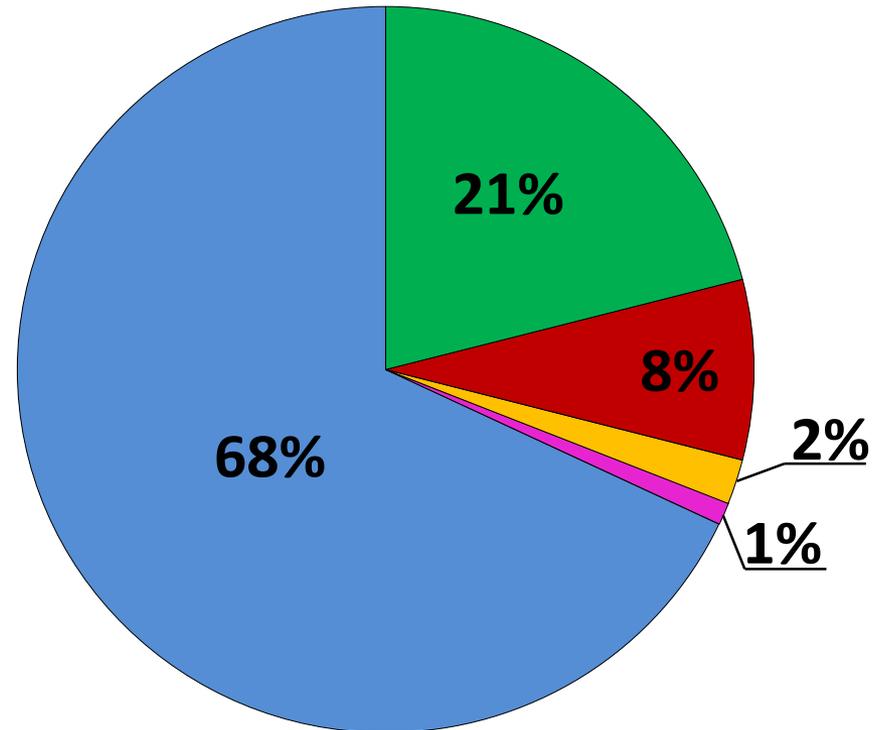
- Estacas cravadas
- Estacas moldadas “in loco”



DFI 2006 – 10TH INTERNATIONAL CONFERENCE ON PILING AND DEEP FOUNDATIONS - AMSTERDAM

MERCADO MUNDIAL DE ESTACAS

- Estacas pré-moldadas de concreto
- Estacas metálicas (perfis laminados e soldados)
- Estacas tubulares de aço
- Estacas aparafusadas (estacas Helicoidais)
- Estacas moldadas “in loco”



BREVE HISTÓRICO DA CRAVAÇÃO DE ESTACAS

2000 A.C. - Estacas Cravadas já utilizadas.

400 A.C. - Heródotos - primeiro documento da história universal - estacas cravadas.

Egípcios, Gregos, Fenícios, Romanos, Chineses e Mesopotâmios.

Lake Constance - situada entre a Suíça e Alemanha - estacas de madeira, totalmente preservadas, com idade estimada de 2000 a 4000 anos.

Em Veneza e Amsterdam - estacas de madeiras cravadas com idade de 1000 a 1300 anos.

Leonardo Da Vinci (1452 – 1519) - “máquina de cravar estacas” - encontra-se no museu Nacional da Ciência e Tecnologia de Milão, Itália.

Século XIX - Com o advento do desenvolvimento dos equipamentos movidos a combustão vegetal que gerava vapor, por exemplo, as locomotivas a vapor, surgiram os primeiros bate estacas a guincho com propulsão a vapor, substituindo a energia de geração humana e animal.

Inicia-se a era dos martelos mecânicos.

1920 - **Martelos Diesel** - Alemanha na década de 1920 e nos EUA após a segunda guerra mundial.

Antes e durante a segunda Guerra Mundial - **Martelos Vibratórios** - União Soviética.

No pós guerra - França e EUA encamparam o mercado de fabricação com opção de até 4000 KN de Força Centrífuga.

Os **Martelos Vibratórios**, entretanto, no Brasil, são de utilização rara na cravação de estacas.

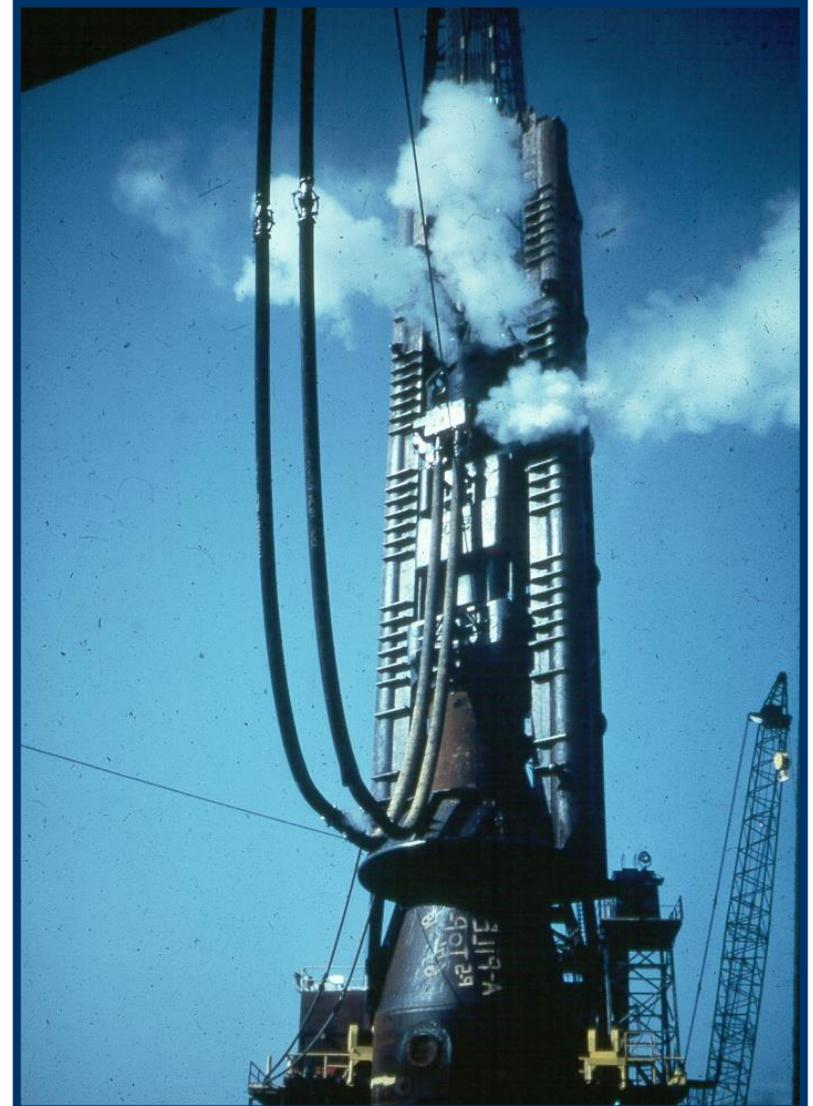
1960 - **Martelos Hidráulicos** - Países Escandinavos, principalmente Suécia.

Martelos Pneumáticos - Martelos de elevada energia de cravação a vapor que na atualidade têm sido substituídos por energia a ar comprimido.

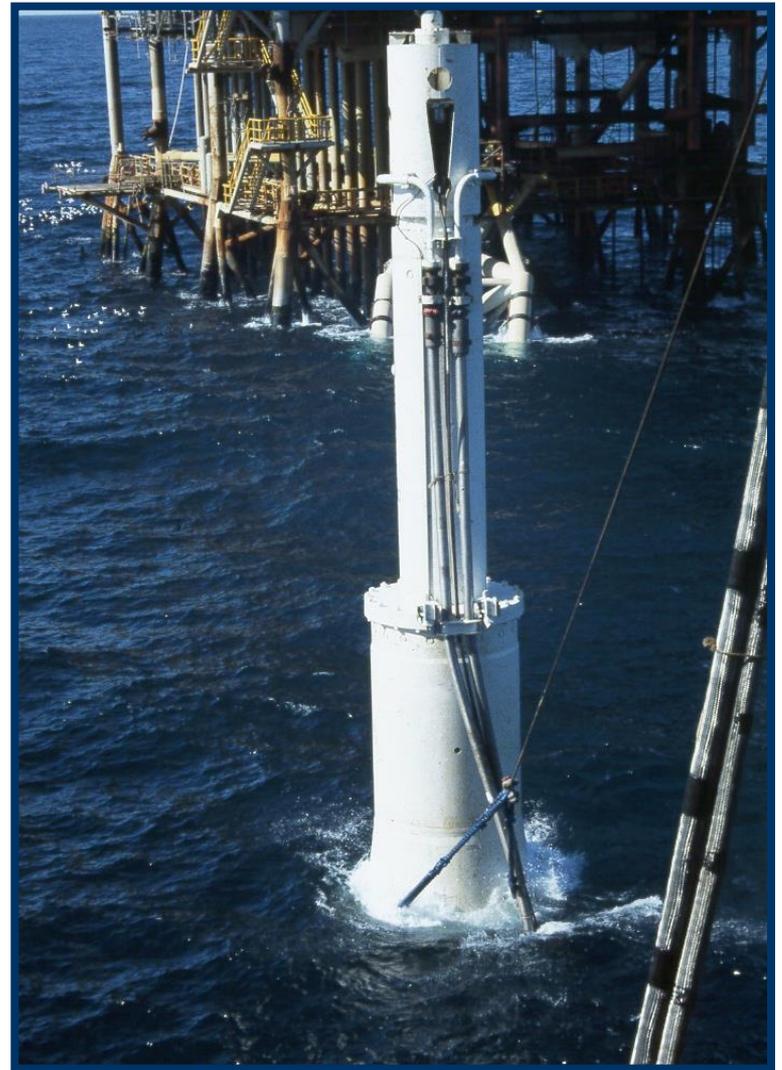
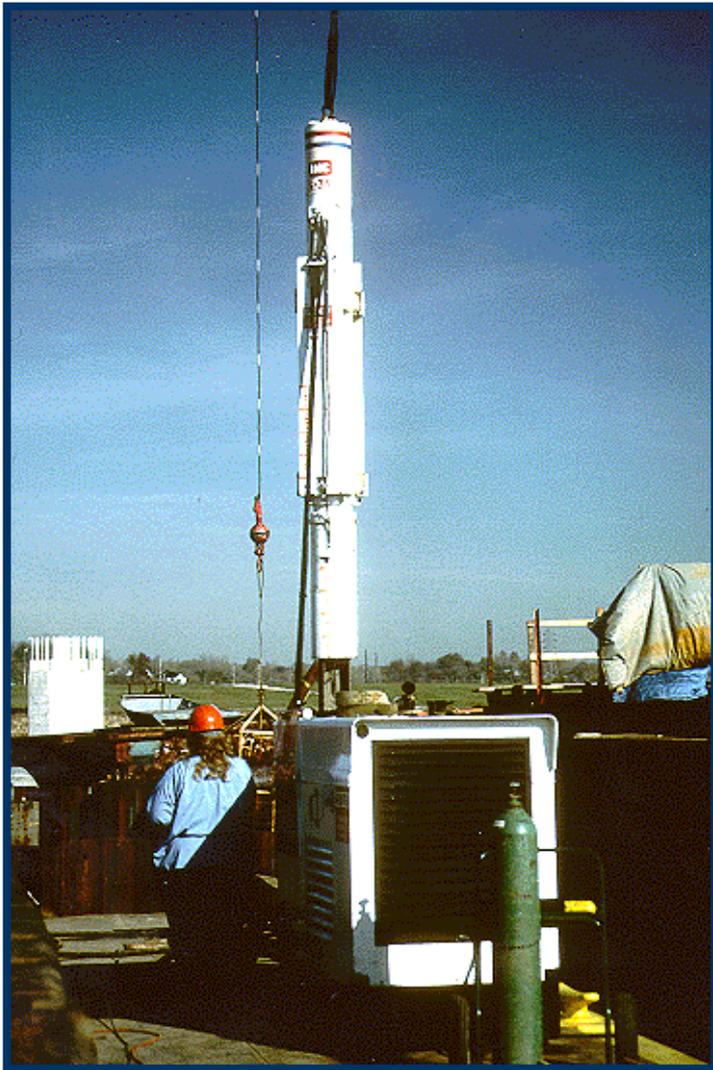
CRAVAÇÃO OFFSHORE

SINGLE ACTING AIR/STEAM HAMMERS

Conmaco; Menck-MRBS; MKT; Vulcan Ram Weights to 125 tonnes;
Rated Energies to 1,500 kJ



HYDRAULIC HAMMERS WITH ENERGY MONITOR (BSP); IHC; (HPSI); Menck-MHU Ram Weights to 100 tonnes; Energies to 2000 kJ



ESTACAS TUBULARES DE AÇO FUNDAÇÕES OFFSHORE

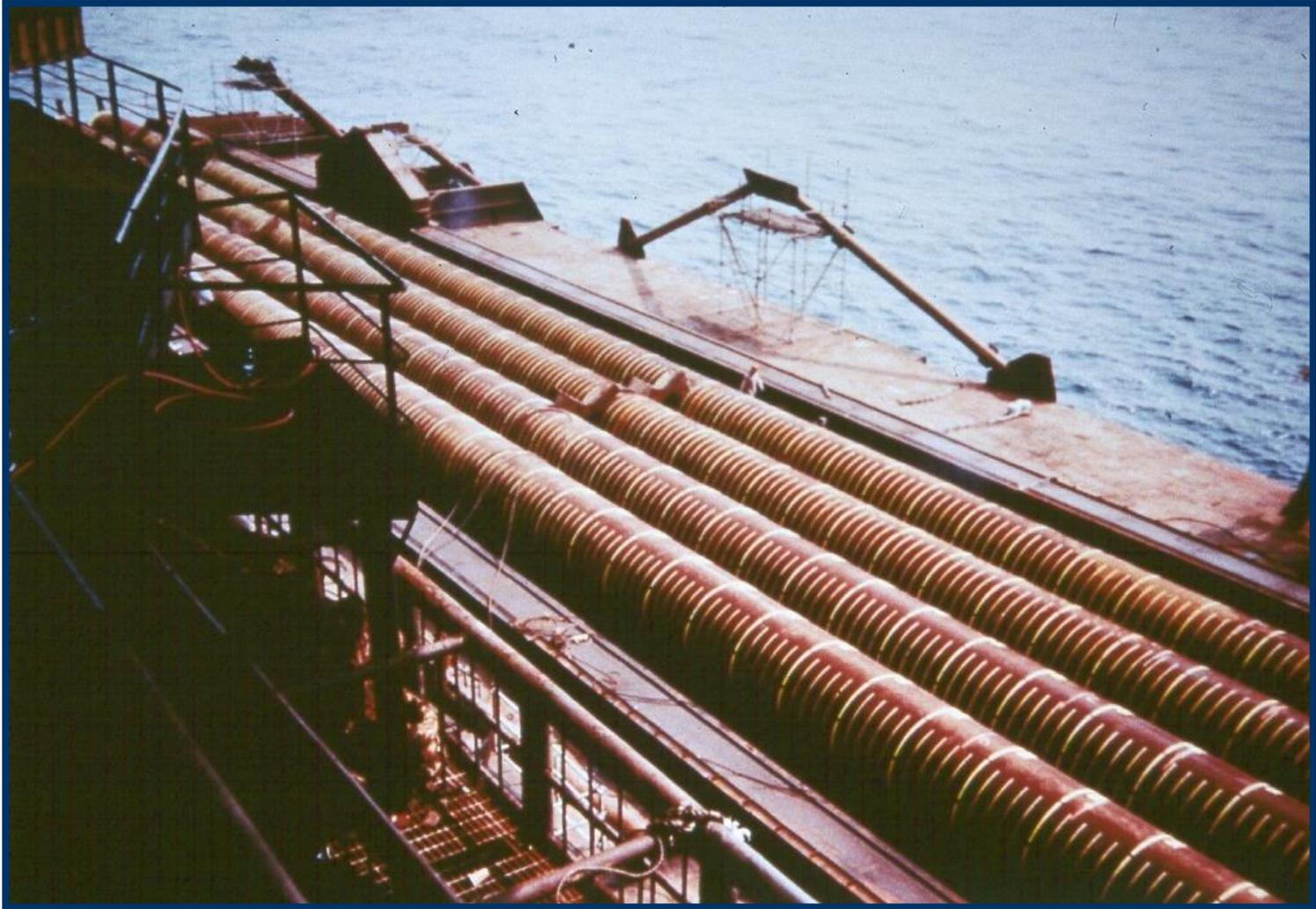
Ø até 4 m

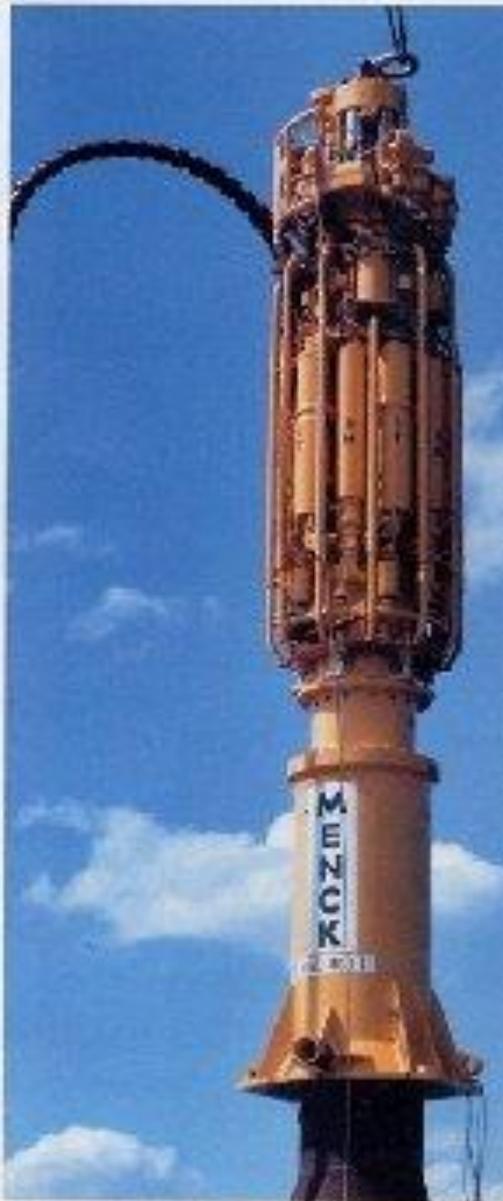
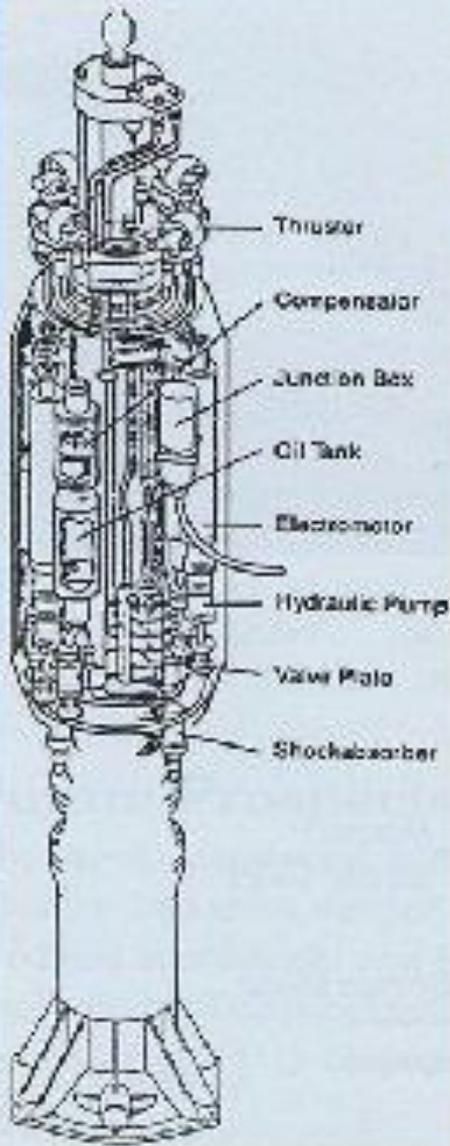
Espessura até 150 mm

Comprimento até 500 m



OFFSHORE PIPE PILES





Hydraulic Hammer for driving offshore pile under water to depths exceeding 1000 m below water.

The new deepwater hammer system

MARTELO QUEDA LIVRE E MARTELO DIESEL

“ A MÁQUINA ” DE CRAVAR ESTACAS



**Bate-Estacas projetado por
Leonardo da Vinci (1452-1519)**

**Este modelo de Bate-Estacas encontra-se
exposto no Museu Nacional de Ciência
e Tecnologia de Milão, Itália.**



ESTACA PRÉ-MOLDADA DE CONCRETO



**Bate-Estacas de Rolos
Martelo Queda-Livre**

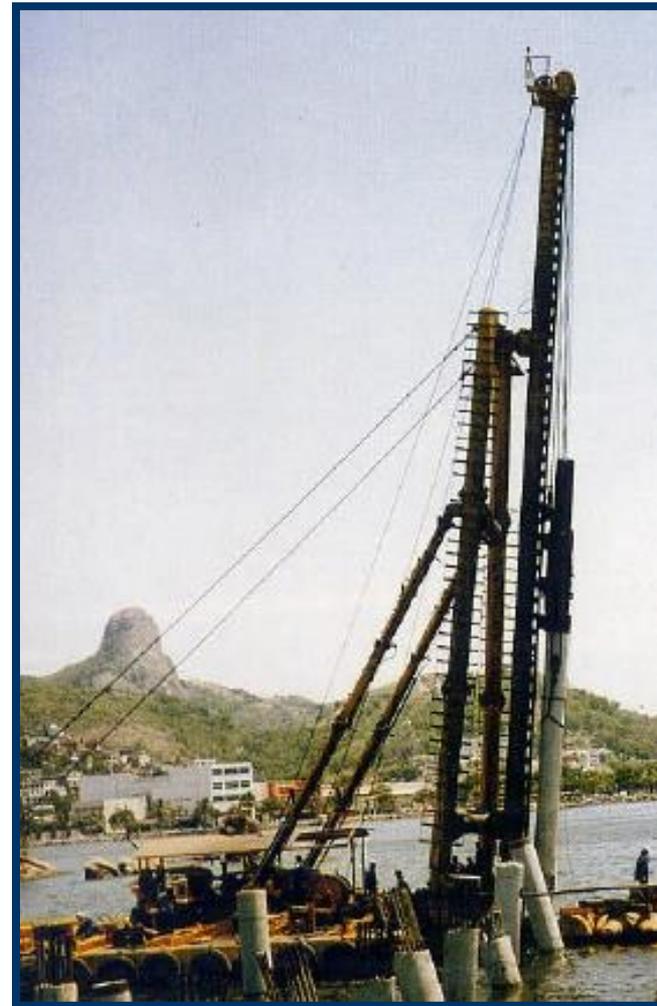


**Bate-Estacas de Rolos
Com Martelo Diesel**

ESTACA PRÉ-MOLDADA DE CONCRETO



**Bate-Estacas de Rolos
Martelo Queda-Livre**

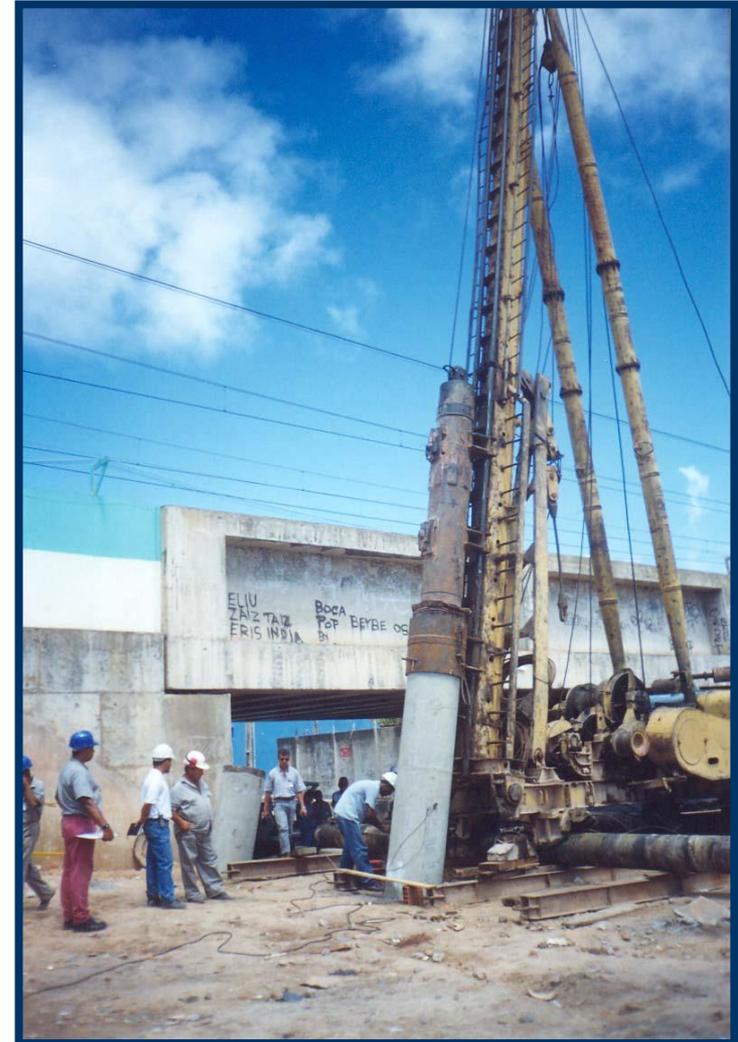


**Bate-Estacas em Flutuante
Com Martelo Diesel**

CRAVAÇÃO ESTACAS INCLINADAS PREMOLDADAS DE CONCRETO



Martelo Queda - Livre

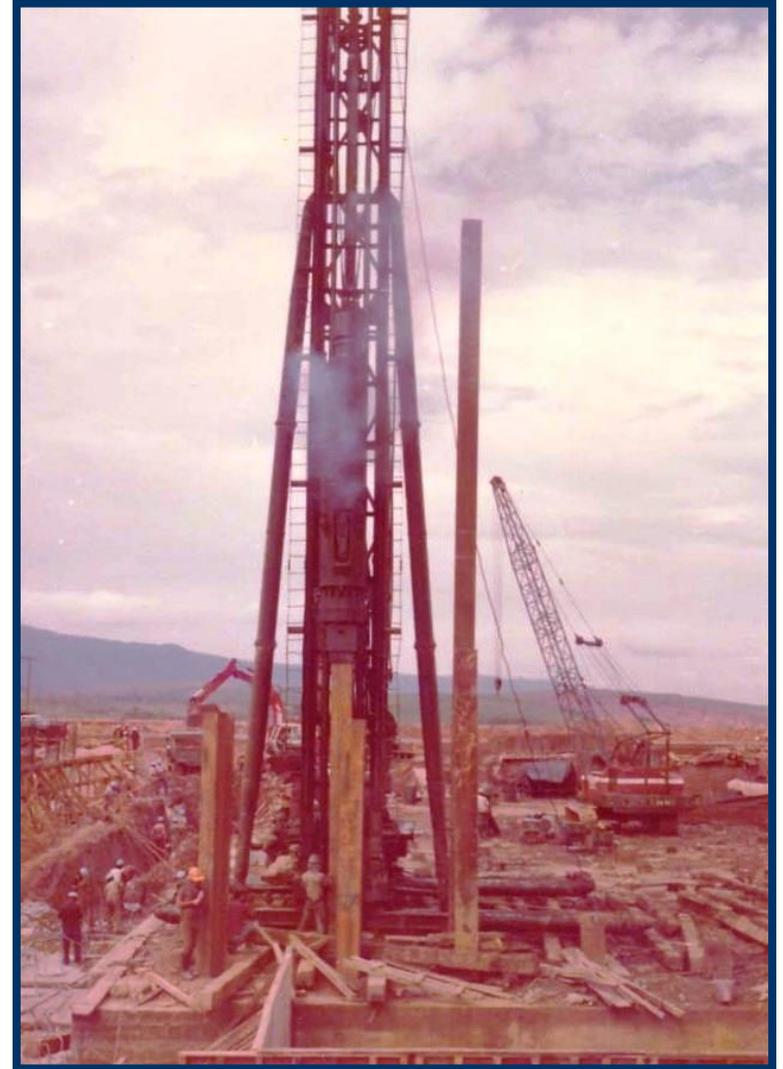


Martelo Diesel

MARTELO QUEDA LIVRE – ESTACA METÁLICA PERFIL H



CRAVAÇÃO MARTELO KOBE – K45



GEOMECC

Estaca Metálica Perfil H



MARTELOS HIDRÁULICOS

MARTELO BAUER - FAMBO - CZM





GEOMECH

MARTELOS JUNTAN



ESTACA TUBULAR DE AÇO



Martelo Hidráulico Sistema de “Jaqueta”

Painel de Controle Externo





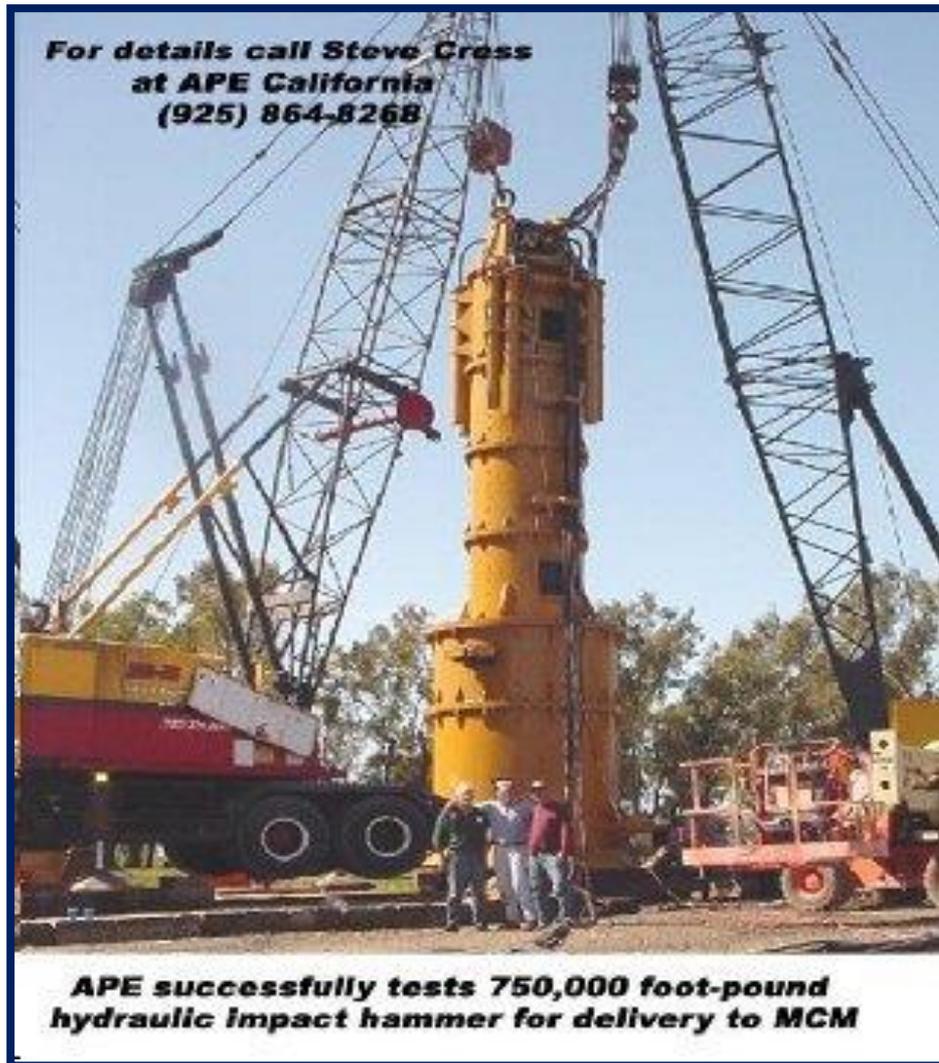
Junttan – PM 20
Martelo Hidráulico – Junttan – HK5S
Piston: 5t.
H_q: 10cm a 150cm
Frequência cravação: 90 a 100 golpes/minuto

GEOMECC

MARTELO CMV BRASIL - BANUT



MARTELO HIDRÁULICO – APE 750



TAMPA - FLÓRIDA - EUA

GEOMECC Fonte: GRL



APE 750 – PISTON: 53,4 ton – H_q : 2m
ENERGIA POTENCIAL: 1017KJ



Hydraulic Hammer for horizontal driving of a 3m diameter, 100m long pipe as a tunnel under a road and railroad track in Tampa - FL-EUA.

Martelo Hidráulico IHC-S1800

CARACTERÍSTICAS DE MARTELOS HIDRÁULICOS

MAKER	TYPE	MASS OF RAM (Kg)	MAXIMUM ENERGY PER BLOW (KJ)	STRIKING RATE AT MAXIMUM STROKE HEIGHT (BLOWS/MIN)
Banut SuperRAM Germany) CMV Brasil	3000	3000	35	100
	4000	4110	47	100
	5000	5060	58	100
	6000	6075	70	100
	6000XL	6110	82	100
	8000XL	8010	109	100
	10000XL	10020	117	100
	12000XL	12025	141	100
Dieseko PVE (Netherlands and USA)	3L	3050	36	45
	4L	4060	48	42
	5L	5080	60	40
	7L	7110	84	40
	10L	10160	120	40
	13L	13210	156	35
	16	16260	192	35
	20	20320	240	32
ICE (Netherlands and USA)	75	3401	41	48
	115	5215	62	45
	160	7256	87	45
	220	9977	119	45
	275	12471	149	45

CARACTERÍSTICAS DE MARTELOS HIDRÁULICOS

MAKER	TYPE	MASS OF RAM (Kg)	MAXIMUM ENERGY PER BLOW (KJ)	STRIKING RATE AT MAXIMUM STROKE HEIGHT (BLOWS/MIN)
American Piledriving Equipment (APE) ^a (USA)	13	3629	38	40-100
	14	4990	45	40-80
	H-5.4MT	5445	34	40-75
	H-7.2MT	7350	68	40-75
	225U	36287	305	30-60
	400U	36287	488	30-72
	750U	54431	847	20-40
BSP International Foundations Limited (UK)	CX40	3000	40	45-100
	CX50	4000	51	45-100
	CX85	7000	83	40-100
	CX110	9000	106	36-100
	CG180	12000	180	34-100
	CG210	14000	210	32-100
	CG240	16000	240	31-100
	CG270	18000	270	31-100
	CG300	20000	300	29-100
CZM - Bauer – Fambo	HR5000	5000	58,8	0-100
	HR7000	7000	84,2	0-100
	HR8000	8000	94,2	0-100
	HR10000	10000	117	0-100

CARACTERÍSTICAS DE MARTELOS HIDRÁULICOS

MAKER	TYPE	MASS OF RAM (Kg)	MAXIMUM ENERGY PER BLOW (KJ)	STRIKING RATE AT MAXIMUM STROKE HEIGHT (BLOWS/MIN)
Junttan ^c (Finland)	HHK 4AL	4000	31	40-100
	HHK 5AL	5000	39	40-100
	HHK 5A	5000	59	40-100
	HHK 7A	7000	82	40-100
	HHK 9A	9000	106	40-100
	HHK 12A	12000	141	40-100
	HHK 14A	14000	164	40-100
	HHK 18A	18000	212	40-100
	HHK 5S	5000	74	30-100
	HHK 9S	9000	132	30-100
	HHK 14S	14000	206	30-100
	HHK 18S	18000	265	30-100
	HHK 25S	20000	294	30-100
	MENCK (Germany)	MHF3-4	4000	40
MHF3-5		5000	50	50
MHF3-6		6000	60	45
MHF3-7		7000	70	45
MHF5-8		8000	80	45
MHF5-10		10000	100	40
MHF5-12		12000	120	40
MHF10-15		15000	150	45
MHF10-20		20000	200	40

CARACTERÍSTICAS DE MARTELOS HIDRÁULICOS

MAKER	TYPE	MASS OF RAM (Kg)	MAXIMUM ENERGY PER BLOW (KJ)	STRIKING RATE AT MAXIMUM STROKE HEIGHT (BLOWS/MIN)
IHC Hydrohammer (Netherlands)	S30	1625	30	65
	S35	3048	35	60
	S70	3556	70	50
	S90	4572	90	50
	S150	7620	150	44
	S200	10160	200	45
	S280	13818	280	45
	S500	25400	500	45
	S600	30480	600	36
	S900	45720	900	30
	S1200	60960	1200	30
	S1800	76200	1800	30
	S2300	116840	2300	30
	SC50 _b	3353	50	50
	SC75 _b	5791	75	50
	SC110 _b		110	40
	SC150 _b	11176	150	40
	SC200 _b	13818	200	40

a Free-fall hammer (many hammers now have assisted acceleration).

b SC series more suited to driving concrete piles.

c AL series hammers: 0.8m stroke, A hammers: 1.2m stroke, S hammers: 1.5m stroke.

MARTELO PNEUMÁTICO AR COMPRIMIDO

PORTO DE SUAPE PERNAMBUCO



ESTACAS PREMOLDADAS DE CONCRETO PROTENDIDAS

De = 80 cm

ELEMENTO MONOLÍTICO: 45 METROS

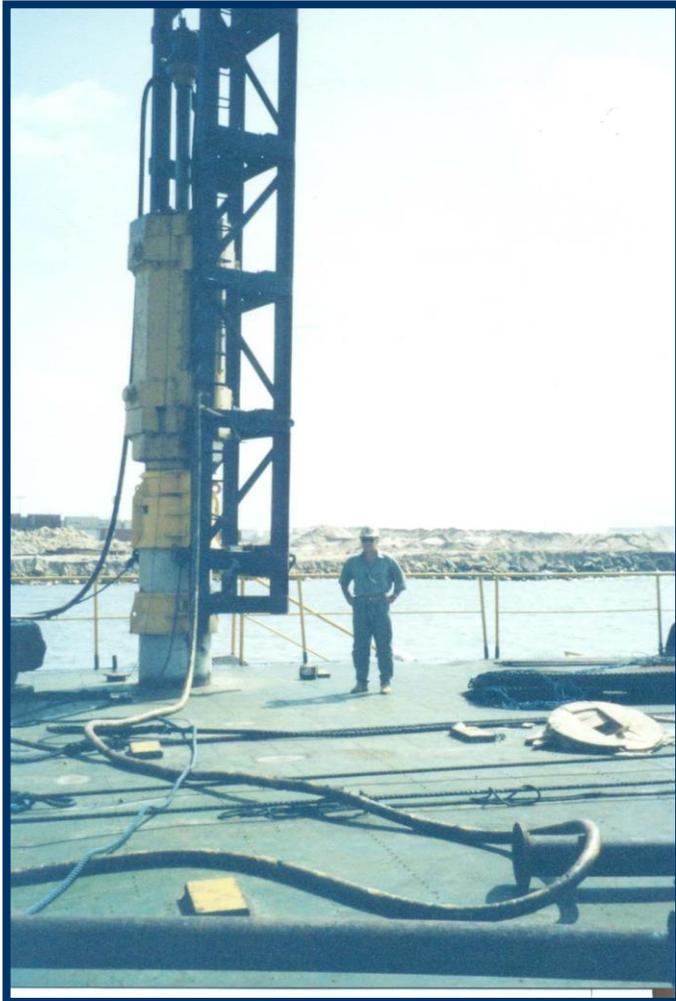
Di = 50 cm

Nt:270 Tf

Fck:30 Mpa



MARTELO BSP- 30
FONTE DE ENERGIA AR COMPRIMIDO
(2X 750 P.C.M.) PISTÃO: 15Tf
 H_q : 1,30 M

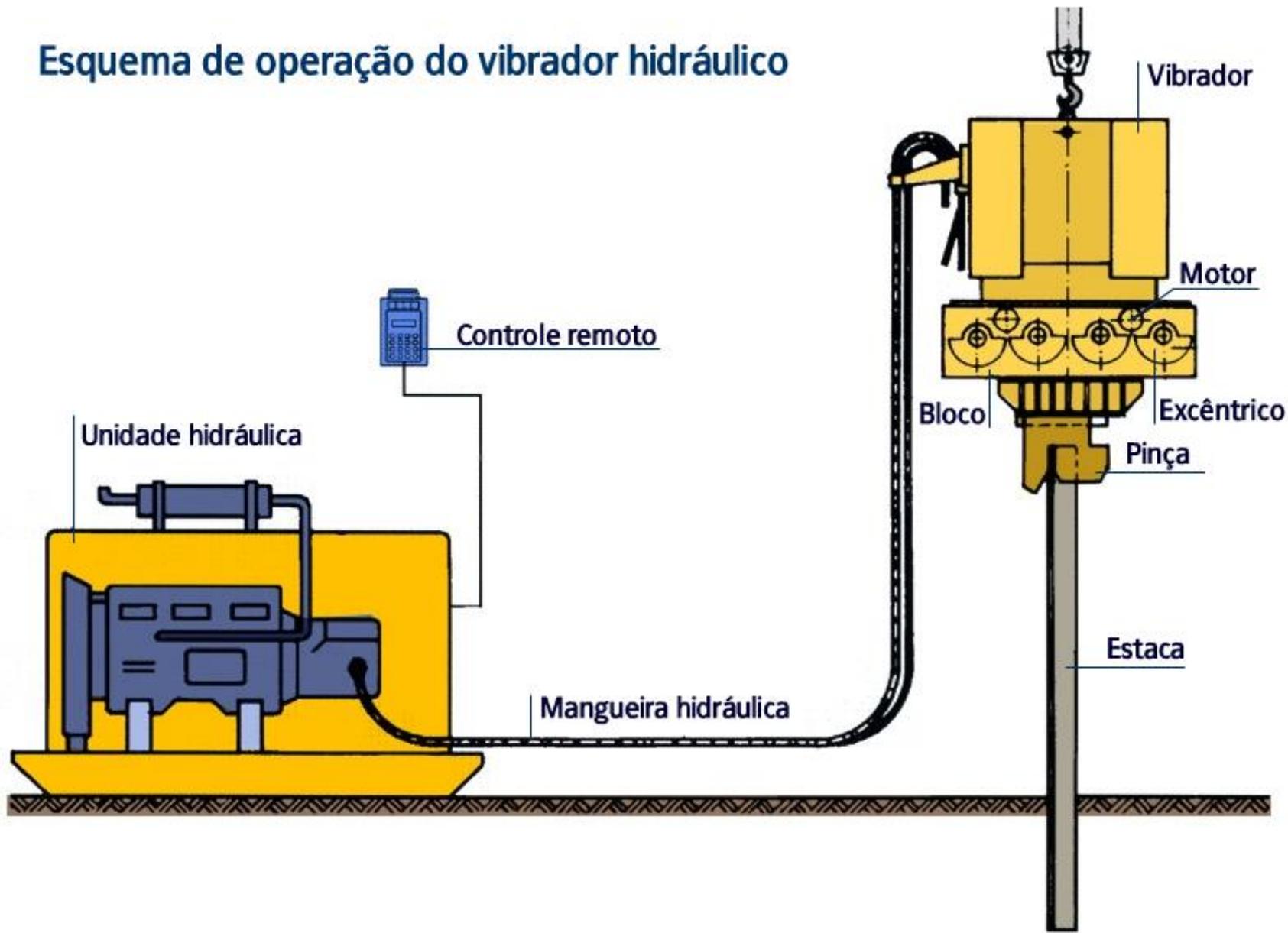


MARTELOS VIBRATÓRIOS

MARTELOS VIBRATÓRIOS



Esquema de operação do vibrador hidráulico





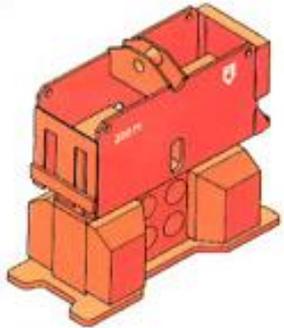
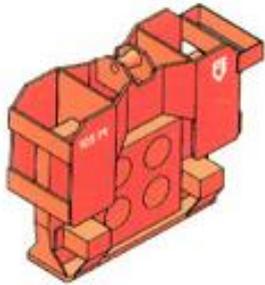


GEOMECC



GEOMECCO



		200 M	105 M
			
Eccentric moment	Kgm	200	105
Frequency	rpm	1400	1350
Centrifugal force	kN	4400	2150
Line pull capacity	kN	1800	800/1200
Total weight	Kg	29000	12000/13500
Vibrating weight	Kg	19000	7000
Amplitude	mm	31	30
LxWxH	mm	3000 x 1600 x 3350	3230 x 1175 x 2500 / 3000

THE 9th INTERNATIONAL CONFERENCE ON TESTING AND DESIGN METHODS FOR DEEP FOUNDATIONS

18 – 20 September, 2012, Kanazawa, Japan

OBRA: The Hong Kong – Zhuhai – Macau

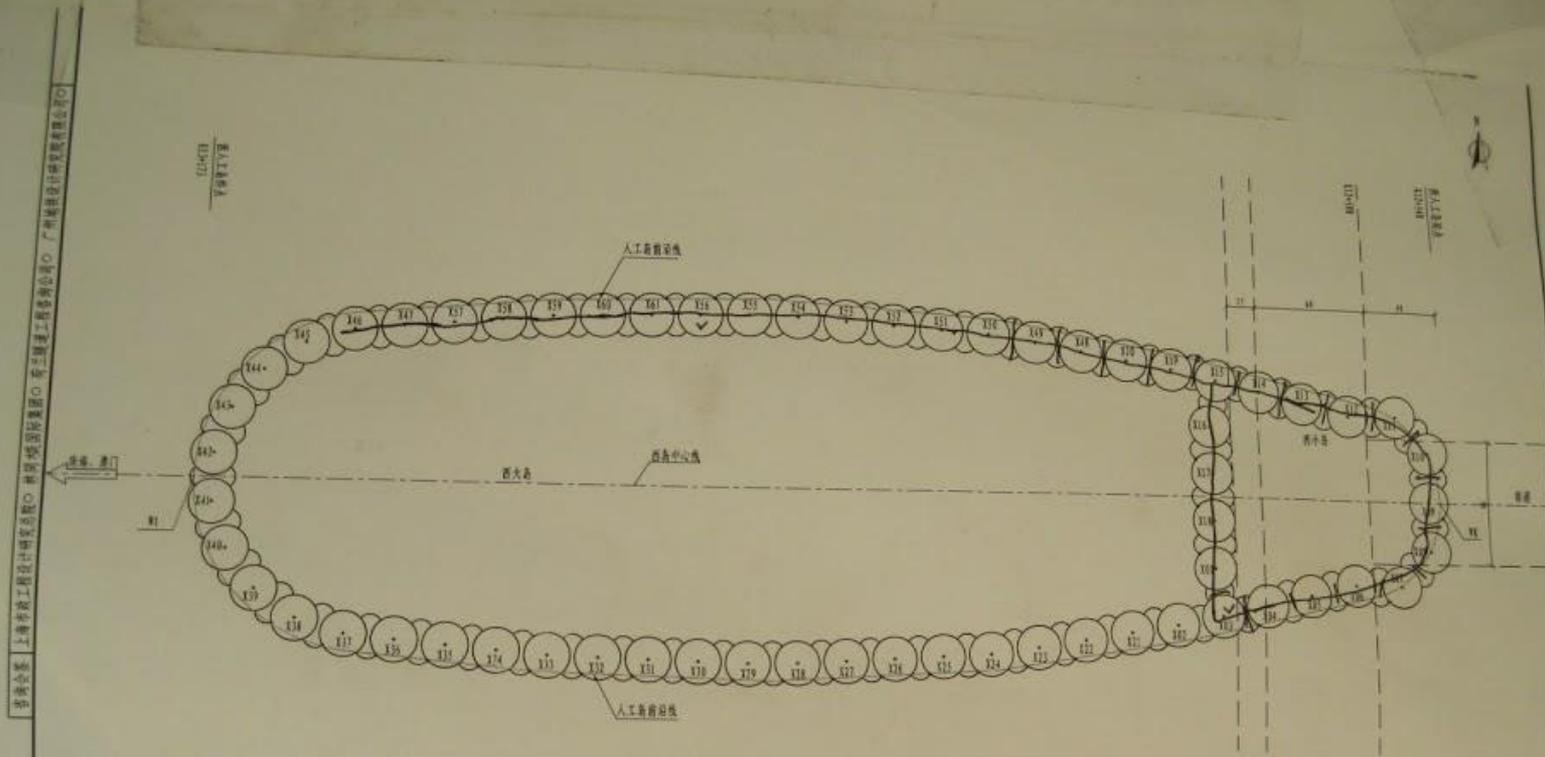
LOCAL: China – Macau

PECULARIEDADE: Construção de duas ilhas artificiais circulares, materializadas cada uma com 60 células, sendo que cada célula constitui-se de estaca tubular de aço, diâmetro de 22 metros, espessura de 1” com sistemas tubulares de aço internos de enrijecimento, 42 a 49 metros de comprimento e peso da ordem de 600 toneladas.

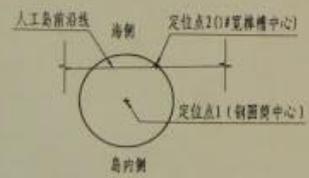
GEOTECNIA: 25 metros cravados em solo na litologia de argila siltosa – argila – areia, com índice SPT variando de 8 a 40 (south china sea).

及 X60 号钢圆筒。

...号钢圆筒振沉至 X61 号钢圆筒, 合拢口设在北侧中部的 X59



西岛钢圆筒平面布置图(一) 比例 1:2000



钢圆筒定位点示意图 比例 1:1000

- 注
1. 本图尺寸均以 ϕ 为单单位, 标高以 m 为单单位;
 2. 本图高程系采用1985国家高程基准;
 3. 本图坐标系为修建工程坐标系, 具体详见施工设计说明;
 4. 钢圆筒直径22.0m, 筒间距净距2.0m;
 5. 西人工岛共61个圆筒, 其中西小岛17个;

中交公路规划设计院有限公司 © COWI 科威国际咨询有限公司 上海市隧道工程轨道交通设计研究院 © 中交第四航务工程勘察设计有限公司	港珠澳大桥主体工程 岛隧工程施工图设计	西岛钢圆筒平面布置图(一)	设计: 何红云 复核: 何红云 一审: 何红云 二审: 何红云 三审: 何红云	图号: ED04P01A1/01 7A/05/1001
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GEOMECC

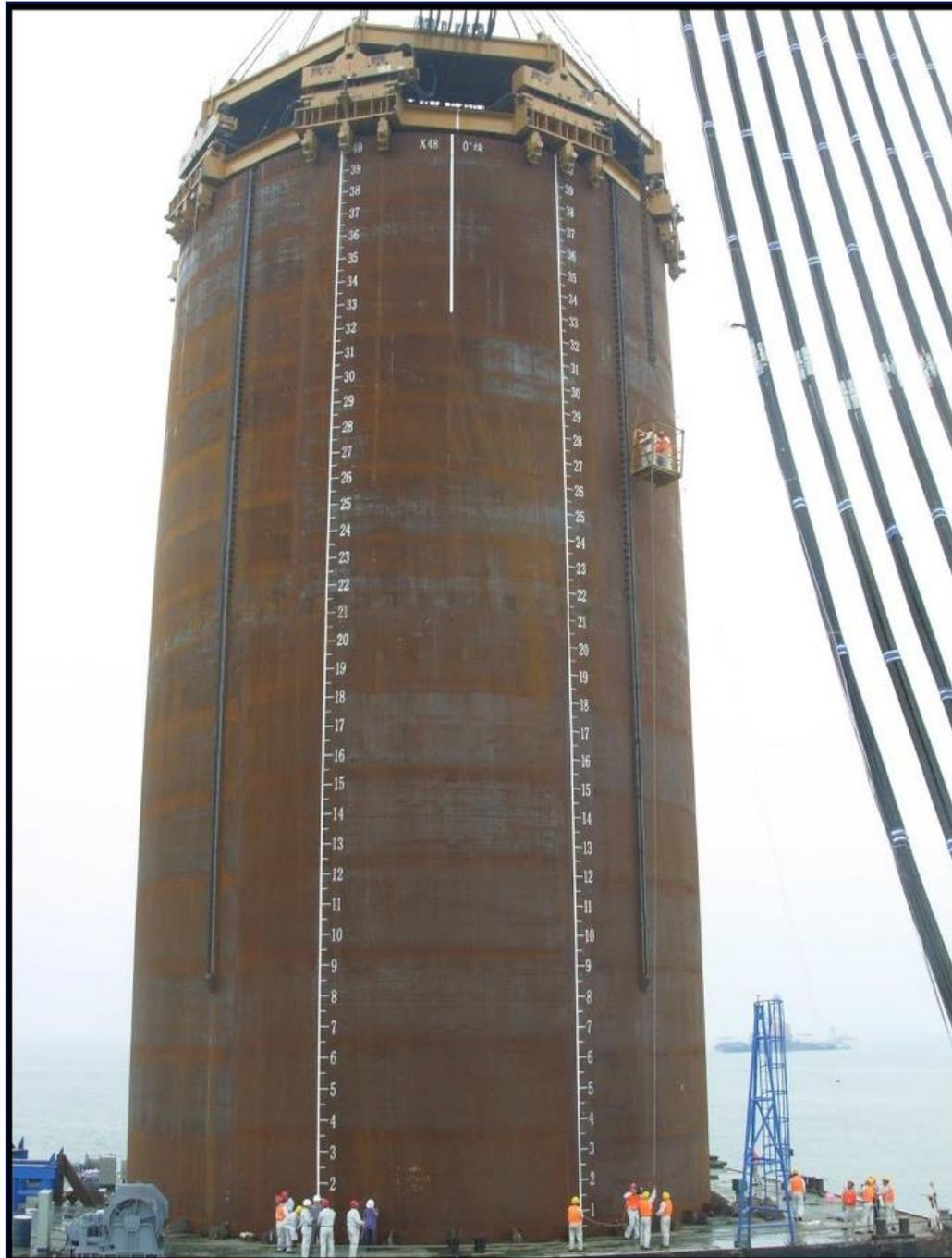
**SISTEMA DE CRAVAÇÃO: “OCTAKONG” HAMMER
(Oito martelos vibratórios acoplados em série)**

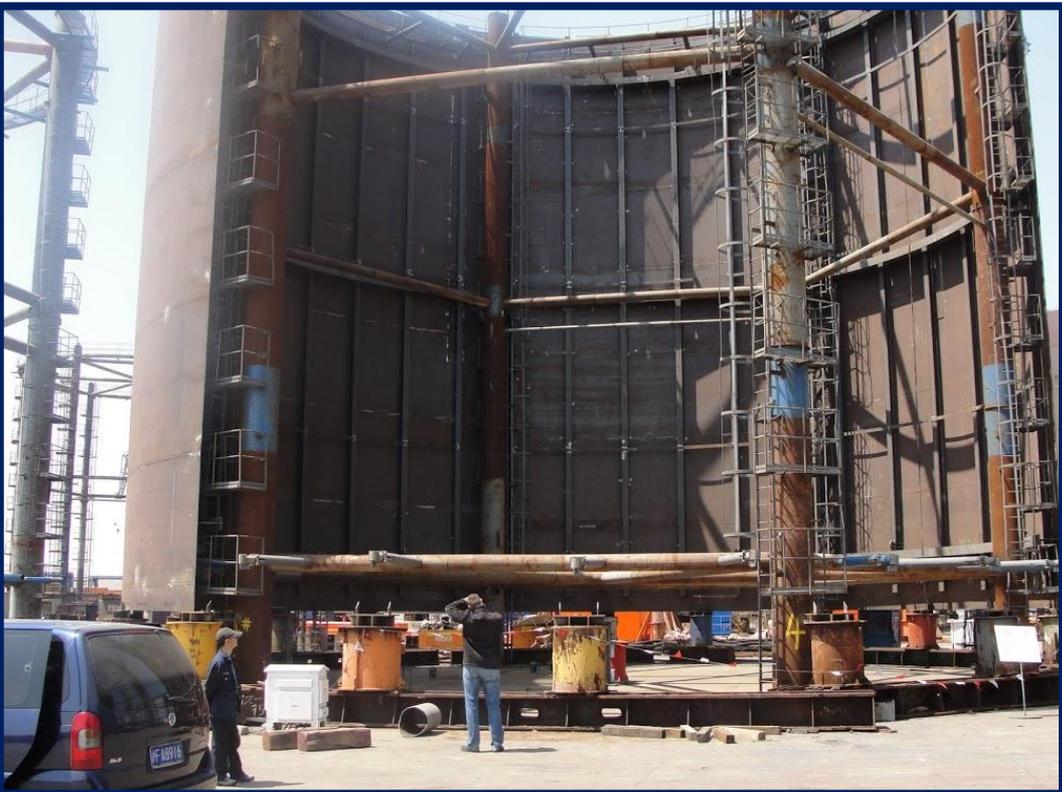
FABRICANTE: APE (AMERICAN PILEDIVING EQUIPMENT)

DESEMPENHO NA CRAVAÇÃO: 25 metros em 7½ minutos

MÁXIMAS PRODUTIVIDADES: 3 estacas/dia; 7 estacas/3 dias

120 ESTACAS: 15/05/2011 a 08/12/2011 – MÉDIA: 1,75 estacas/dia





GEOMECC

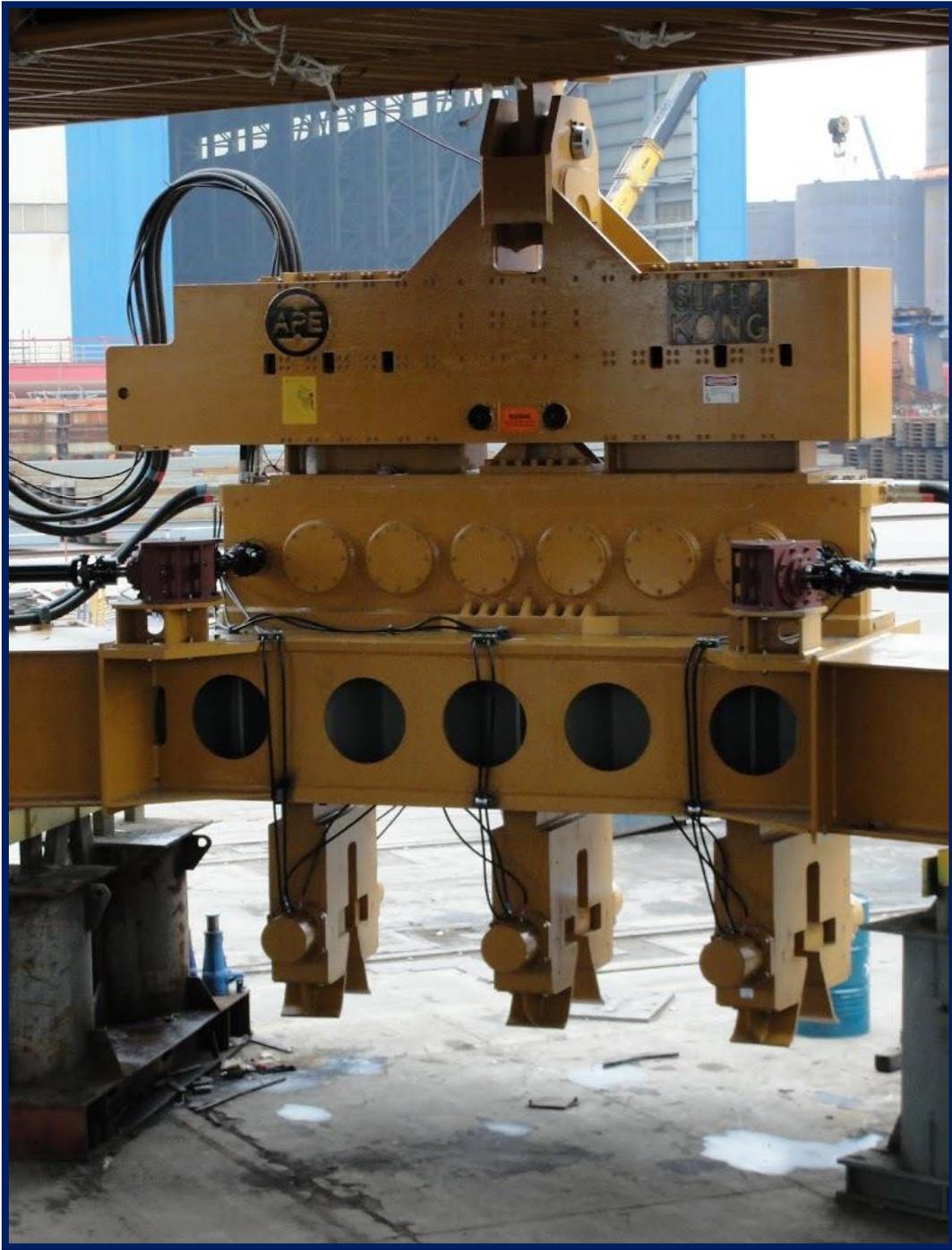


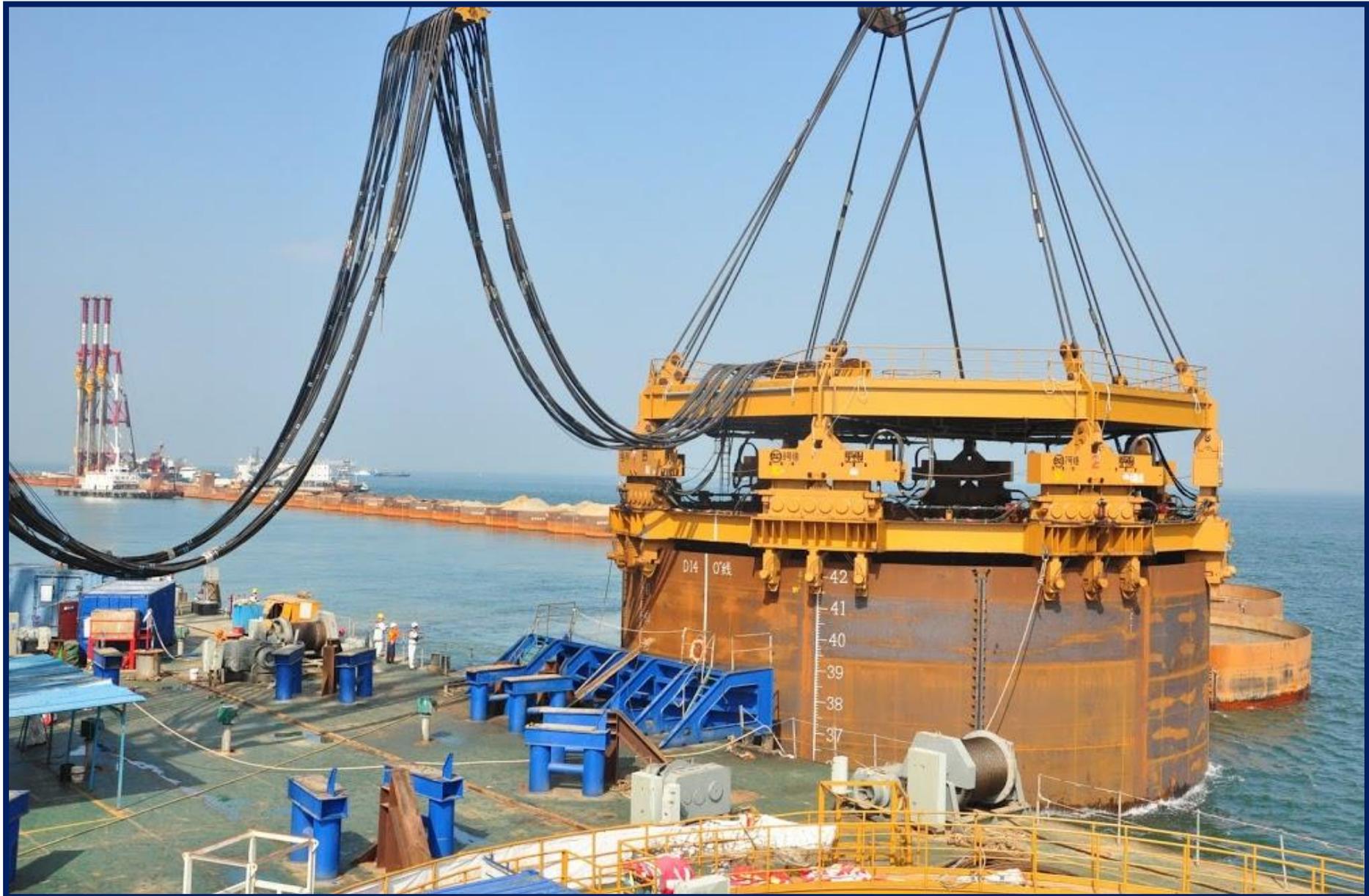


HAMMER WEIGHT: 550 US TONS
DRIVE FORCE: 4,450 US TONS
HORSE POWER: 9,600 HP

PILE DIAMETER: 72 FT
PILE WEIGHT: 500 US TONS
PILE HEIGHT: 131 FT

Octakong in Macau









CONCEITOS DE ENERGIA

CONCEITOS DE ENERGIA CONDIÇÃO IDEAL

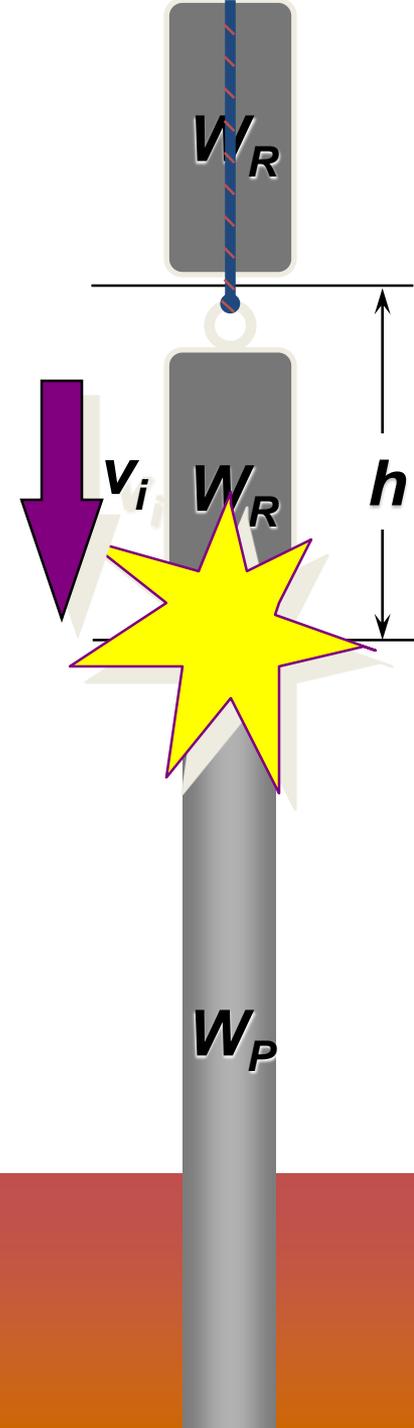
$$E_P = W_R h \text{ (potencial)}$$

$$E_K = \frac{1}{2} m_R v_i^2 \text{ (cinética)}$$

$$m_R = W_R / g$$

$$E_P = E_K$$

$$v_i = \sqrt{2g h}$$



CONCEITOS DE ENERGIA REALISTA

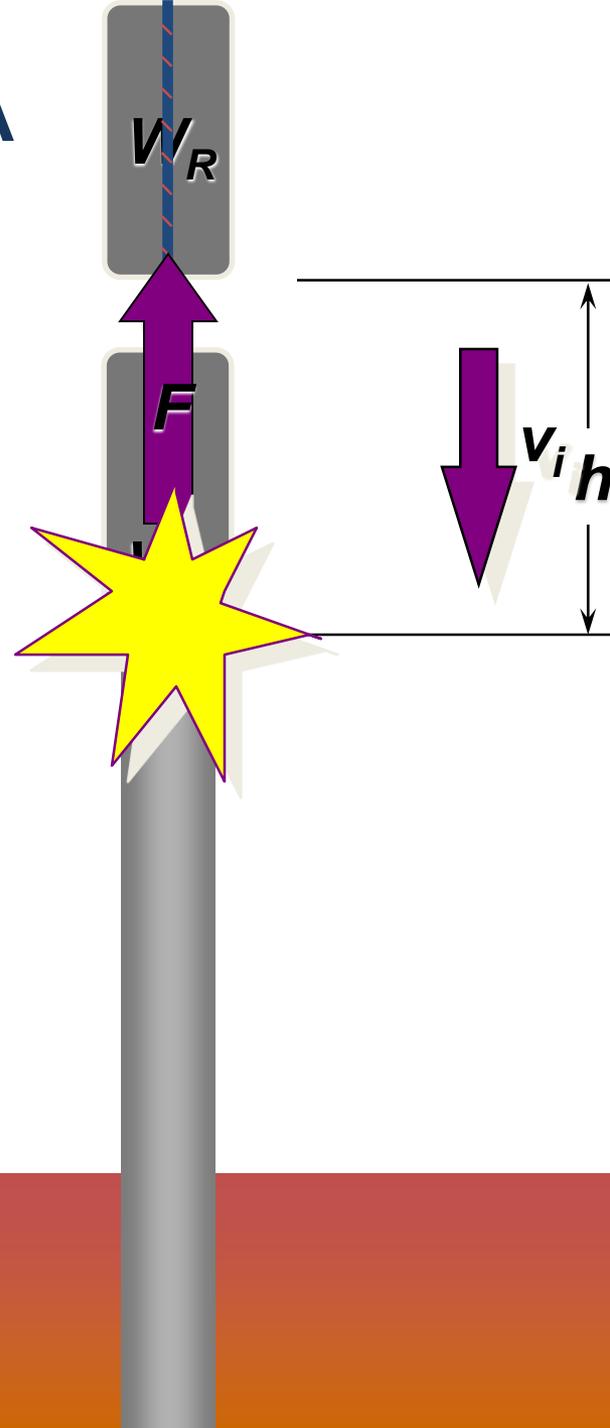
$$E_P = W_R h - F h$$
$$= \eta W_R h$$

η Fator de Eficiência
 F Forças de Atrito

$$E_K = \frac{1}{2} m_R v_i^2 \text{ (Cinética)}$$

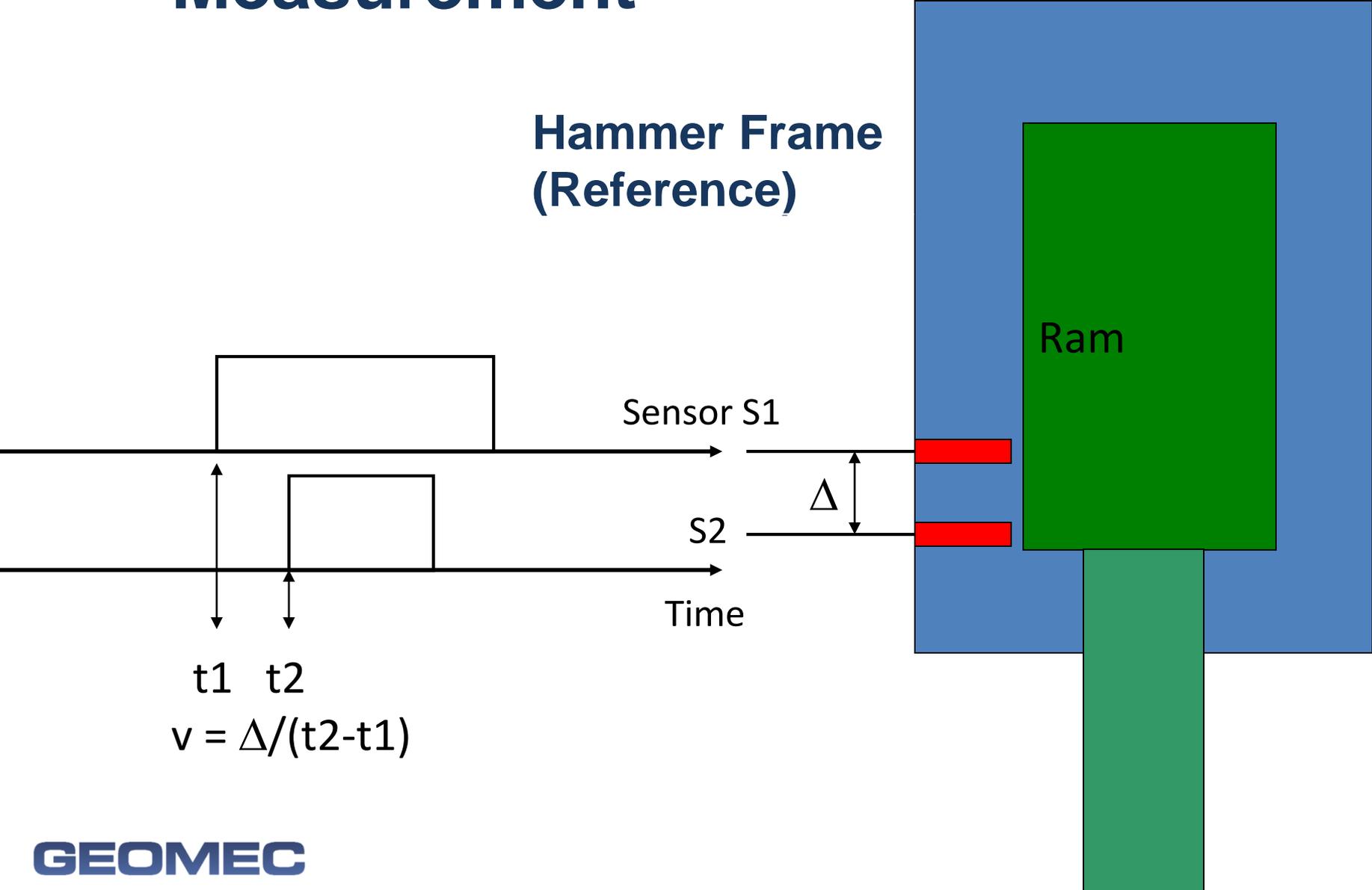
$$E_P = E_K$$

$$v_i = \sqrt{2g\eta h} \text{ (reduzido)}$$



Hammer Performance Measurement

Hammer Frame
(Reference)



SISTEMA DE MEDIÇÃO DE ENERGIA CINÉTICA BAUER - FAMBO



SISTEMA DE MEDIÇÃO DE ENERGIA CINÉTICA



ENERGIA TRANSFERIDA

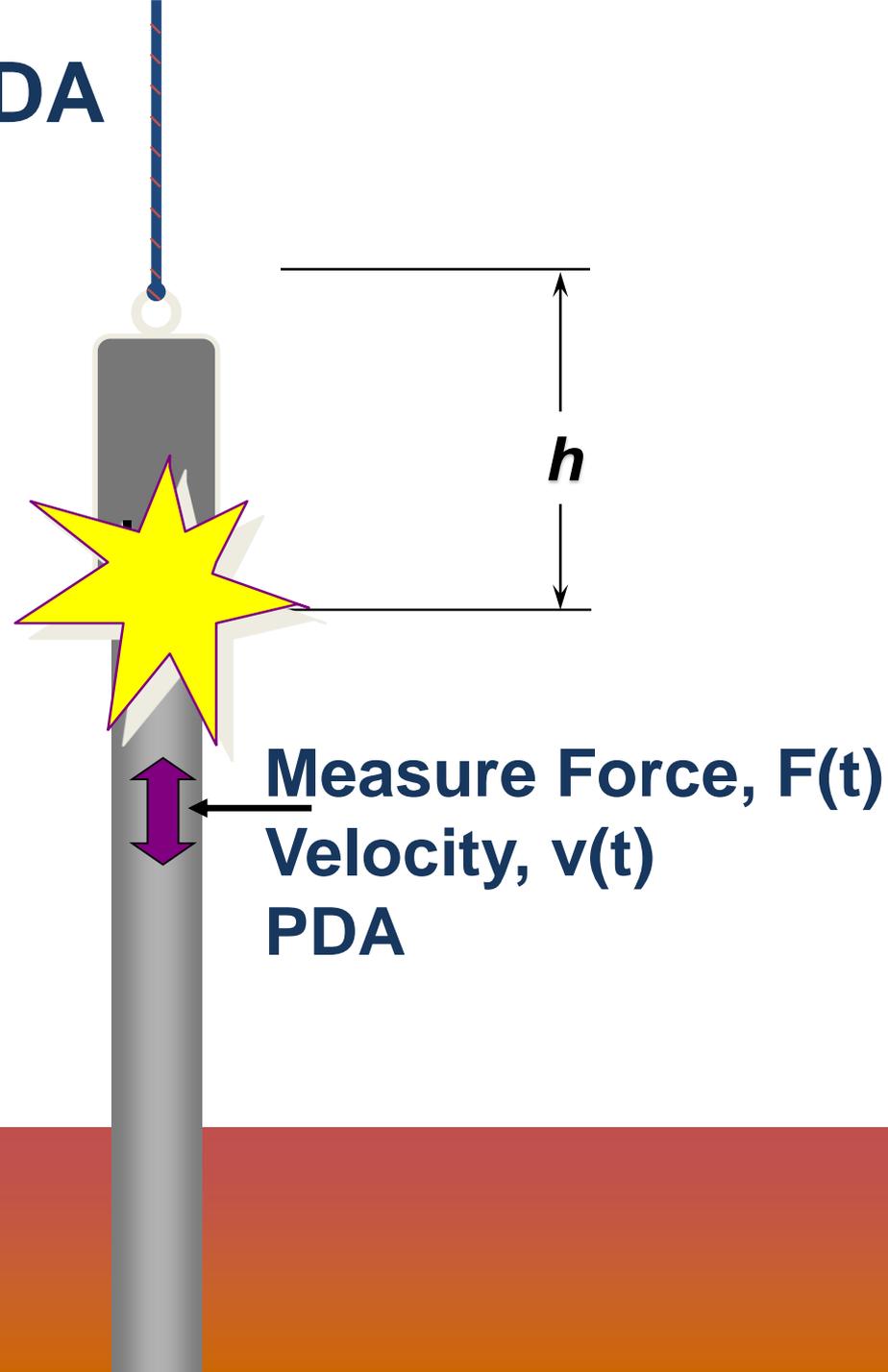
$$E_R = W_R h$$

Manufacturer's Rating

$$\text{Max } E_T = \int F(t) v(t) dt$$

(EMX or ENTHRU)

$$e_T = ENTHRU / E_R \text{ (transfer efficiency, ratio)}$$



PERDAS DE ENERGIA

- ATRITO MARTELO
- ALTURA DE QUEDA INSUFICIENTE
- PRECOMPRESSÃO NO MARTELO DIESEL
- ALINHAMENTO MARTELO-ESTACA
- AMORTECIMENTO CEPO – CAPACETE - COXIM
- DESNÍVEL DO TOPO DA ESTACA
- FOLGA CAPACETE
- RIGIDEZ DA ESTACA
- ESTACAS INCLINADAS
- DISSIPAÇÃO DE ENERGIA CALÓRICA E SONORA
- ETC...



GEOMECC

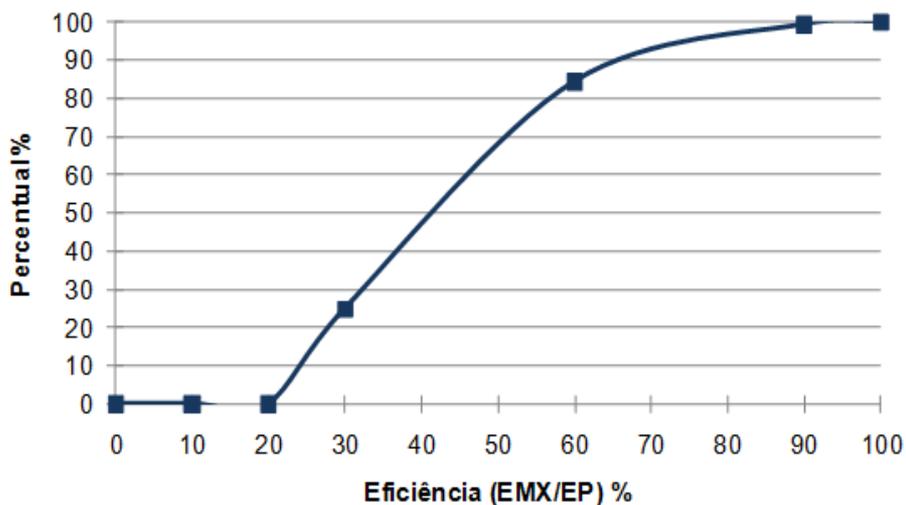
DESEMPENHO DE SISTEMAS DE IMPACTO

MARTELOS:
HIDRÁULICO
DIESEL
PNEUMÁTICO / VAPOR
QUEDA LIVRE

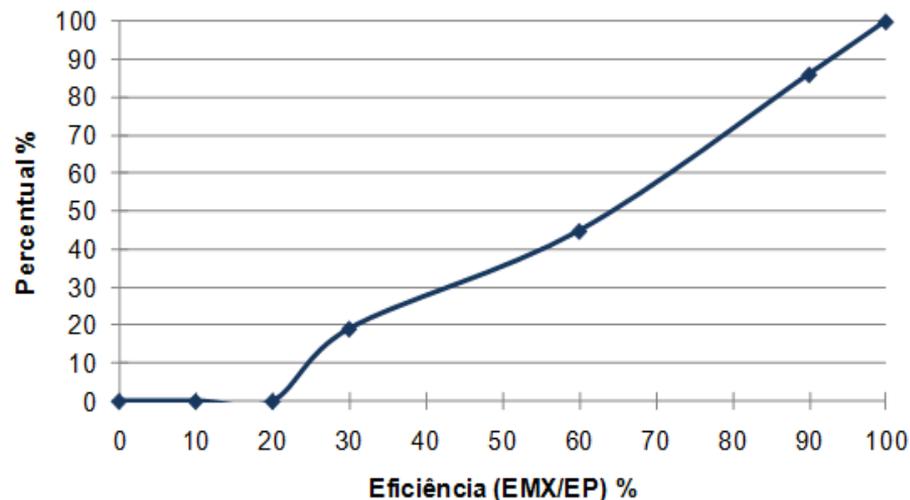
EXPERIÊNCIA BRASILEIRA

Fonte: GEOMECC

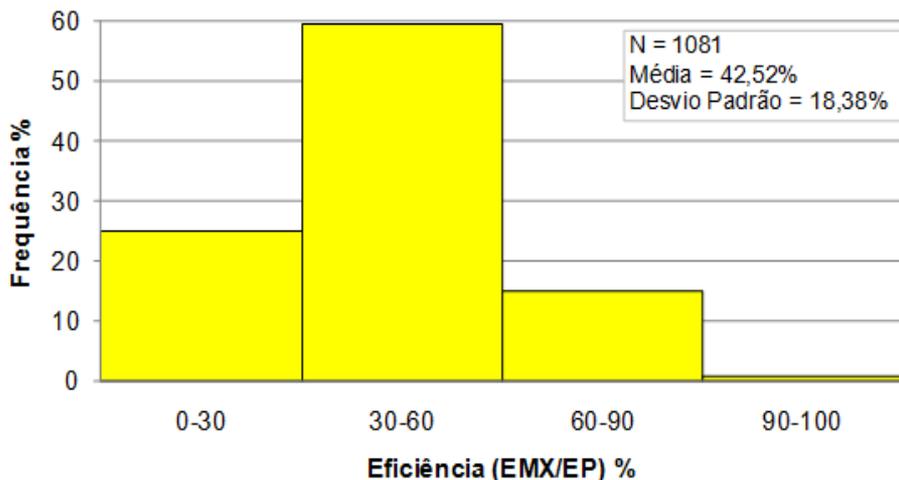
Queda Livre - Premoldada de Concreto



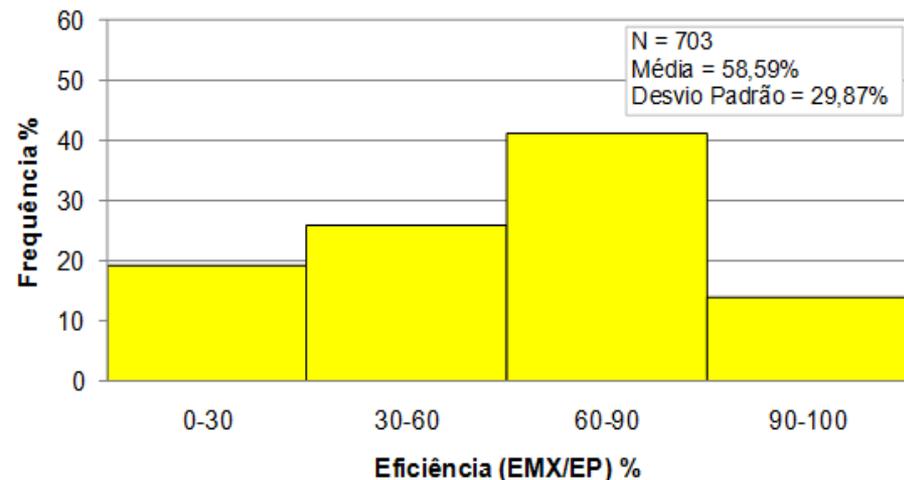
Martelo Hidráulico - Premoldada de Concreto



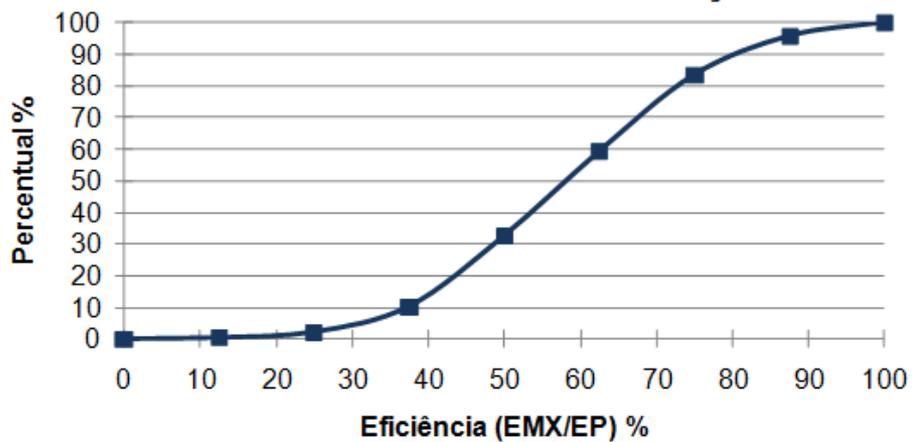
Queda Livre - Premoldada de Concreto



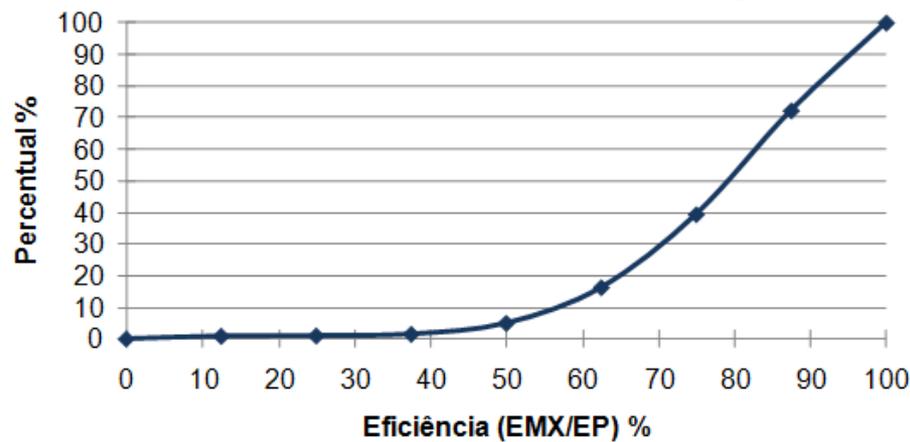
Martelo Hidráulico - Premoldada de Concreto



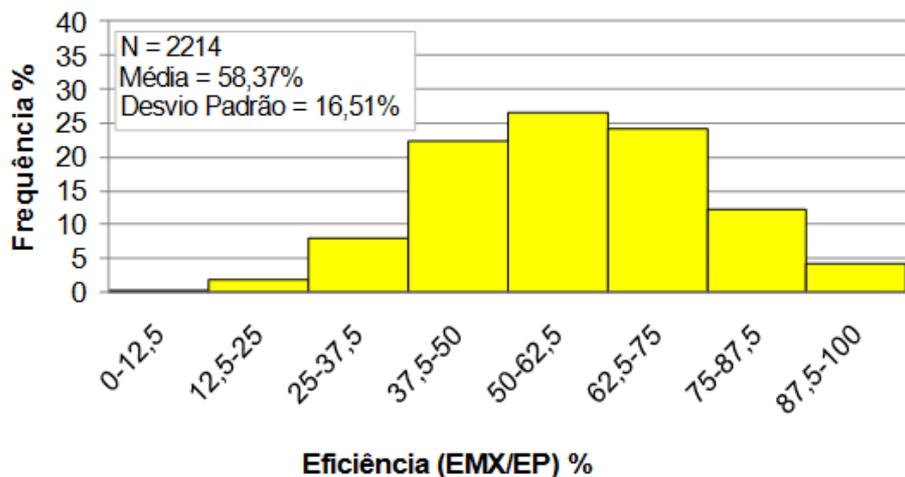
Queda Livre - Estacas de Aço



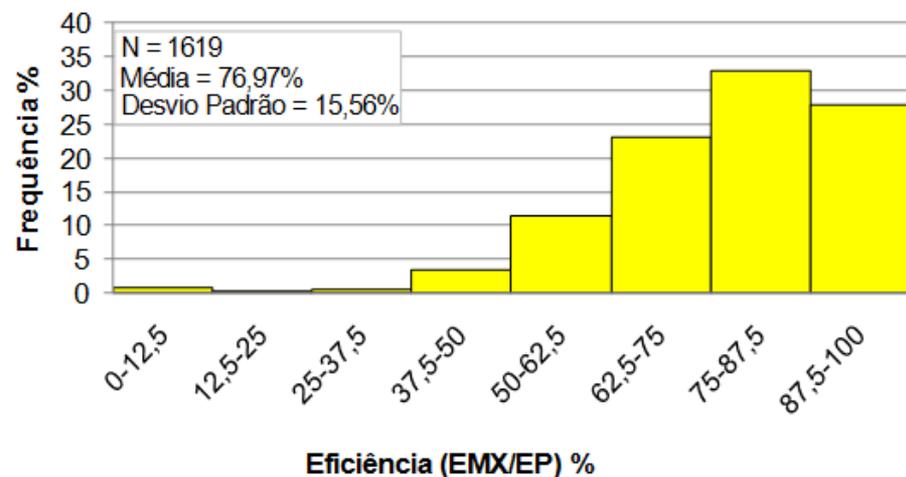
Martelo Hidráulico - Estacas de Aço



Queda Livre - Estacas de Aço

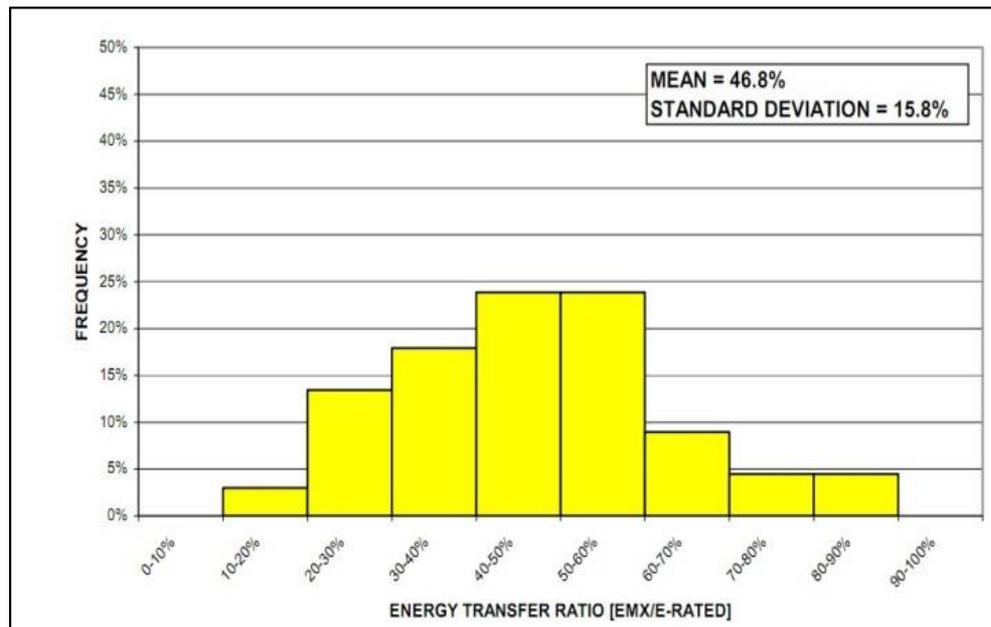
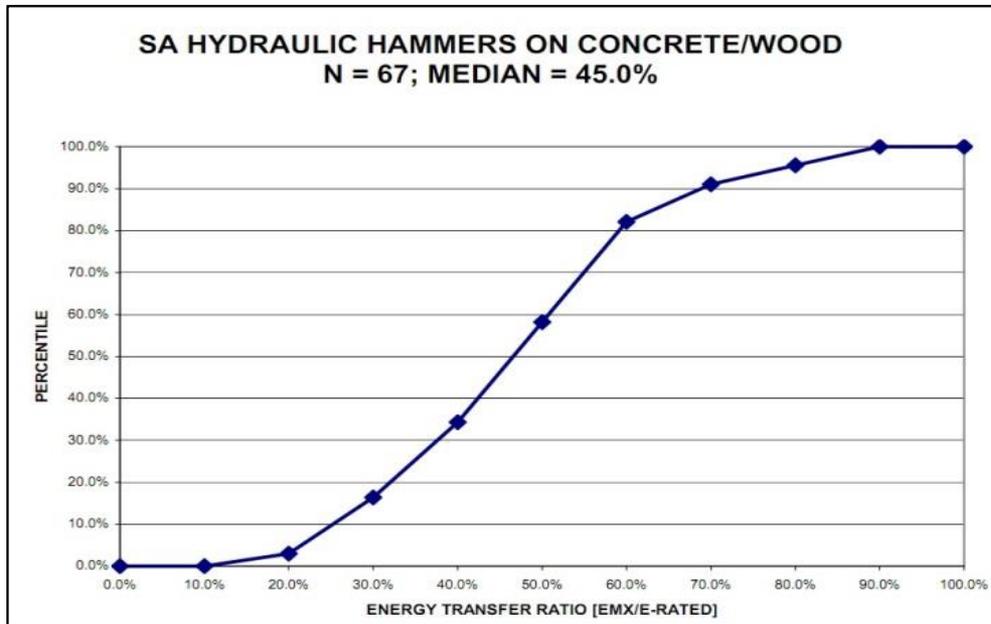


Martelo Hidráulico - Estacas de Aço



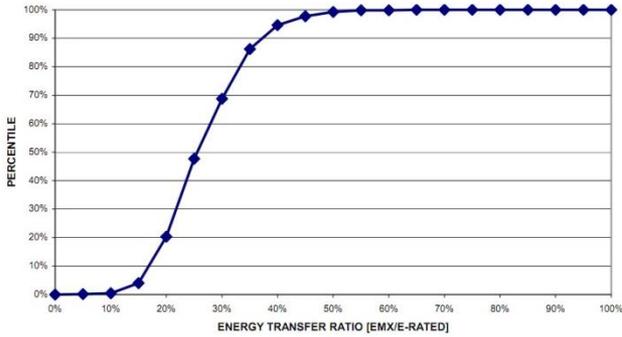
DADOS INTERNACIONAIS

Fonte: GRL Engineers, Inc
(USA)

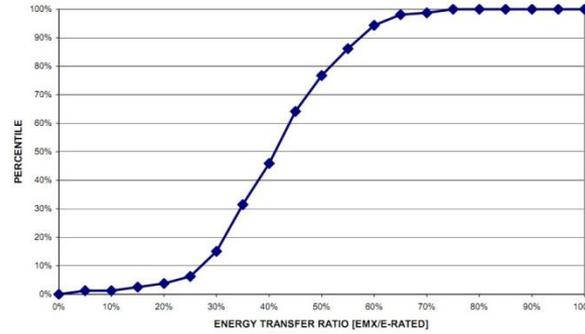


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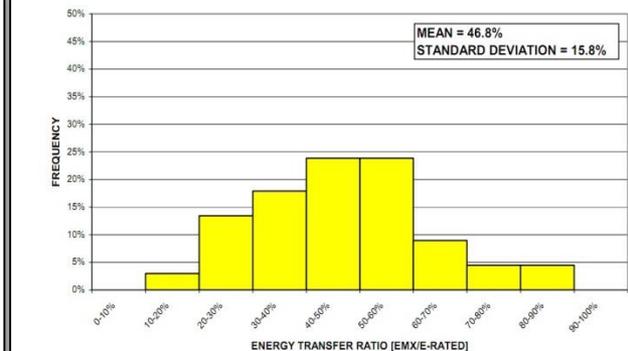
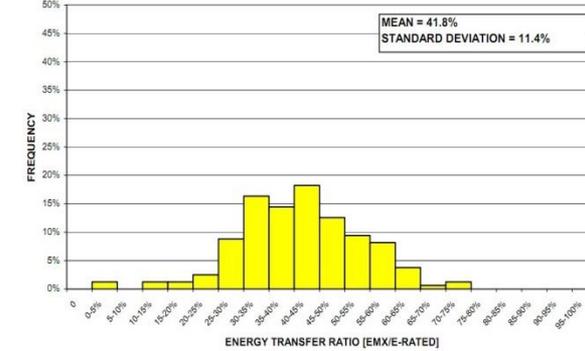
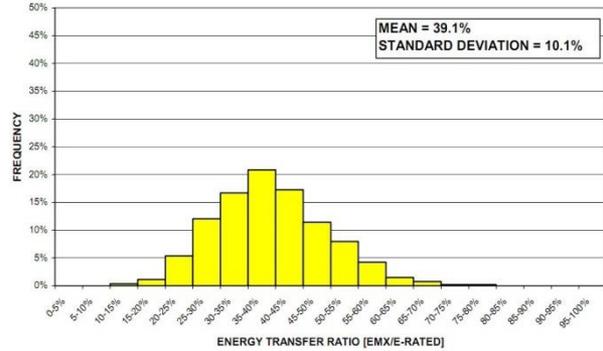
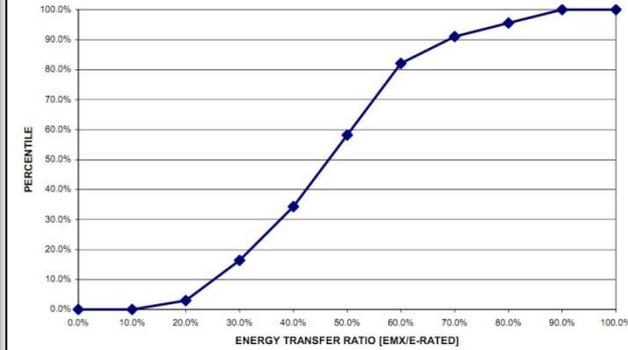
ALL DIESEL HAMMERS ON CONCRETE/WOOD
N = 668; MEDIAN = 25.5%



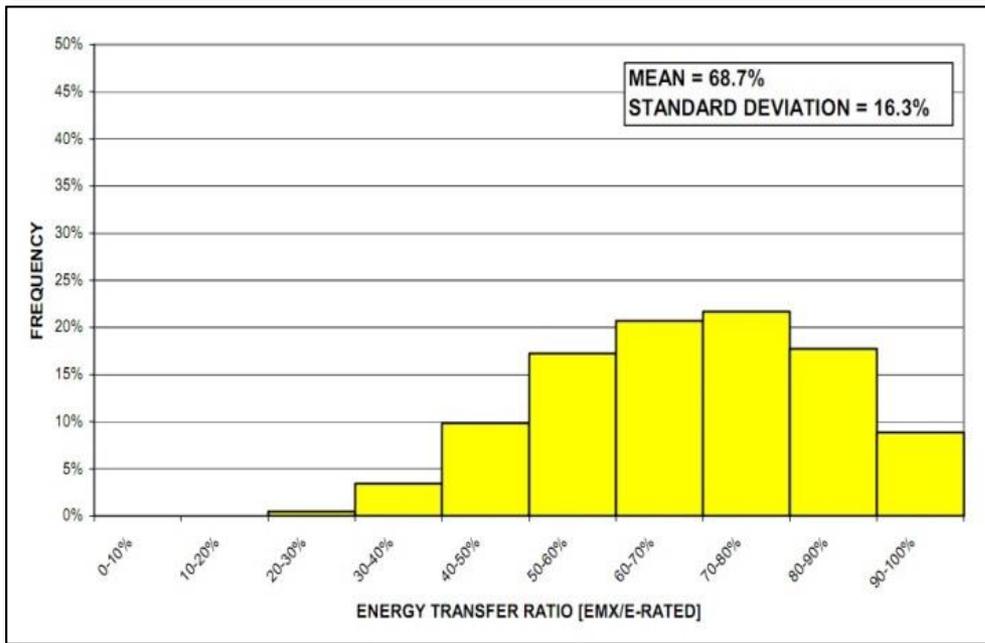
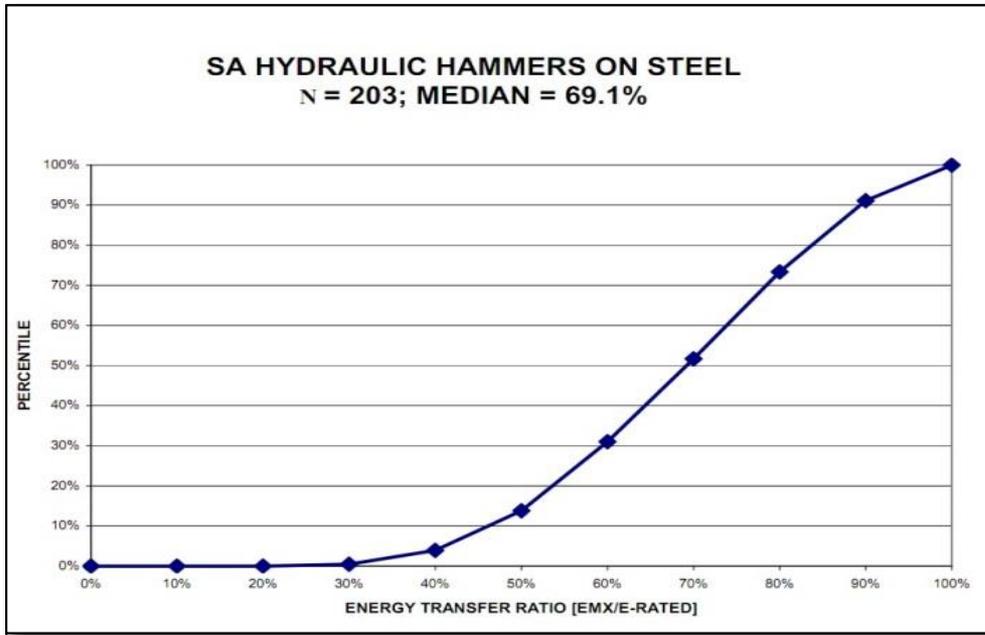
SA AIR/STEAM HAMMERS ON CONCRETE
N = 156; MEDIAN = 41.4%



SA HYDRAULIC HAMMERS ON CONCRETE/WOOD
N = 67; MEDIAN = 45.0%

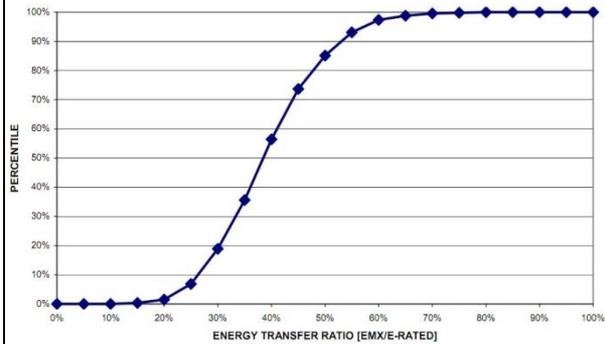


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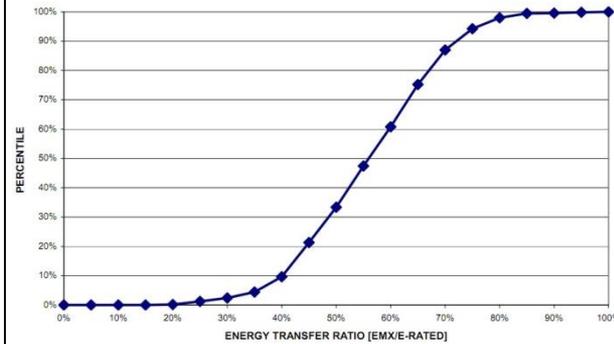


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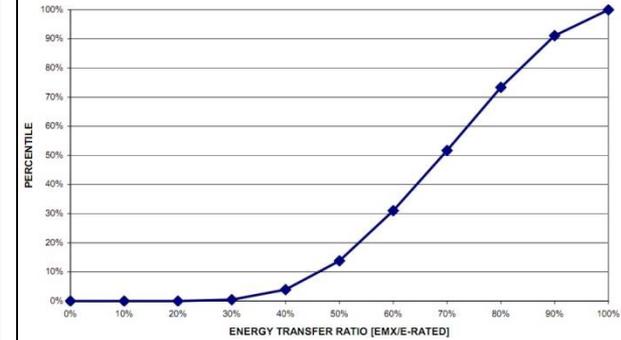
ALL DIESEL HAMMERS ON STEEL
N = 1419; MEDIAN = 38.5%



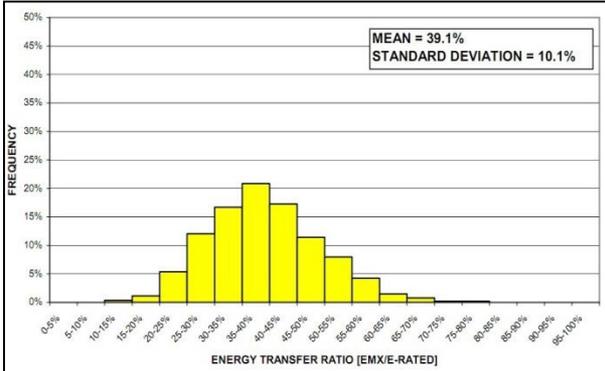
SA AIR/STEAM HAMMERS ON STEEL
N = 747; MEDIAN = 55.9%



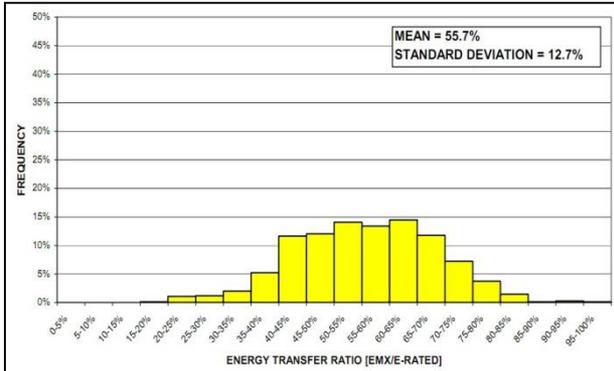
SA HYDRAULIC HAMMERS ON STEEL
N = 203; MEDIAN = 69.1%



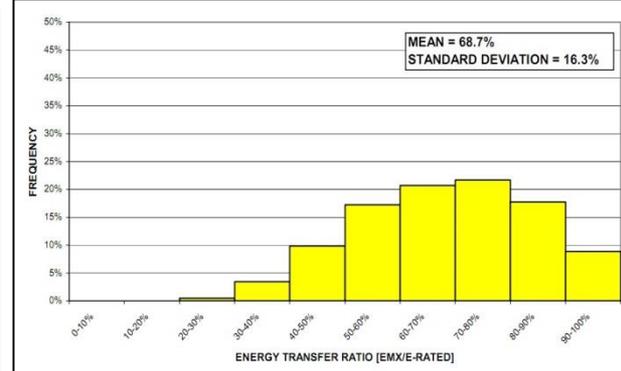
MEAN = 39.1%
STANDARD DEVIATION = 10.1%



MEAN = 55.7%
STANDARD DEVIATION = 12.7%



MEAN = 68.7%
STANDARD DEVIATION = 16.3%



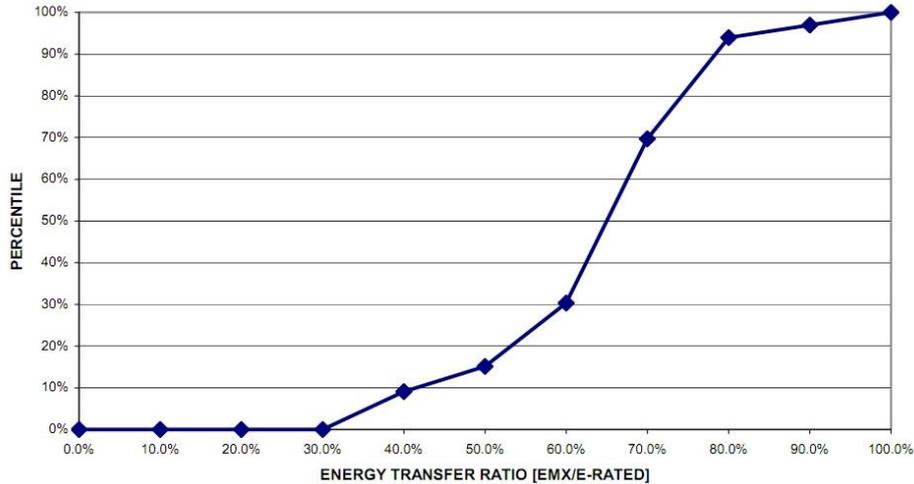
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(Revised 8/09)

OFFSHORE HYDRAULIC HAMMERS ON STEEL

N = 33; MEDIAN = 66.6%

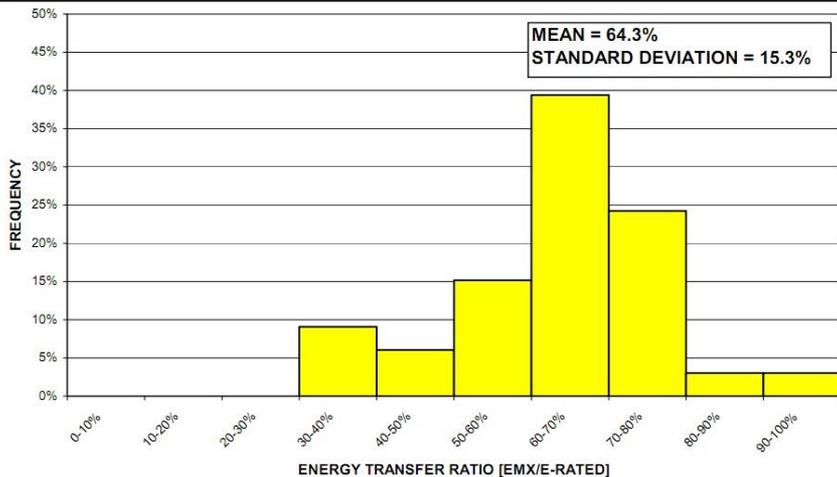


OFFSHORE SA HYDRAULIC HAMMERS ON STEEL

The following is a summary of Single Acting Hydraulic Hammers for offshore projects completed by GRL Engineers, Inc. The hammers were reportedly at reduced energy settings; therefore they were not included in the GRL Hammer Database. This summary should primarily be used to provide insight to the past efficiencies of the offshore projects alone.

All piles were open-ended pipes

Diameter (in)	Thickness (in)	Count
30	1.00	1
36	0.75	1
36	1.75	3
42	1.50	12
42	1.75	3
42	2.00	3
60	2.00	1
66	2.00	6
72	2.00	1
72	2.36	2

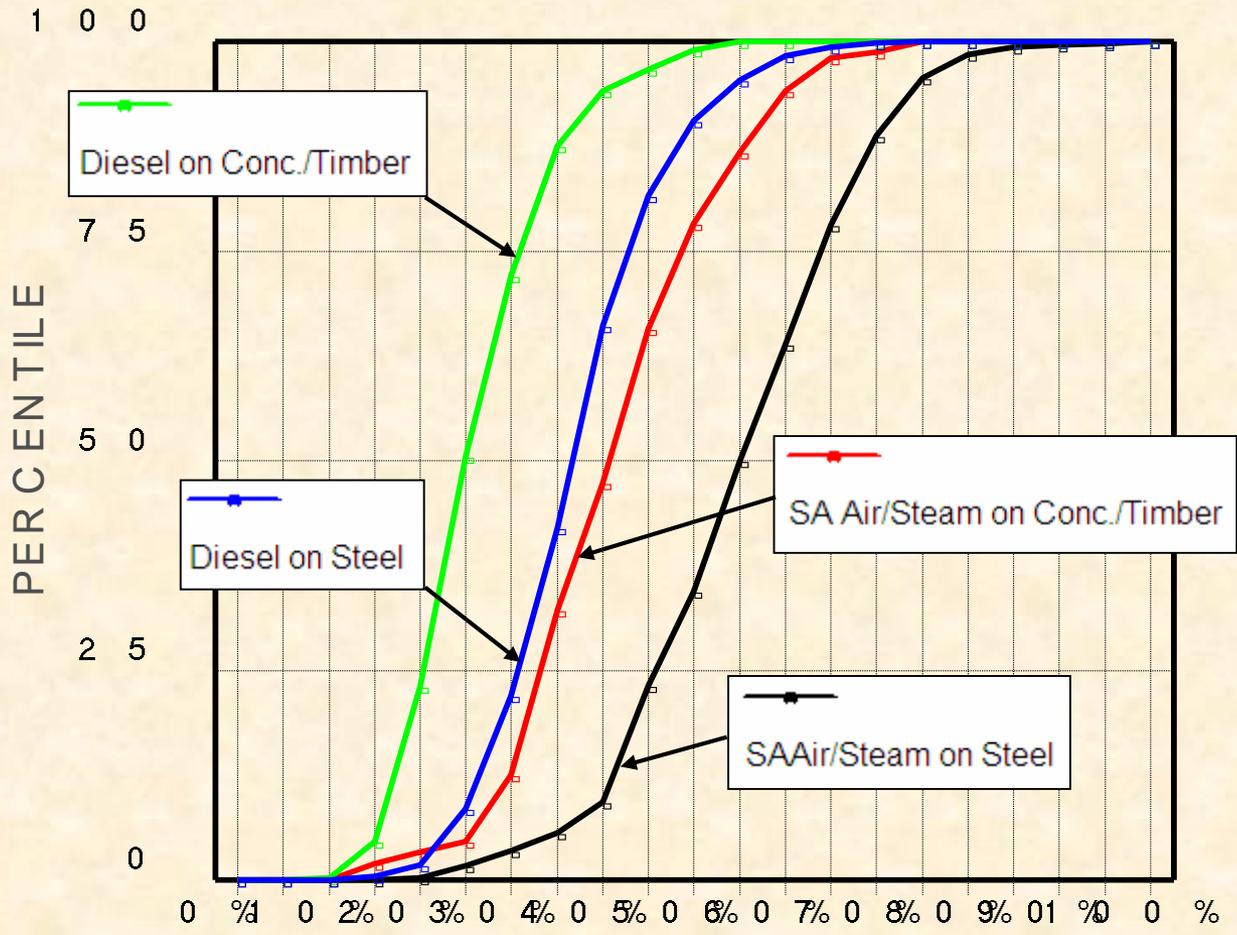


This chart has been assembled from data collected by GRL engineers and may only be copied with the express written permission of GRL Engineers, Inc.

totaling a sample size of 33 steel pipe piles. Please note that the wall thickness often varied by ± 0.25 " along the shaft of each pipe.

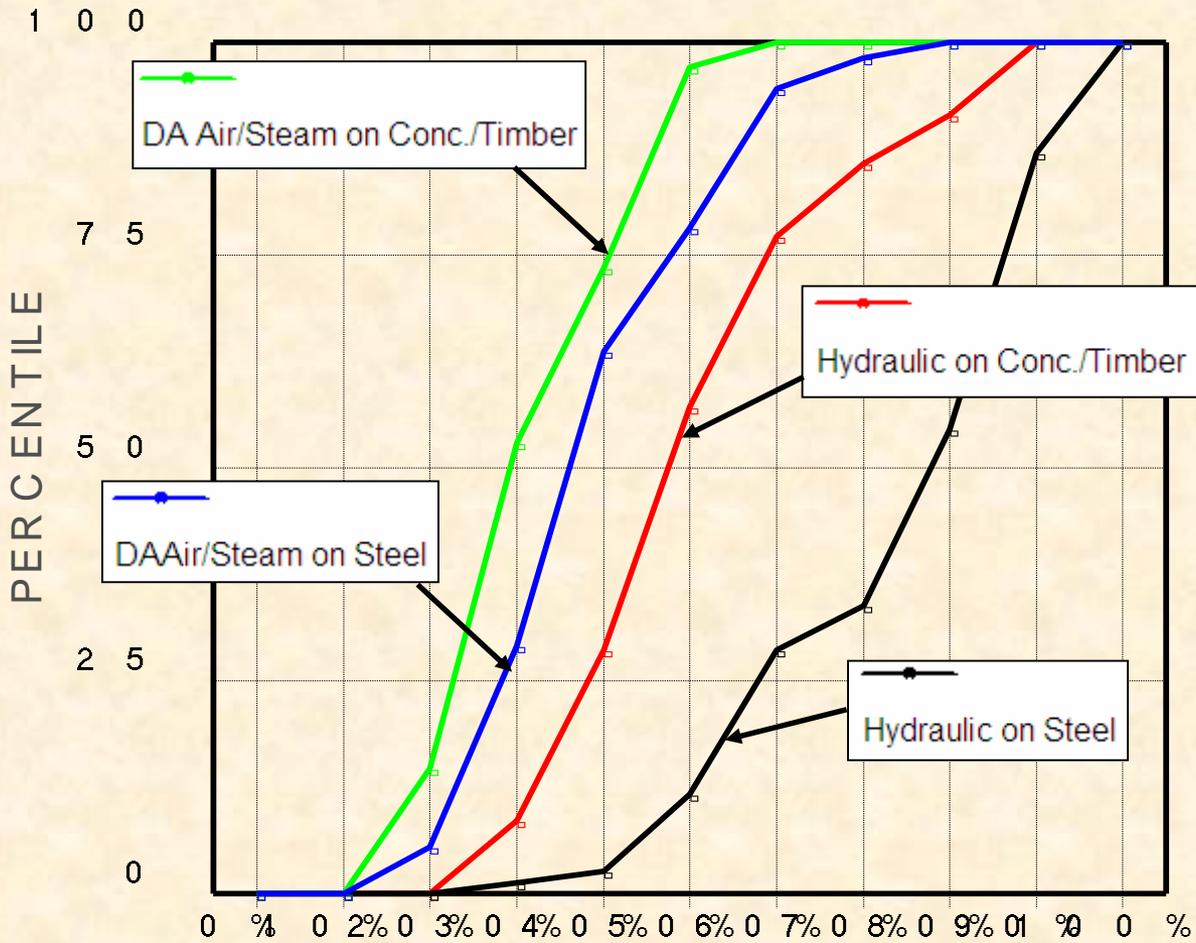
Because no information was given about the reduced energy settings, the efficiencies were still calculated using the maximum rated energy from the hammer manufacturer. Consequently, the mean and median are lower for the offshore projects than other projects in the GRL Hydraulic Hammer Database.

HAMMER TYPES ON DIFFERENT PILES



RATED TRANSFER EFFICIENCY [EMX/E-RATED

HAMMER TYPES ON DIFFERENT PILES



RATED TRANSFER EFFICIENCY [EMXE-RATED]

ANÁLISE COMPARATIVA DE SISTEMAS DE CRAVAÇÃO

TIPOS DE MARTELOS - CARACTERÍSTICAS - CONDIÇÕES DE UTILIZAÇÃO

MARTELO TIPO	QUEDA LIVRE	DIESEL	HIDRÁULICO
GOLPES / MINUTO	8 A 12	40 A 60	40 A 100
VELOCIDADE DE IMPACTO	NÃO MEDIDA	NÃO MEDIDA	MEDIDA (?)
ALTURA DE QUEDA	MEDIDA????	$H=4400/(BPM^2) - 0,09$ H (m) BPM Golpes por minuto	MEDIDA (?)
ENERGIA POTENCIAL	PESO x Hq	$E_p = W / (N_b/66)^2$ W: KN E_p : KNxm N_b : golpes/min	PESO x Hq
EFICIÊNCIA NA CRAVAÇÃO	35% A 50%	40% A 50%	50% A 90%
SISTEMA OPERACIONAL	GUINCHO A CABO	EXPLOSÃO NA CÂMARA DE COMBUSTÃO POR INJEÇÃO REGULÁVEL DE ÓLEO DIESEL	HIDRÁULICO
LOCOMOÇÃO	MUITO LENTA. SISTEMA DE IMPACTO APOIADO SOBRE ROLOS	DEPENDENTE DO APOIO DO SISTEMA DE IMPACTO, ROLO OU ESTEIRA	RÁPIDA
MANUTENÇÃO	SIMPLES	COMPLEXA	COMPLEXA
ADEQUABILIDADE	TODOS OS TIPOS DE ESTACAS	TODOS OS TIPOS DE ESTACAS	TODOS OS TIPOS DE ESTACAS
VANTAGENS	BAIXO CUSTO DE INVESTIMENTO	PRODUTIVIDADE MÉDIA A ELEVADA	ELEVADA PRODUTIVIDADE
DESvantagens	BAIXA PRODUTIVIDADE	POLUIÇÃO, CUSTOS E FUNCIONAMENTO DEPENDENTE DA RESISTÊNCIA DO SOLO	ALTO CUSTO INICIAL

TENSÕES DINÂMICAS ADMISSÍVEIS NA CRAVAÇÃO

TENSÕES DINÂMICAS ADMISSÍVEIS NA CRAVAÇÃO

TIPO DE ESTACA	ABNT NBR6122-2010	
	$\sigma_d (c)$	$\sigma_d (t)$
AÇO	$0,8F_y + (10\%)*$	$0,8F_y + (10\%)*$
MADEIRA	-	-
CONCRETO ARMADO	$0,85F_{ck}$	$0,7F_y + (10\%)*$
CONCRETO PROTENDIDO	$0,85F_{ck} - F_{pe}$	$0,9F_{pe} + (50\%)F_{ctk}$

*"Caso sejam feitas medições de tensão durante a cravação"

ABNT - Associação Brasileira de Normas Técnicas

TENSÕES DINÂMICAS ADMISSÍVEIS NA CRAVAÇÃO

TIPO DE ESTACA	FHWA (MPa)		AASHTO (MPa)	
	$\sigma_d (c)$	$\sigma_d (t)$	$\sigma_d (c)$	$\sigma_d (t)$
AÇO	$0,9f_y$	$0,9f_y$	$0,9f_y$	$0,9f_y$
MADEIRA	$3\sigma_a$	$3\sigma_a$	$3\sigma_a$	$3\sigma_a$
CONCRETO ARMADO	$0,85f'_c$	$0,25\sqrt{f'_c}$	$0,85f'_c$	$0,7f_y$ (armadura)
CONCRETO PROTENDIDO	$0,85f'_c - f_{pe}$	$0,25\sqrt{f'_c} + f_{pe}$	$0,85f'_c - f_{pe}$	$0,25\sqrt{f'_c} + f_{pe}$ (1) < f_{pe} (2)

$$5,5 \leq \sigma_a \leq 8,3 \text{ (MPa)}$$

(1) solos não agressivos

(2) severas condições de corrosão.

FHWA – Federal Highway Administration

AASHTO – American Association of State Highway and Transportation Officials

TENSÕES DE CRAVAÇÃO “NÃO CONTROLADAS”







GEOMECC

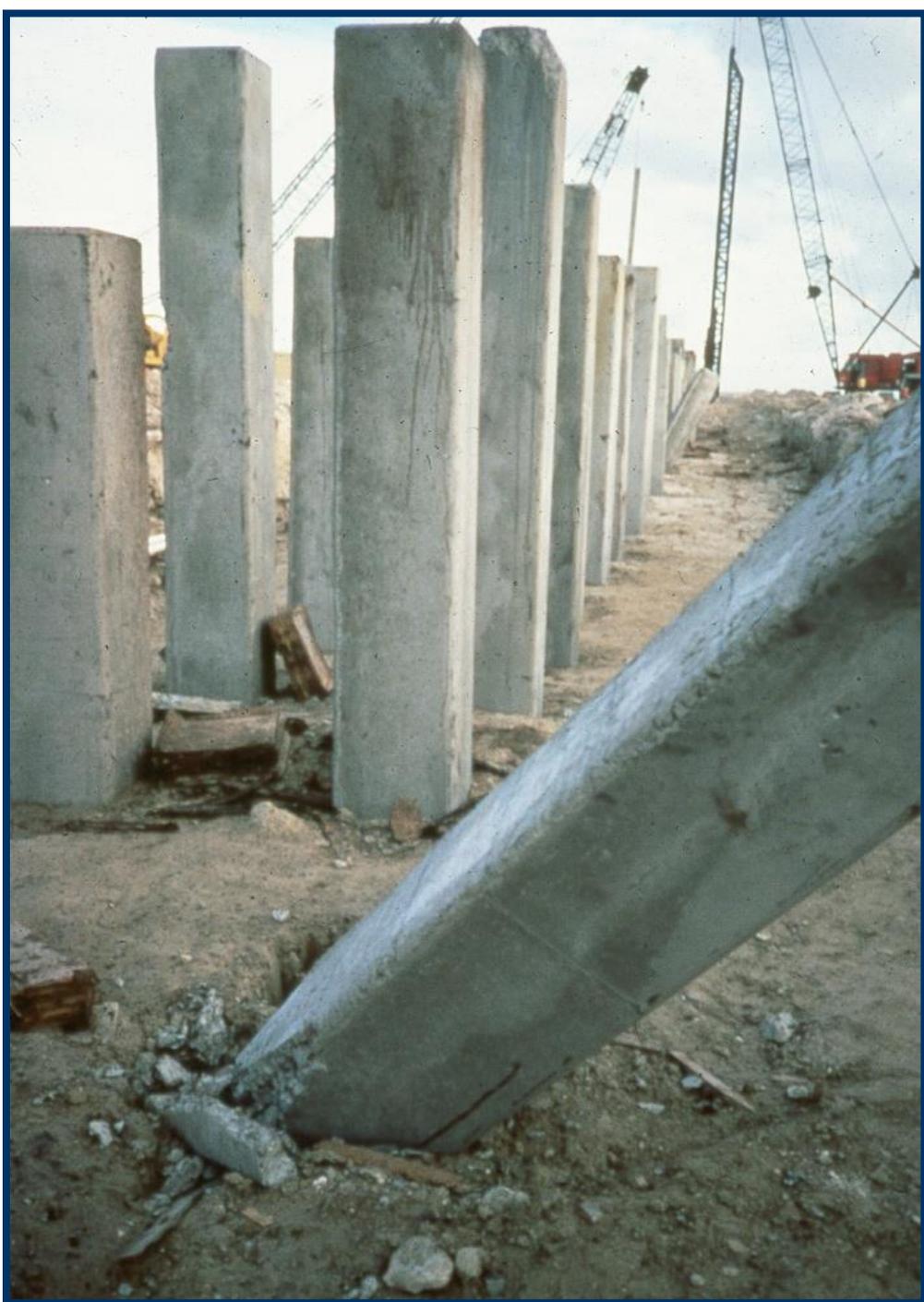


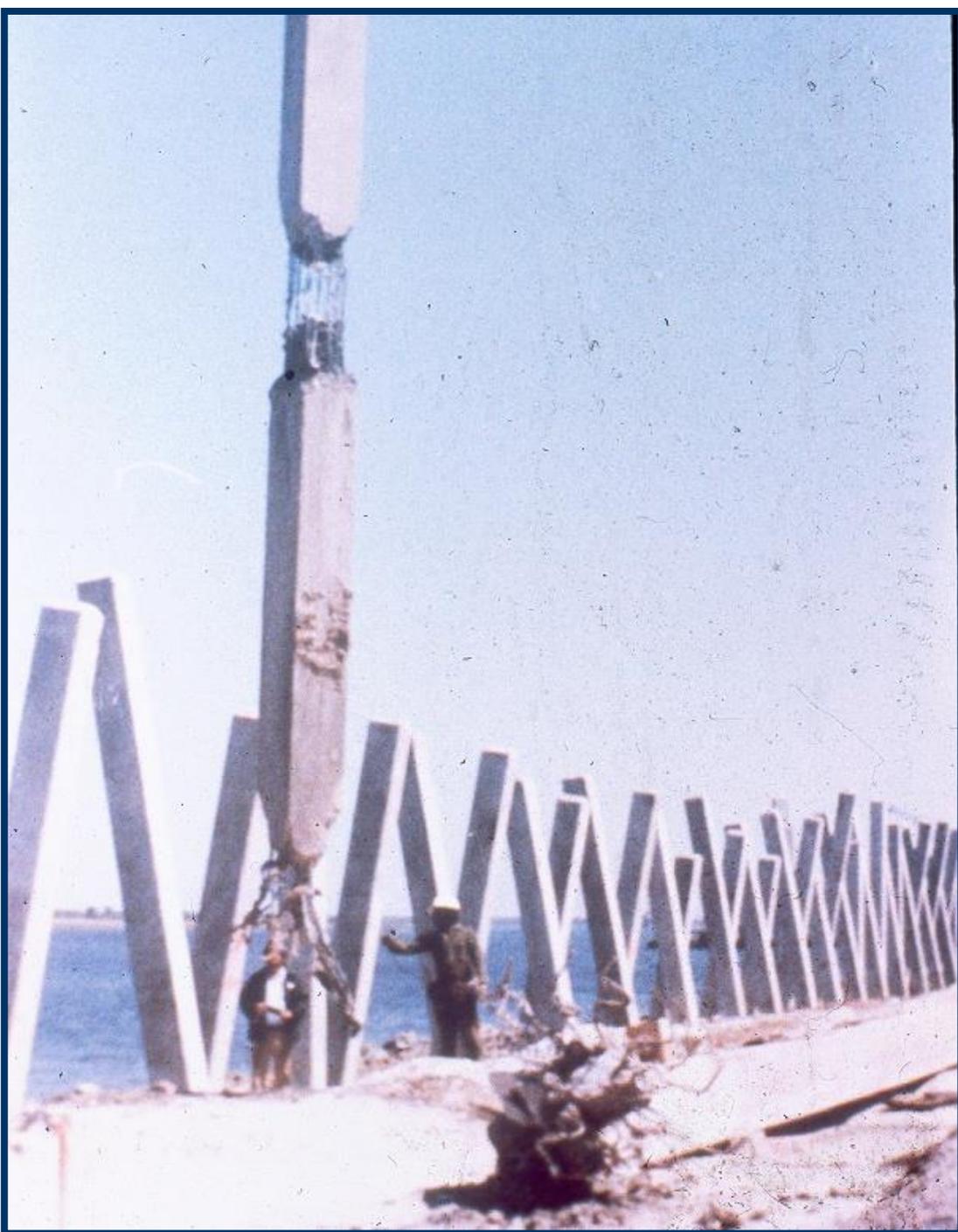
**ESTACA TUBULAR DE AÇO
24" X 0,5"**





Estaca de Aço
HP 310x79 (120tf) ???
Martelo Fambo 7ton.





GEOMECC

VERIFICAÇÃO DAS TENSÕES DE CRAVAÇÃO

INSTRUMENTAÇÃO NA CRAVAÇÃO (PDA)

INSTRUMENTAÇÃO NA CRAVAÇÃO (PDA)

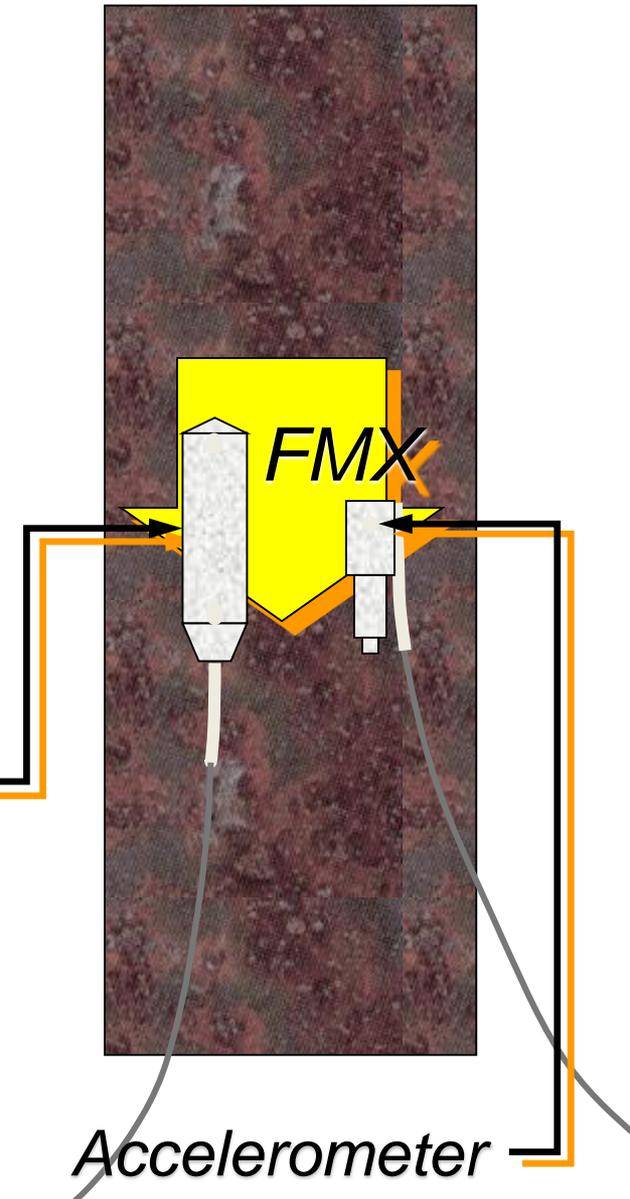
FMX

Force Maximum

*FMX = max. measured section
force at gage location*

$$= \varepsilon_{av} E_p A_p$$

Strain transducer



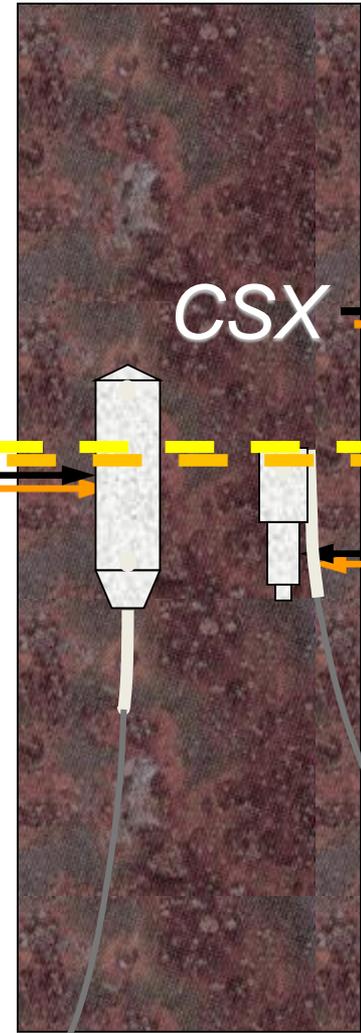
CSX

Compressive Stress Maximum
 $CSX = \text{max. measured average}$
 $\text{stress at gage location}$
 $= \varepsilon_{av} E_p$

Strain transducer

CSX

Accelerometer

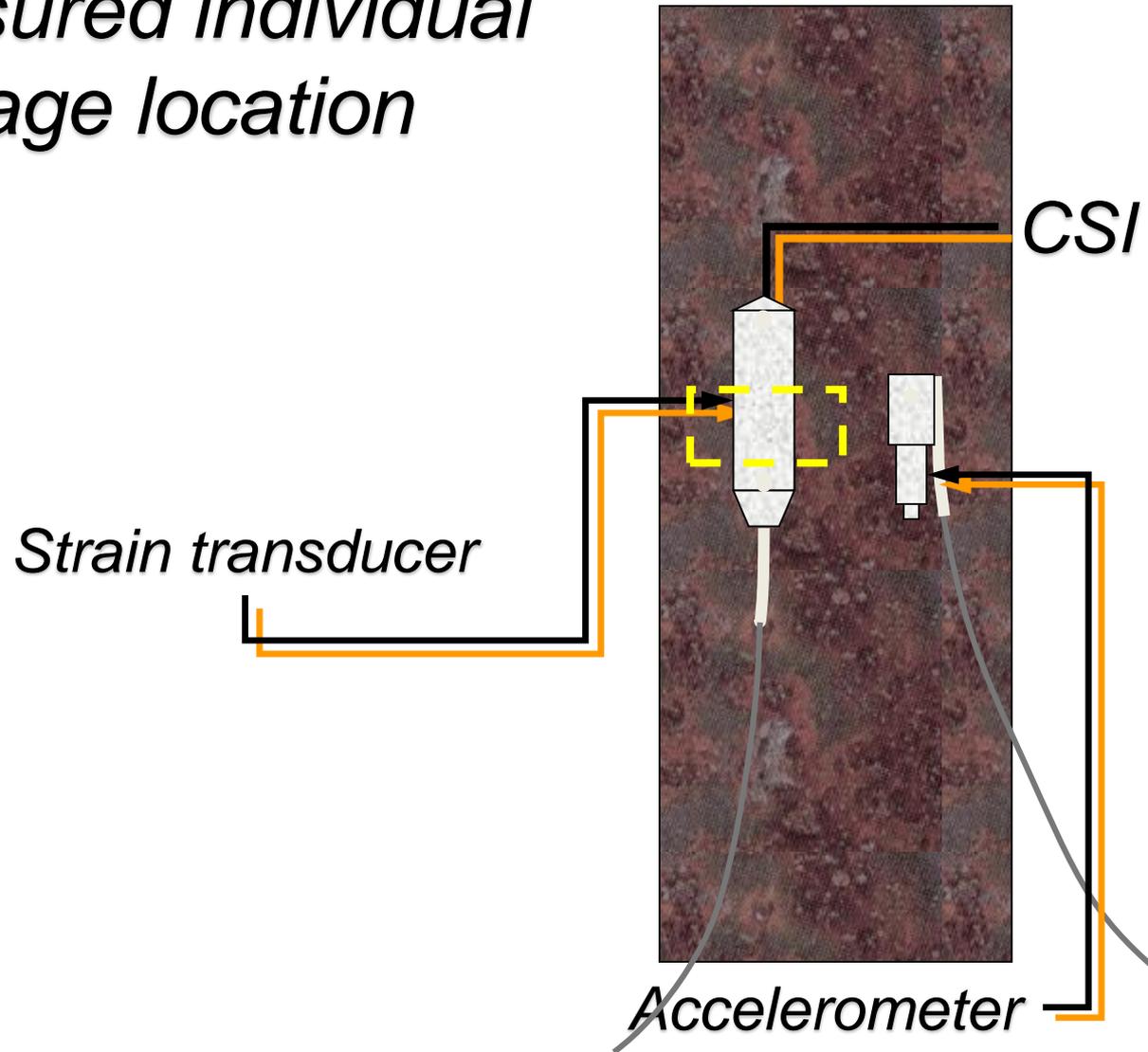


CSI

Compressive Stress I (where $I = 1, 2, 3$ or 4)

$CSI = \text{max. measured individual stress at gage location}$

$$= \varepsilon_i E_p$$

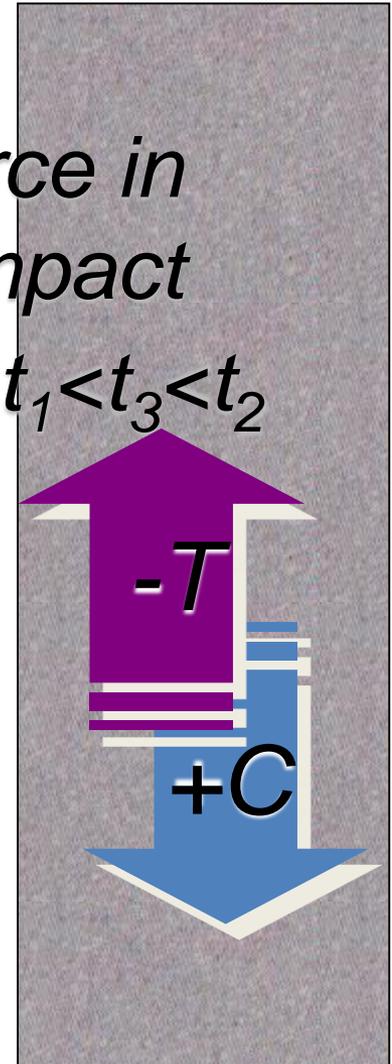


CTN

Computed Tension

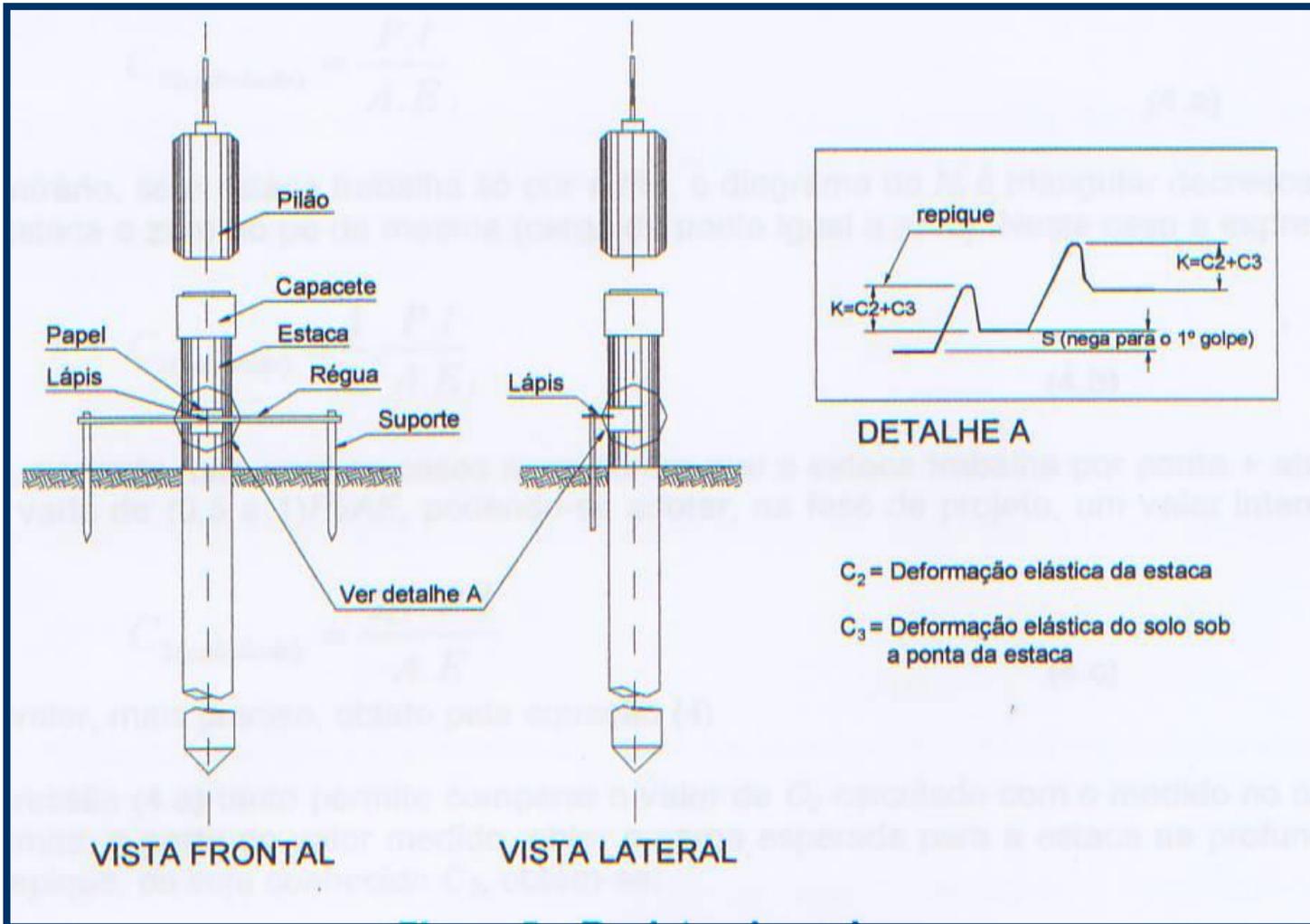
CTN = max. computed tension force in pile in period $2L/c$ after impact

$$= F_{\uparrow}(t_2) + F_{\downarrow}(t_3)_{min} \text{ where } t_1 < t_3 < t_2$$



UTILIZANDO DADOS DE REPIQUE ELÁSTICO

REPIQUE ELÁSTICO/PENETRAÇÃO PERMANENTE (NEGA)



REGISTRO DO REPIQUE ELÁSTICO

ESTIMATIVA DE C2

$C2 = K - C3$, SENDO

K = REPIQUE

C3 = DESLOCAMENTO ELÁSTICO DO SOLO DA PONTA DA ESTACA “QUAKE”

$C3 = D/120$, D = DIÂMETRO.

MÓDULO DINÂMICO

$$E_d = \rho \cdot C^2$$

ρ = DENSIDADE ESPECÍFICA; $\rho = \gamma/g$

γ = PESO ESPECÍFICO DO CONCRETO

g = GRAVIDADE (9,81m/s²)

c = VELOCIDADE DE ONDA

c = 3200 a 4200 m/s - concreto

c = 5120 m/s - aço

L = DISTÂNCIA ENTRE A PONTA DA ESTACA E A SEÇÃO ONDE SE MEDE O REPIQUE

TENSÃO DINÂMICA DE COMPRESSÃO

$$\sigma_d = E_d \cdot C2/L$$

PREVISÃO E CONTROLE DA CRAVAÇÃO

- ANÁLISE WEAP (Wave Equation Analysis of Pile Driving)
CALIBRAÇÃO DO SISTEMA MARTELO – ESTACA – SOLO.

- CONTROLE RIGOROSO DA CRAVAÇÃO E PÓS CRAVAÇÃO
ENSAIO DE CARREGAMENTO DINÂMICO – ABNT NBR 13208/2007

GRLWEAP

Wave Equation Analysis of Pile Driving

© 2005-2 Goble Rausche Likins and
Associates, Inc.

GEOMECH



QUEIROZ GALVAO VIA MANGUE RECIFE PE

Hammer Information
 Select from following list [21/04/2008-2003]: ID: 490

ID	Name	Type	Ram Wt	Energy/Power
489	JUNTTAN HHK 5A	ECH	49.050	58.860
490	JUNTTAN HHK 7A	ECH	68.670	82.404
491	JUNTTAN HHK 9A	ECH	88.290	105.948

Hammer parameters

Efficiency: 0.95

Stroke: 1.2 m

Type: ECH
 Fixed

Pile material

Concrete Steel Timber

Cushion Information

	Hammer	Pile	Unit
Area	2827.74	1600	cm ²
Elastic Modulus	2500	210	MPa
Thickness	200	200	mm
C.O.R.	0.9	0.5	
Stiffness	0	0	kN/mm
Helmet Weight	9.808		kN

Pile Information

Length: 35 m
 Penetration: 35 m
 Section Area: 1600 cm²
 Elast Modulus: 34500 MPa
 Spec Weight: 23.6 kN/m³
 Toe Area: 1600 cm²
 Perimeter: 1.6 m
 Pile Size: 400 mm

Segments: Auto
 S-Length: Auto
 S-St. Wt: Auto
 Splices: 0
 Pile Type: Unknown

Ultimate Capacities (up to 10) kN

1	380.0	6	2280.0
2	760.0	7	2660.0
3	1140.0	8	3040.0
4	1520.0	9	3420.0
5	1900.0	10	3800.0

Incr.: 0 Action >>

Soil Parameters

Quake

Shaft: 2.54 mm Const
 Toe: 3.333 mm

Damping

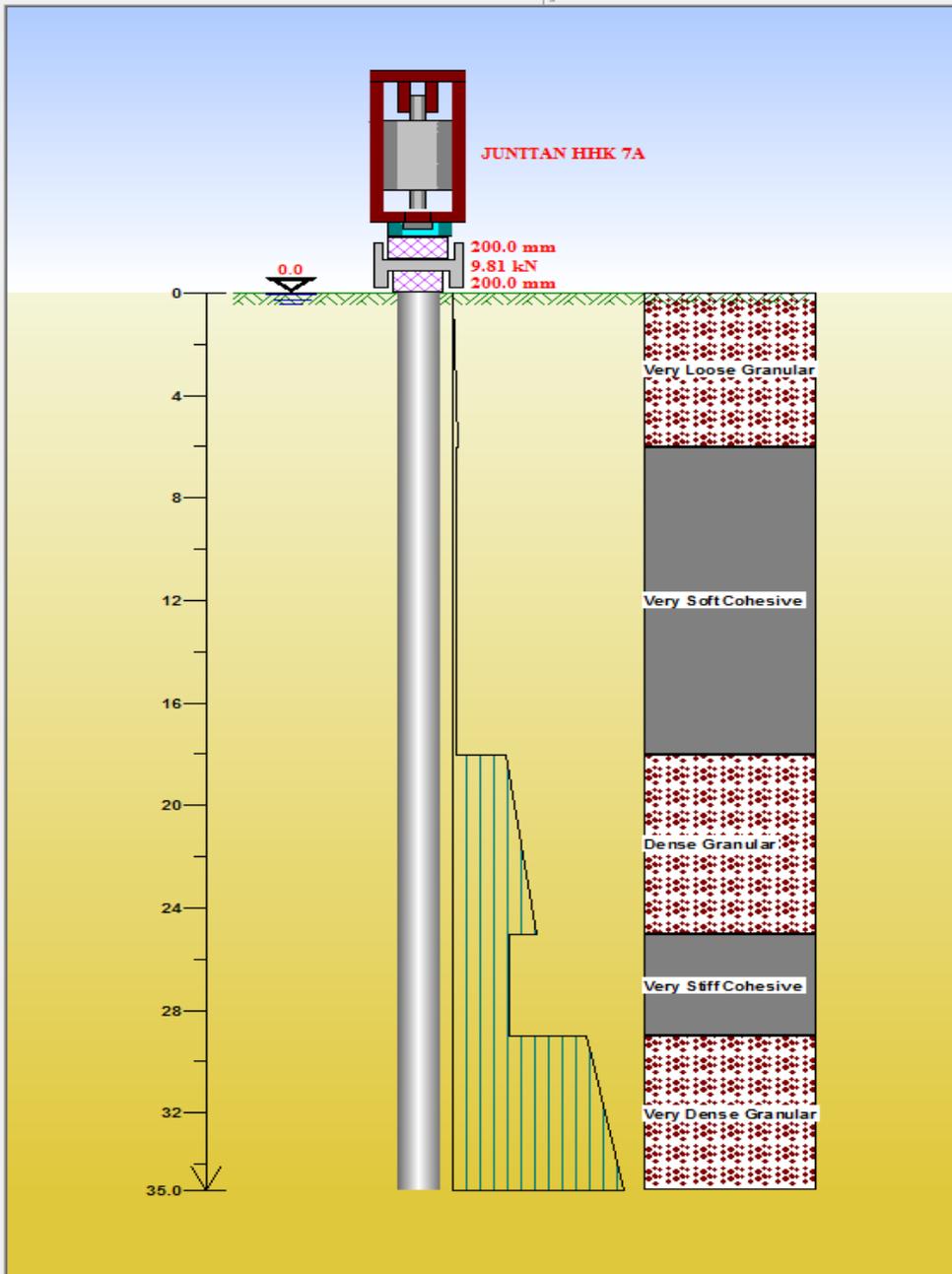
Shaft: 0.312 s/m Const
 Toe: 0.49 s/m Smith

Shaft Resistance

Percentage: 35 %

Dist. Shape Num: 0.0

Residual Stress Analysis: No



CONTROLE RIGOROSO DA CRAVAÇÃO

ENSAIO DE CARREGAMENTO DINÂMICO (ECD)

REGULAMENTAÇÃO:

ABNT – NBR 13208 – 2007

ASTM - D4945 – 00 – USA

AASHTO - LRFD – 00 – USA

- **ANO DE 2010 – ENSAIOS DINÂMICOS**

NOTICIA-SE QUE SÃO REALIZADAS POR ANO 5.000 OBRAS COM ENSAIOS DINÂMICOS. NOS ÚLTIMOS 30 ANOS JÁ FORAM REALIZADOS DA ORDEM DE 2.700.000 ENSAIOS DINÂMICOS.

- **AVALIAÇÕES NO MOMENTO DO ENSAIO:**

CARGA MÁXIMA MOBILIZADA NA INTERFACE SOLO-ESTACA

TENSÕES DINÂMICAS DE COMPRESSÃO E DE TRAÇÃO

ENERGIA LIQUIDA TRANSFERIDA NA ESTACA

FORÇA DE IMPACTO

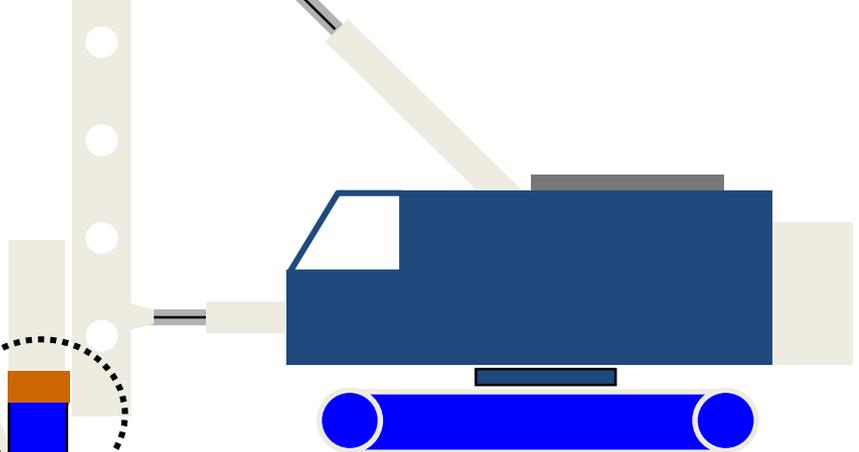
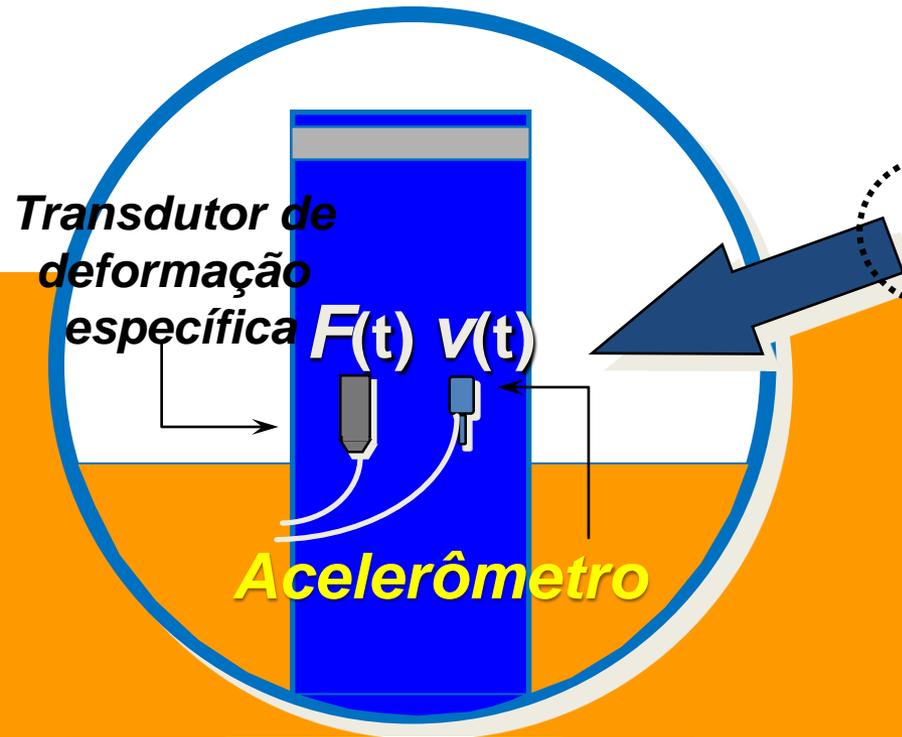
ACELERAÇÃO, VELOCIDADE, DESLOCAMENTO MÁXIMO, ETC.

- **ANÁLISE NUMÉRICA CAPWAP® (CASE PILE WAVE ANALYSIS PROGRAM)**

CONFERÊNCIAS TÉCNICAS INTERNACIONAIS STRESS-WAVE

Conferência	Ano	Localidade/ País	Artigos	Países
1ª	1980	Estocolmo/Suécia	24	11
2ª	1984	Estocolmo/Suécia	54	16
3ª	1988	Otawa/Canadá	88	21
4ª	1992	Haia/Holanda	116	21
5ª	1996	Orlando/EUA	101	27
6ª	2000	São Paulo/Brasil	100	24
7ª	2004	Petaling Jaya/Malásia	58	20
8ª	2008	Lisboa/Portugal	101	37
9ª	2012	Kanazawa/Japão	111	35
Totais	32	8	753	-
10ª	2015	Holanda	-	-

ECD



- $F(t) = E A \varepsilon(t)$
 - $\varepsilon(t)$ é a média dos 2 ou mais sinais de deformação
- A velocidade é obtida integrando-se a aceleração:
 - $V(t) = \int a(t) dt$
 - $a(t)$ é a média dos 2 ou mais sinais de aceleração
- O deslocamento é obtido integrando-se a velocidade:
 - $D(t) = \int V(t) dt$



Pile Driving Analyzer®

Geomec Engenheiros Consultores
Serial Number: 3701L



Pile Driving Analyzer®
PDA

Copyright © 2007-2008 Pile Dynamics, Inc.
PDA Version 2, 1, 0, 72

TOUCH SCREEN TO CONTINUE

TOUCH SCREEN FOR 10 SECONDS TO CALIBRATE

PAX

INSTALAÇÃO DE CHUMBADORES PARA FIXAÇÃO DOS SENSORES



SENSORES INSTALADOS



ESTACA TUBULAR DE AÇO







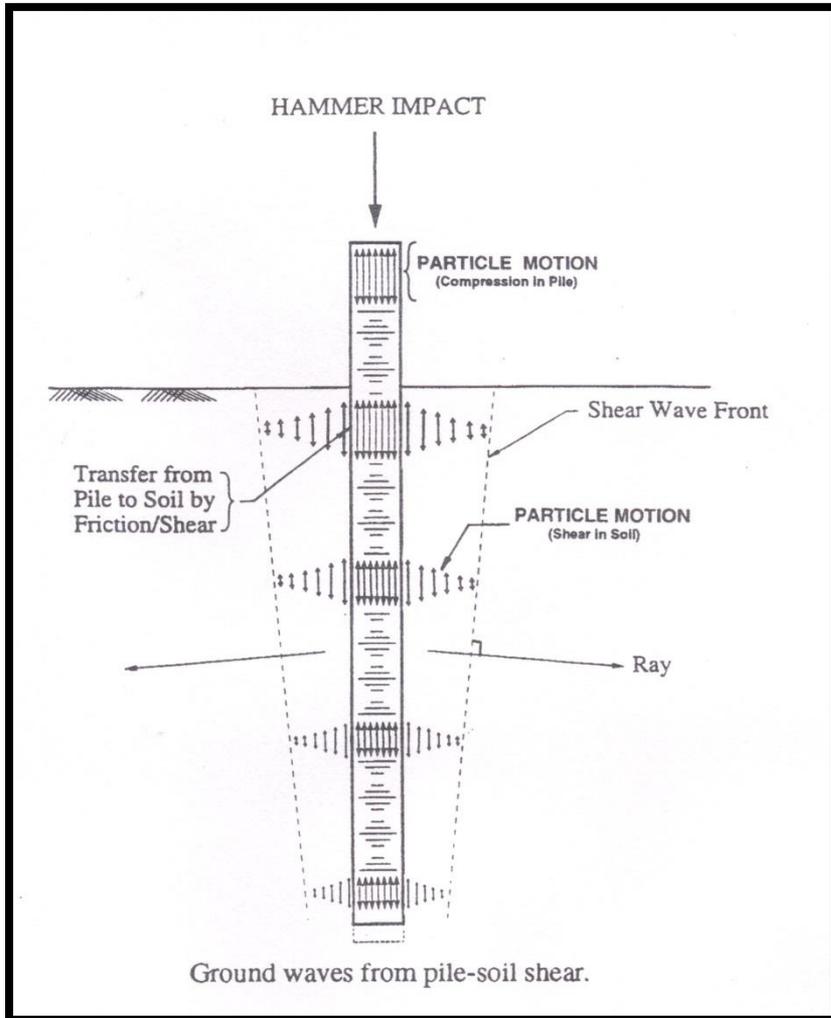
QUESTÕES AMBIENTAIS

VIBRAÇÃO

POLUIÇÃO SONORA

VIBRATION

Peak Particle Velocity (ppv)



$$ppv = \frac{k \sqrt{E}}{\Delta h} \quad (\text{mm/sec})$$

k = constant

E = driving energy per blow or per cycle in joules

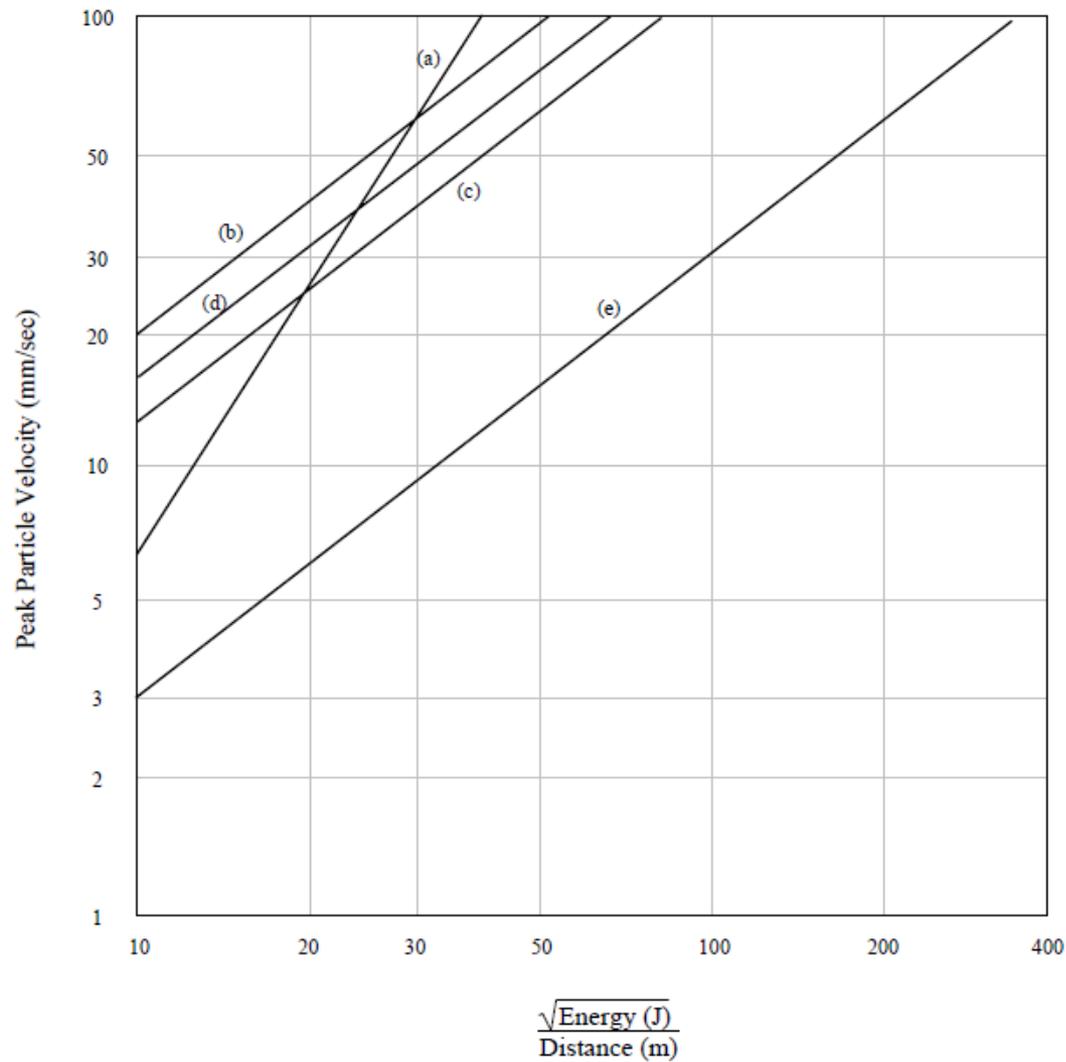
Δh = horizontal distance from the pile axis in metres

$K= 1,5$ (first approximation)

$K= 1,0$ (precast concrete piles) – Hong Kong

$K= 0,85$ (H-piles) – Hong Kong

$K= 0,75$ (hammer-driven piles) – BSI,1992



Legend :

- (a) Wiss (1967) – Clay
- (b) Wiss (1967) – Wet sand
- (c) Wiss (1967) – Dry sand
- (d) Attewell & Farmer (1973) – Sand & gravel, silt, clay
- (e) Brenner & Chittikuladilok (1975) – Clayey sand or stiff clay

LIMITING PARTICLE VELOCITY

Structure and Condition	Limiting ppv (mm/sec)
Building of historical significance	2/3
More sensitive structures such as water retaining structures, water tunnels, masonry retaining walls and dilapidated buildings	7,5
Historic and some old structures	12
Residential structures	12
New residential structures	25
Industrial building	50
Bridges	50

Code of Practice on Vibration Control (Hong Kong)

Dynamic Effects of Pile Installations on Adjacent Structures

NCHRP Synthesis 235 – National Cooperative Highway Research Program - 1997

Green Concrete

When pile driving or blasting is conducted in close proximity to freshly poured concrete, special care must be taken not to damage the cement bonds. The limits in Table 1 for controlling transient vibration impacts (from pile driving with an impact hammer or from blasting) on green concrete foundations have been successfully applied on similar projects (Oriard and Coulson, 1980).

Table 1 – Recommended Vibration Limits for Mass Concrete

Concrete Age from Batching	Allowable Particle Velocity (mm/sec) x Distance Factor (DF)
0 to 4 hrs.	50.8 x DF
4 hrs. to 1 day	76.2 x DF
1 to 3 days	114.3 x DF
3 to 7 days	152.4 x DF
7 to 10 days	190.5 x DF
10 days or more	254 x DF

DF is defined as follows:

Distance = 0 to 15.24 meter

DF = 1.0

Distance = 15.24 to 45.72 meter

DF = 0.8

Distance = 45.72 to 76.2 meter

DF = 0.7

Distance = over 76.2 meter

DF = 0.6

- A minimum distance of 30.48 meter is recommended between pile driving and freshly poured concrete elements less than three days old. Vibrations shall be controlled to the levels detailed in Table 1 for curing mass concrete.
- Concrete forms must be braced sufficiently to withstand vibration during the first 24 hours after concrete is poured, before it has attained sufficient strength.
- For above grade walls, the vibrations should be limited to one half of the limits listed in Table 1.

As discussed above, driving of sheet piles using a vibratory hammer produces continuous steady state vibrations as opposed to the transient vibrations generated by impact pile driving hammers. Limits for continuous vibrations should be established at 25% of those established for transient vibrations (Oriard and Coulson, 1980).

Table 2 – Vibration Effects on Loose Objects (Oriard, 1999):

Risk of Toppling Objects	Particle Velocity (mm/sec)
Rare	Under 2.54
Occasional	2.54 to 25.4
Common	25.4 to 101.6
Extensive	Above 101.6

Sensitive Equipment and Computers

- Standards are typically in accelerations expressed in (g)
- Common acceleration standard is 0.25 g. At a frequency of 20 Hz, the equivalent PPV is about 19.04 mm/sec (0.75 in/sec).
- These standards are typically designed for earthquake standards or steady state vibrations during operation
- Equipment and computers are far less susceptible to short term transient vibration effects from construction than from the steady state operating standards usually published

VIBRATION ANALYZER



Resumo de dados

Data:	14-05-09	Nº de série:	0165
Hora:	10:08:41	Data de calibração:	06-05-09
Nota 1:	VIBRACORD		
Nota 2:	SEISMOGRAPH		
Nota Post-Registro:			

Valores pico obtidos

Canal: 1	Canal: 2	Canal: 3	Canal: 4
0.42 mm/s	0.61 mm/s	0.38 mm/s	0.2 Pa <100 dB
Resultante:	0.68 mm/s		

Norma NP-2074

$$V_r = (V_v^2 + V_l^2 + V_t^2)^{0.5} = 0,83 \text{ mm/s}$$

$$V_r = (V_v(t)^2 + V_l(t)^2 + V_t(t)^2)^{0.5} = 0,68 \text{ mm/s}$$

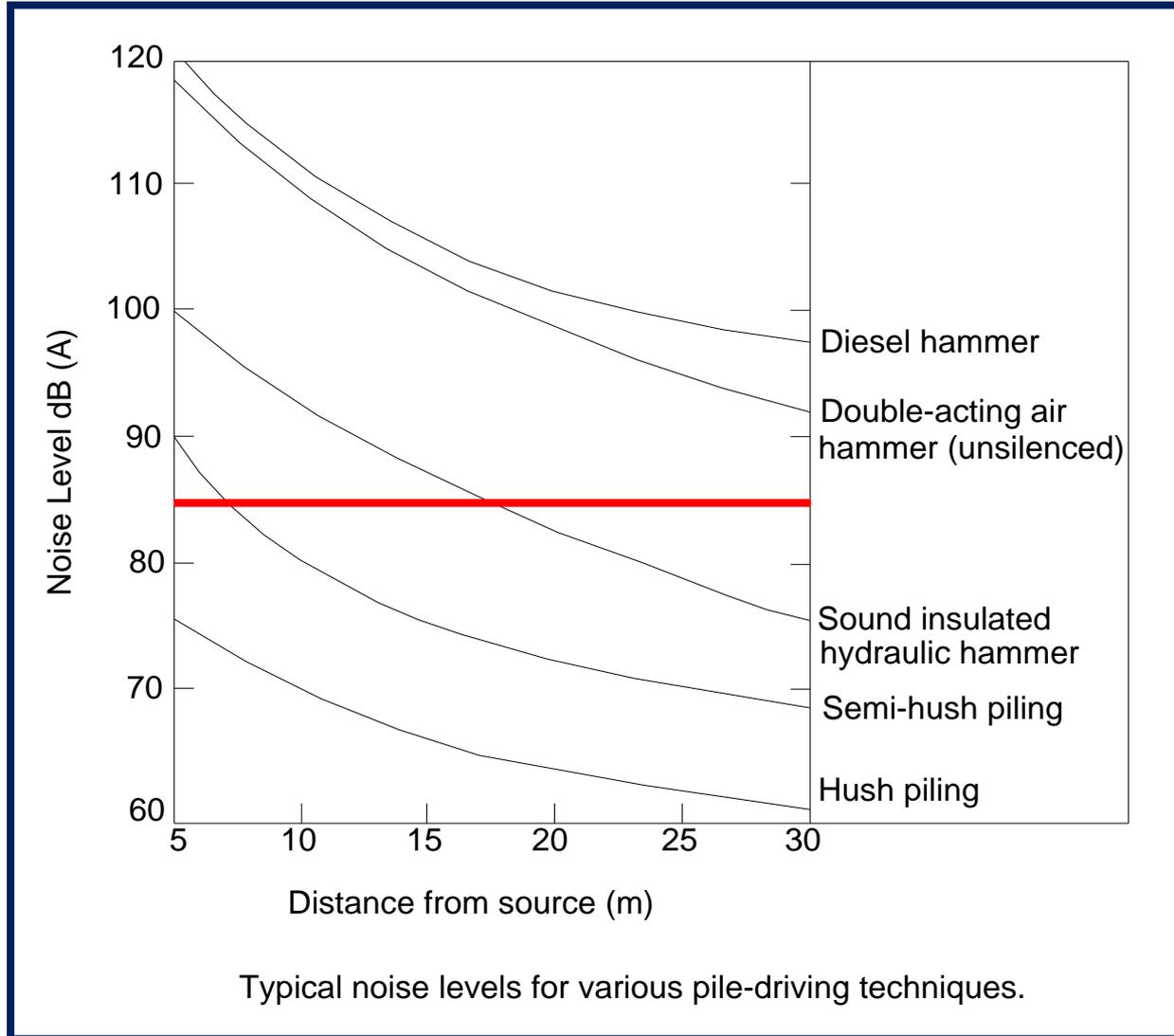
Canal 1
Vertical

Canal 2
Longitudinal

Canal 3
Transversal

Canal 4
Onda Aérea

POLUIÇÃO SONORA



Noise \leq 85dBA for eight hours a day in five-day week

CONCLUSÕES

MARTELOS

EFICIÊNCIA X PRODUTIVIDADE

CRAVABILIDADE

CALIBRAÇÃO DO SISTEMA MARTELO-ESTACA-SOLO

COMPATIBILIDADE

INTERFACE SOLO-ESTACA

CONSEQUÊNCIA

QUALIDADE TÉCNICA ELIMINANDO PERDAS, INSUFICIÊNCIA E OU EXCESSO DE CRAVAÇÃO.

GARANTIA DE CAPACIDADE DE CARGA ESTRUTURAL E GEOTÉCNICA OBSERVANDO PREVISÕES DE PROFUNDIDADES ESTABELECIDAS EM PROJETO.

Obrigado!

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