DINAS PERTAMBANGAN DAN ENERGI
PROVINSI NAGGROE ACEH DARUSSALAM
REPUBLIC OF INDONESIA

SHALLOW REFLECTION SEISMIC SHEAR-WAVE VELOCITY ANALYSIS ON PAVED SOILS USING A LAND STREAMER UNIT

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Summary

As part of the Project “Management of Georisk” of the Federal Institute for Geosciences and Natural Resources (BGR), Hannover, high resolution shear-wave reflection seismic has been applied in the Indonesian province Nanggroe Aceh Darussalam in cooperation with the Government of Indonesia and local counterparts. Target was the earthquake site effect classification in the city of Banda Aceh and the surrounding region of Aceh Besar.

Using a land streamer system was advantageous in the dense populated city area and yield to an easy recording operation. Additionally, paved roads, compacted dirt roads or concrete surfaces suppress Love waves and refracted waves, if the soil layer below the surface is of lower seismic velocity. The recorded wave field of single records often includes direct and reflected SH shear-waves only in such cases, allowing RMS-velocity-depth determination on site. Because RMS-velocity is higher than mean velocity, this gives a good estimation of the mean shear-wave velocity-depth function.

Results show that shear-wave reflection seismic combined with a land streamer unit is a useful tool to evaluate the soil stiffness in dense populated urban areas. The specialized seismic system for compacted soil surfaces allows a wide range of applications within cities, industrial sites, paved roads and also on small dirt roads.

Fig. 1: Detail of the official geologic map (1981) of the Krueng Aceh river delta showing undifferentiated alluvial sediments of holocene age for the whole investigation area. Post tsunami groundwater exploration drillings yield stacks of organic clay, silt, sand, and gravel down to a depth of 220 m without any hints of the basement contact.

Fig. 2: Operators seat inside the recording van with 48 channel Geode recording system installed (stack of yellow boxes at left). The whole equipment including spare parts could be integrated into the hired van. Differential GPS (backround right) has been used for positioning.

Fig. 3: Investigation site Kampong Jawa (**A**) in the floodplain area near the coast line now in preparation for reconstruction. The land streamer has been positioned at the left side of the dirt road to enable traffic bypass.

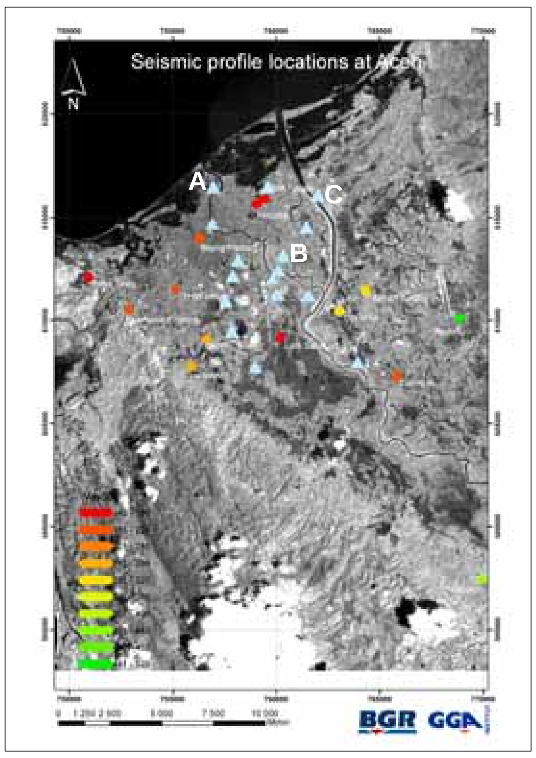

Fig. 4: Site classification results of the 2005 seismic campaign (coloured dots). Blue triangles show the added 2006 investigation sites to fill existing gaps in areas of dense population and potential relocation areas.

Acquisition parameters

Period:	1th Nov. – 15th Dec. 2006
Instrument:	GEOMETRICS GEODE
Channels/rec:	48
Shot Locations:	25-50 per profile location
Seismic Source:	GEOSYM wheel barrow shear-wave source system
Sweep Type:	20-160 Hz linear, 10 s, 100 ms Taper at both sides
Recording:	12 s (2 s after correlation)
Sampling int.:	1 ms
Recording filter:	out
Spread type:	2D variable split spread, SH-SH configuration, fixed receiver setup
Geophone type:	20DM10-280 (10 Hz), single units attached at GEOSYM land streamer unit.
Receiver int.:	1 m
Source int.:	2 m
Vertical stack:	2-fold [+Y]-[-Y] alternated vibrations

Fig. 5 (top): Indonesian counterpart team Efvendi, Razali, Andrij, and Mulkal (left to right, almost smiling) during streamer roll off operation subsequent to seismic surveying.

Fig. 6 (left): Oyo horizontal geophone type 20DM10-280 (10 Hz) mounted on a streamer baseplate. Connection to common Mueller clip cable (5 m intervals) integrated in the hose enables easy dismount to use for other applications.

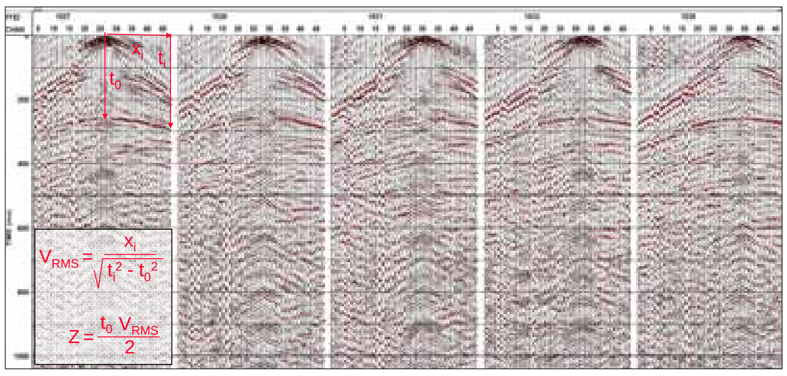

Fig. 7: Site Kampong Jawa(**A**)**:** Sequence of raw shots after preprocessing (correlation, AGC 250 ms, stack of 2 records) showing strong shear-wave reflection hyperbolas with top near 260 ms. Total spread distance of 46 m and estimated 40 ms hyperbola moveout for the leftmost shot indicate a RMS-velocity of 154 m/s down to 20 m in depth.

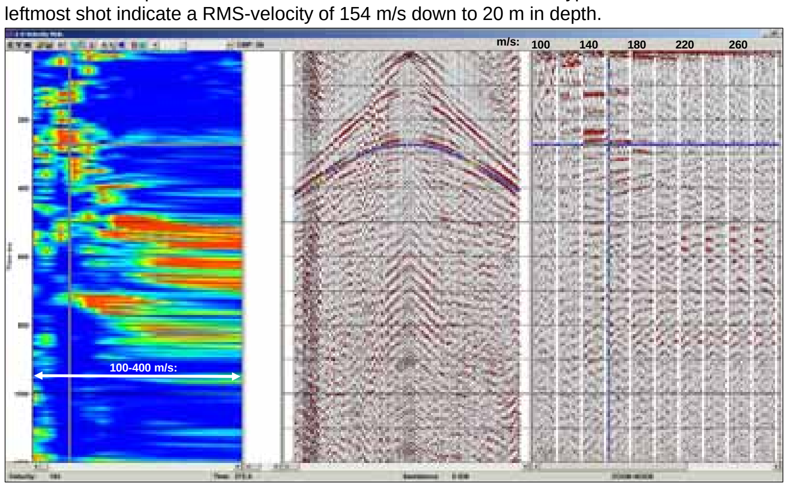

Fig. 8: Site Kampong Jawa (**A**)**:** Screen shot of Interactive Velocity Analysis during seismic processing showing Semblance Analysis, CMP-Gather, and Constant Velocity Stack panels (left to right).

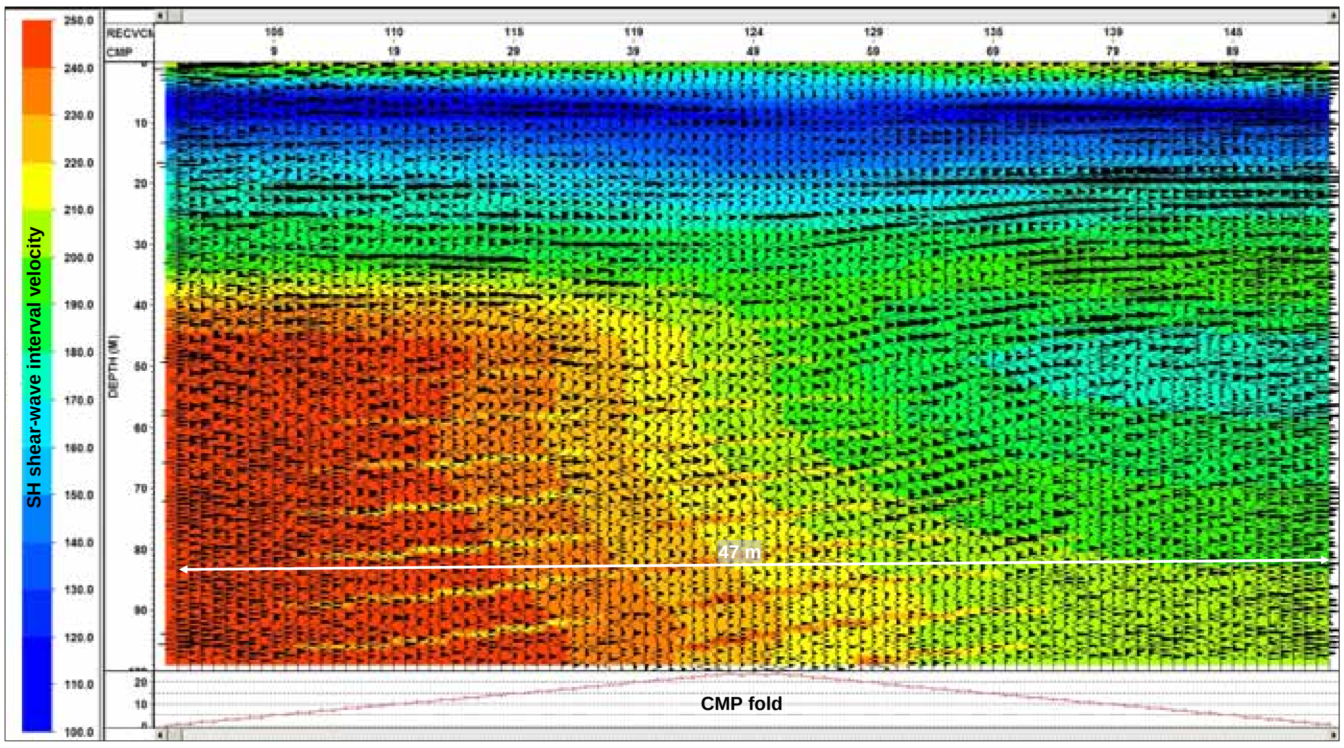

Fig. 9: Site Kampong Jawa (**A**)**:** SH shear-wave seismic depth section colour coded by interval velocities derived from RMS stacking velocities. The average shear wave velocity down to 30 m in depth (VSav30) results to 137 m/s, indicating very soft soil class S_E (< 180 m/s) of the IBC 2003 which will tend typically to strong wave amplification values. High velocities near surface are mostly due to continuous man made land fills and road compaction in this area.

Acknowledgements

KERJA SAMA REPUBLIK INDONESIA REPUBLIK FEDERAL JERMAN

The authors are gratefully acknowledged to the Government of Indonesia and the local Government of Nanggroe Aceh Darussalam for the support and permissions. All photos courtesy Guenther Druivenga (www.geosym.de) and ST Wiyono.

This work is kindly supported by the Federal Institute for Geosciences and Natural Resources (BGR), Hannover, and was founded by the Federal Ministry of Economic Cooperation and Development, Government of Germany.

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Results

Fig. 10: Investigation site Desa Ilie (B).

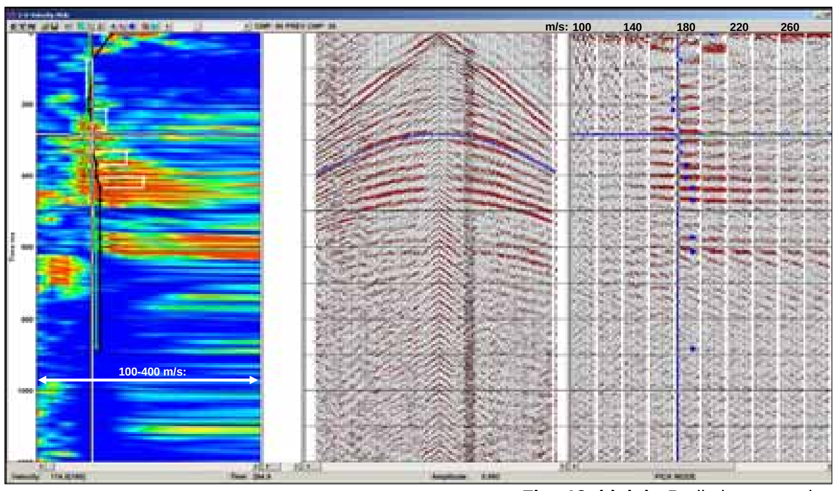

Fig. 12 (top): Interactive Velocity Analysis of investigation site Desa Ilie (**B**) showing a sequence of reflection hyperbolas within a small velocity range of 160-200 m/s.

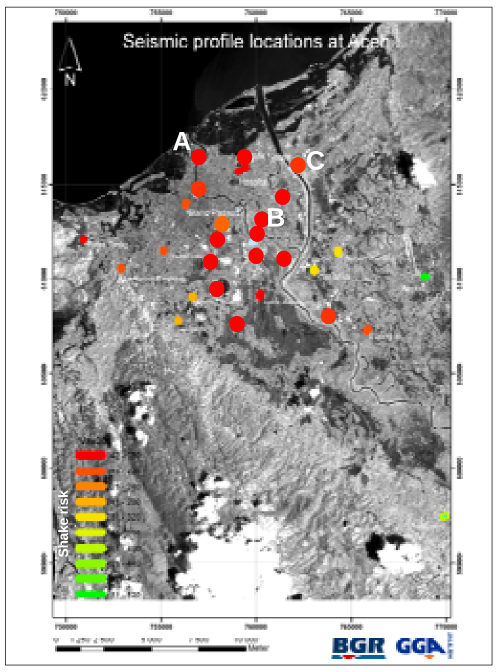

Fig. 13 (right): Preliminary results of site amplification classification including small dots of 2005 and bigger dots of the 2006 campaign.

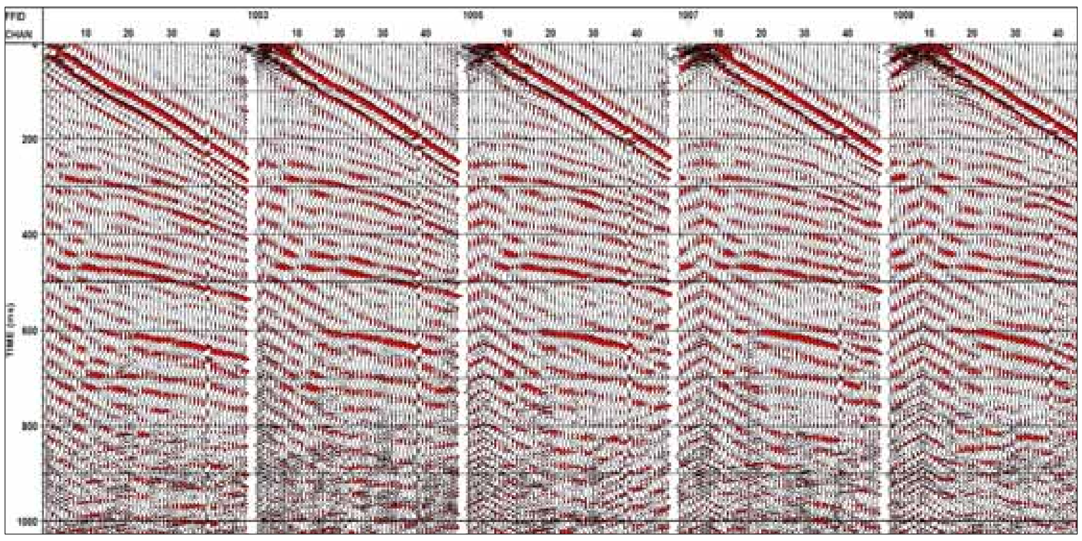

Fig. 11 (below left): Sequence of preprocessed raw shots of Desa Ilie (**B**).

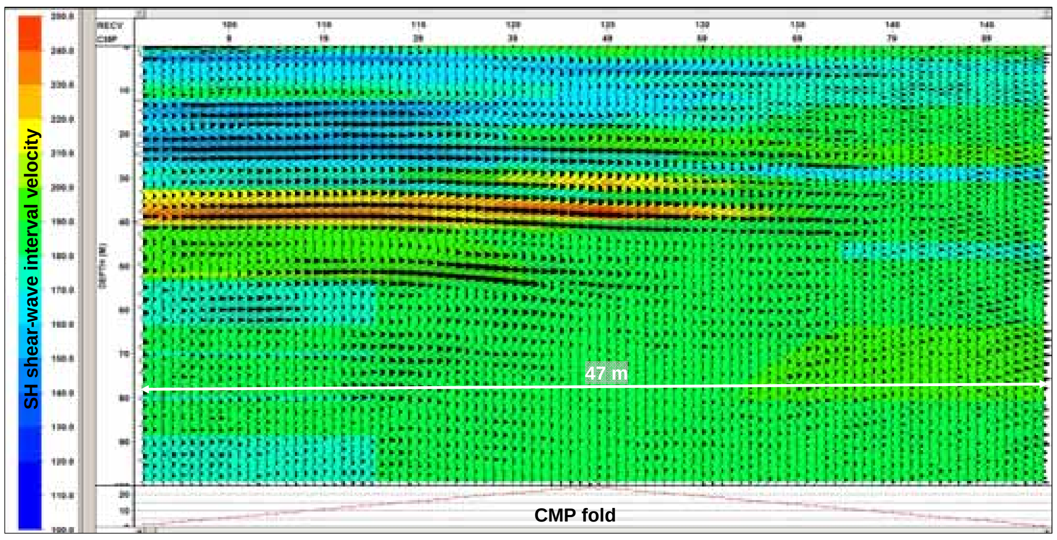

Fig. 14 (below right): Resulting depth section of Desa Ilie (**B**) colour coded by interval velocities.

Fig. 15: Investigation site Kopelma Darussalam (C), near campus of University Syiah Kuala, Banda Aceh.

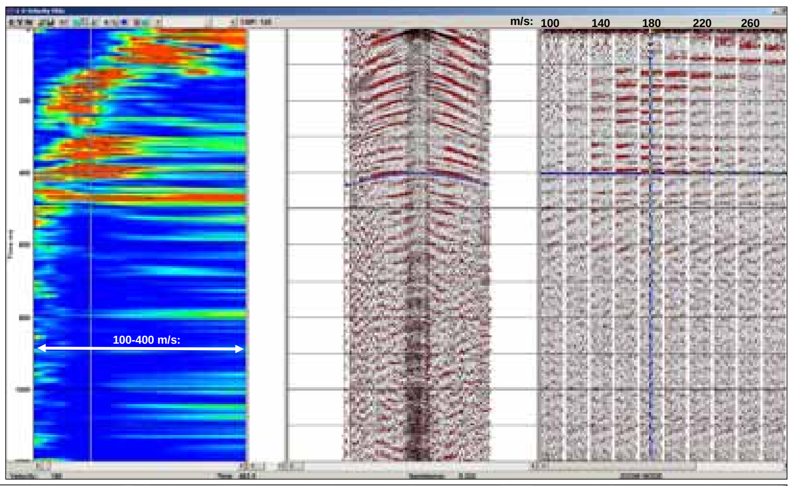

Fig. 17 (right): Interactive Velocity Analysis of site **C** showing strong decreasing RMS velocities from the surface into depth. This is often due to man made land fills at the surface and subsequent compaction during the road construction process.

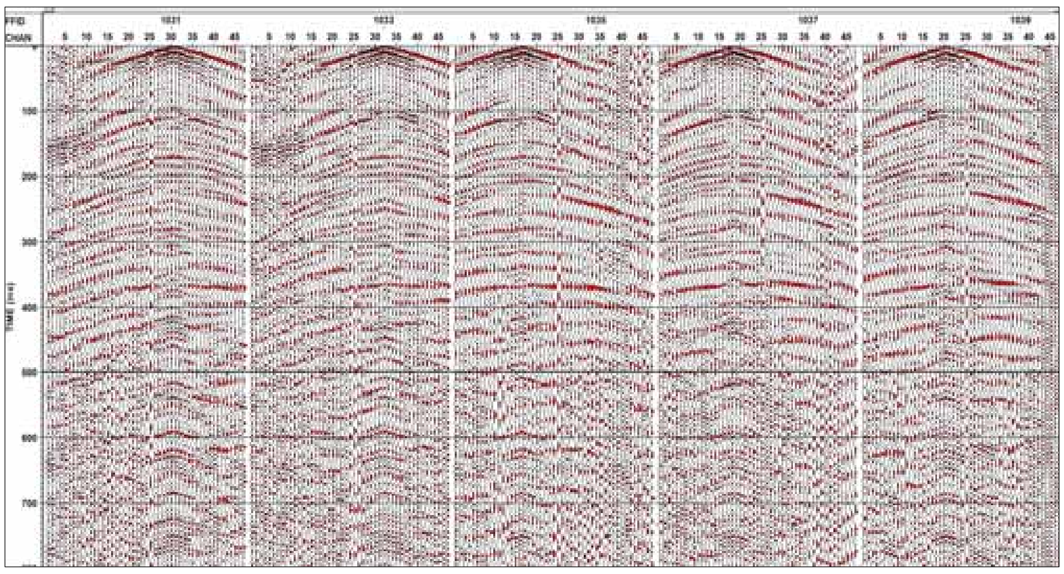

Fig. 16 (below left): Sequence of preprocessed raw shots of **C**.

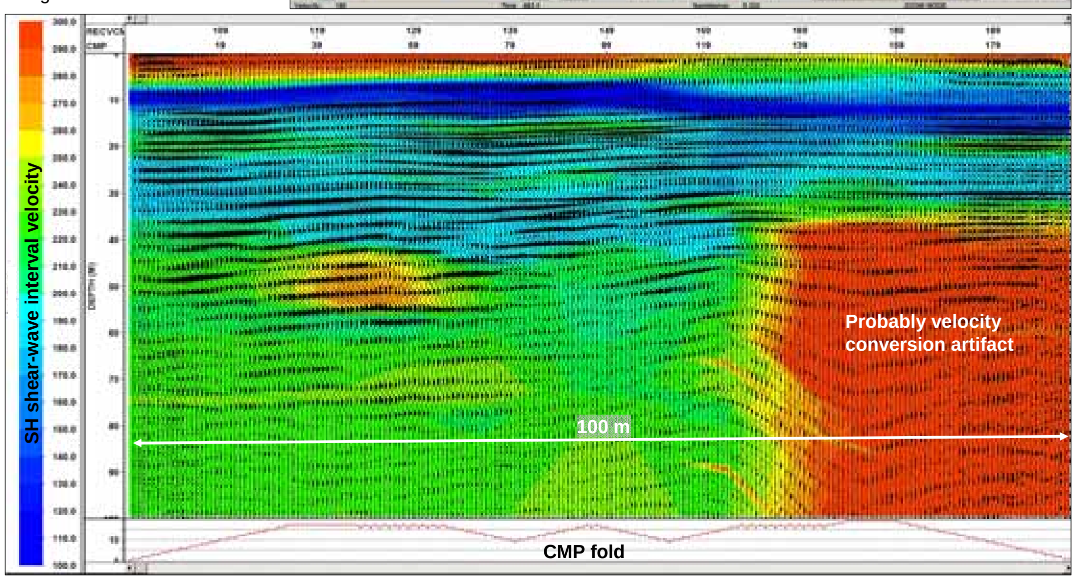

Fig. 18 (below right): Resulting depth section of **C** colour coded by interval velocities. The high interval velocities near surface lead to a higher value of VSav30 compared to other sites, whereas subsurface velocities at 5-30 are nearly in the same range.

Conclusions

The seismic site effect evaluation by shear-wave land streamer investigations has been found to be a useful tool in the sedimentary regions of the Aceh province and enables a clearly faster and more flexible field operation. The results are also useful for detailed insights in the basin sedimentation processes of the Krueng Aceh River delta concerning the exploration of new areas for save building foundation and groundwater acquifer detection. Using a vibratory seismic source, this technique was applied successfully also in areas of high building density in the city of Banda Aceh or in areas of surface compacted soil like farm tracks in the surrounding mostly agricultural environment.

SITE CLASSIFICATION

The site classification systems considered in this study are the International Building Code (IBC 2003) system (International Code Council 2003).
The IBC system is based on the average shear wave velocity over the top 30 m (VSav30).

Soil classification by shear wave velocity and material properties:

		Average Soil Properties for Top 30 m (100 feet)		
Soil Type	**Soil Name**	**Shear-wave Velocity, Vs (m/s)**	**Standard Penetration Test, N (blows/foot)**	**Undrained Shear Strength Su (kPa)**
S_A	Hard Rock	>1,500	not applicable	not applicable
S_B	Rock	760 to 1,500	not applicable	not applicable
S_C	Very Dense Soil and Soft Rock	360 to 760	>50	>100
S_D	Stiff Soil	180 to 360	15 to 50	50 to 100
S_E	Soft Soil	<180	<15	<50
S_F	Su < 23.9 kPa - Soil requiring site-specific evaluation			
A site also may be classified as soft soil if more than 3 m of soft clay is present.				

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