Environment Impact Assessment Report

for

Development of Holiday Inn Geoenvironmental and Geotechnical Aspects, Ameeneege, Male` Maldives, (Part I).

Proposed by
Male' Hotel Associate Pvt. Ltd.

Signature:

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November 2007

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Executive Summery

This is the part I of the full Environmental Impact Assessment (EIA) on development of a 15-story hotel (Holiday Inn), project, at Ameeneege Ameeru Ahmed Magu, Male Maldives. The proposed development includes construction of a 15-storey building on deep pile foundation. A total of 256 piles, 250x250mm steel H piles, will be driven into the bed rock, 85 piles will be penetrated to 36m deep, 153 piles to 39m, 8 piles to 30m and 16 piles to a depth of 33m. The project involves building the Holiday Inn, with 119 guest rooms and other accompanied hotel facilities such as swimming pool, banquette facilities, bakeries etc. The total investment cost of the project is estimated to be 20 million US$.

All the necessary permits to start the construction of the building was obtained, but once the construction started particularly pile driving was started, Male Municipality informed the developer to stop the work because neighbours complained about the vibration and noise from the construction work. Then the developer was asked to prepare an EIA as a fulfilment of the requirement by the Ministry of Environment Energy and Water (MEEW) for granting permission to continue the halted pile driving work of the project at the building site. According to the Environmental Protection and Preservation Act (EPPA) (law 4/93) of the Government of the Republic of Maldives has the authority to terminate projects that has any undesirable impact on the environment without compensation. Hence the work of the project was terminated until an Environmental Impact Assessment Report is submitted and approved by the MEEW.

Due to the termination of the work it is expected to delay the project work for more than 2 months during the construction period and the idle charges of the project is estimated to cost approximately 2.3 million US$/month for the developer.

Male` Municipality in a letter communicated to the developer on the 18th of October 2007 (Ref 99-I/mis/2007/10) informed that MEEW requested to submit a full EIA for the project, however, agreed to accept the report in two parts, where the first part should include the geotechnical aspects of deep piling and the second part would be the rest of the EIA components such as water, sewage, energy, waste management etc. Hence, this report has been mainly focussed on the environmental impacts associated with the geotechnical and geo-environmental aspects of the project.

This report has been prepared in accordance with the EIA regulations published by the MEEW in May 2007 and the Terms of Reference (ToR) given by the Environment Research Centre (ERC) and covers both negative and positive geoenvironmental geotechnical impact arising from the proposed development. Major findings of this report are based on assessments and studies undertaken from the project site, literature review and computer modelling as well as the following reports that have been prepared for the project at various stages of project development:

- Geotechnical Report by ELS-Amin International (Pvt) LTD.
- Structural Design Report CPLIM and Partners (Singapore)
- Concept Report of Mechanical and Electrical Engineering Services PCR Consulting Pte. Ltd. (Singapore)
- Acoustic Report by ViPAC Engineers and Scientists Pte. Ltd. (Singapore)
- High Strain Dynamic Pile Test Report by ABV Technology Pte. Ltd (Singapore)
- Existing structural conditions assessment report on ADK Tower, Asters Building, Athiriveli and Dharumvantha School by CIVENG Pvt. Ltd (Maldives)

Ameeneege (project site) is located on the northern part of Male` approximately 66m from the shoreline, at the corner of Nasreenu Goalhi- Ameeru Ahmed Magu corner. Subsurface geological condition of Ameenege shows that; the ground water level was at a depth of 1.57m; the top soil contains medium dense slightly silty fine coral sand with coral rock fragments; the soil below ground water table consist of medium dense coral sand with coral fragments, with occasional intrusions of thin layer of loose coral sand; between the basement coral rock and the medium dense coral sand layer there is an intermediate layer of dense coral sand with coral fragments and the bedrock consist of highly fractures very porous coral rock. Rock quality and rock mass property assessment shows that the foundation rock in Ameeneege is on weak rock mass in geological terms but that does not mean the rock doesn't have the capacity to hold and support the building because the rock has strength of 1GPa. Pile driving test carried out in the site shows that shaft resistance above 8m is about 10kPa and 10-19 kPa between 8and 14m and below 14m the resistance was between 20-35kPa. This shows that the pile could be easily driven into the ground without much resistance. Structural assessment of the status of the existing buildings in the vicinity (Athiriveli, Asters bulding, ADK Tower, Dharumavantha School) show that generally no building shows risk of structural failure but Athiriveli (about a pile length from the site) and Asters buildings (10-25m west of the site) need to be continuously monitored during pilling. Ambient sound level measurement in Male` during the day and early morning shows that the noise level is within the range of 54.4-70.2 dBA at day time and 44.7-65.7dBA at night time. Vibration level during pile driving was measured in Dharumawantha school, Asters building and ADK tower and recorded maximum Peak Particle Velocity (PPV) was 2.98mm/s with a frequency of 18HZ. According to the existing literature and internationally used vibration standards minor defect (hair crack) in buildings will call at PPV of 50mm/s.

For the purpose of this EIA report and in order to predict the environmental impacts associated with the construction of Holiday Inn and pile driving, the building was modeled by using Plaxis® software. The building was modeled to analyse the amount of vibration generated from pile driving, calculate the ground settlement levels and hydraulic hammer impact change with change in hammer weight, to the work as well as vibration and sound.

The overall impact from pile driving and the construction work would be short term increase in noise and vibration level in the area during the working hours, increase traffic and other short-term impacts arises from any similar construction site.

The long-term impact of the project would be ground settlement in that area various degree of ground settlement could be reached to 110m radius from the building. The highest level of settlement will be about 17mm near the building. These levels of settlements are within the allowable vertical and horizontal movement of the buildings and ground, therefore this could not be visually observed neither it would have physical damage impact on the buildings in the vicinity. Hair cracks might appear on the wall of buildings within a distance of pile length.

Short-term exposure of building and structures within the range of 2m radius to vibration might cause minor cracking in the buildings and the road.

The report has identified and described in detail possible change that would occur to the existing condition caused by pile driving during the construction phase and have suggested appropriate mitigation measures for each and every impact identified in the report. Appropriate monitoring and installation of vibration measuring devices crack monitoring devices, and vertical lateral ground movement measurements are found to be the most important mitigation measures. The main object is to detect any movement or impending damage before it is apparent to the eye and to take necessary corrective action before damage spreads.

The study has evaluated three alternative options for the project and has suggested that the path proposed in this EIA report is the best option. Also the report found that the long-term impact of ground settlement is within the allowable limits of horizontal and vertical movements of buildings therefore visually apparent or physical structural damage impact to the buildings is not anticipated from the development. However the report has come-up with an extensive monitoring programme and a mitigation action flow charts to keep on monitoring the existing cracks in buildings vibration and sound levels associated with the development and make necessary adjustment to the activities of the project based on the findings and measurements suggested in the monitoring and environmental management plan. A comprehensive compensation plan acceptable for both the developer and the affected person and the government has to be agreed prior to construction work in accordance with the laws and regulations of the Republic of Maldives.

On the basis of this EIA study and the impact mitigation measures proposed in the report will be duly implemented and suggestions made in the report are given due consideration, it is concluded that the benefits of the proposed development of a 15-storey Holiday Inn at Ameeneege will substantially outweigh its imposition on the environment.

1 Introduction

1.1 Background

This Report highlights the findings of the Environmental Impact Assessment (EIA) carried out for the development of a 15-story hotel (Holiday Inn), project, at Ameeneege Ameeru Ahmed Magu, Male Maldives (hereinafter referred to as the Project).The project has been proposed by Male` Hotel Associates Pvt. Ltd. (hereinafter referred to as the Proponent). The EIA was prepared as a fulfilment of the requirement by the Ministry of Environment Energy and Water (MEEW) for granting permission to continue the halted pile driving work of the project at the building site. According to the Environmental Protection and Preservation Act (EPPA) (law 4/93) of the Government of the Republic of Maldives has the authority to terminate projects that has any undesirable impact on the environment without compensation. Hence the work of the project was terminated until an Environmental Impact Assessment Report is submitted and approved by the MEEW.

The project involves building a 15-storey Holiday Inn, with 119 guest rooms and other accompanied hotel facilities such as swimming pool, banquette facilities, bakeries etc. The total investment cost of the project is estimated to be 20 million US$.

This is the first time MEEW requested to prepare an EIA for a high-rise building in the Maldives. So far number of high-rise buildings, even 15-storey buildings, has been built in Male` and developers were not asked to submit an EIA report. In this regard MEEW was asked to explain why this particular project has been asked to prepare an EIA, and they said that this is the first instance where pile foundation is used for a high rise building in the Maldives. During the preparation of the EIA it was noticed that pile has been driven fairly deep in the same block on western corner (Velaanaage) and also one block away, the Maldives National Defence Force (MNDF), west of the proposed building. It was also noticed that in those two buildings pile was driven only for dewatering and unlike the proposed project those are on rafts not pile foundations. Discussion with the concerned government authorities reveals that they have received several complaints from the neighbours on noise and vibrations. Therefore the whole purpose of requesting for an EIA is to document and address both developer and community concerns as well as the environmental impacts to take the appropriate mitigation measures to minimise the impacts.

General administrative practice in obtaining construction permission in Male` is that the land owner submits all the necessary document including architectural and structural details to the Male Municipality to seek permission for the building. Then the Male` Municipality will seek guidance from the Ministry of Construction and Public Infrastructure (MCPI) on structural details of the building, and Ministry of Housing and Urban Development (MHUD) will be asked to provide guidance on architectural and land use planning etc.. If any other permission from any concerned government authority is needed, Male` Municipality would inform the developer to seek it prior to construction work starts in the site, and in such a case a conditional permit will be given to the developer. As far as this project is concerned the developer has not been informed of requirement of any additional permission or documentation and building permission was given from the Male` Municipality on the 18th of July 2007 (Appendix 1).

As soon as the building permission was given the developer mobilised all the equipment and material and started the work. After few days of construction work and few piles were driven into the ground, the proponent was asked to submit the EIA for the project and terminate the work until the EIA submission. Due to the termination of the work it is expected to delay the project work for more than 2 months during the construction period and the idle charges of the project is estimated to cost approximately 2.3 million US$/month for the developer.

Male` Municipality in a letter communicated to the developer on the 18th of October 2007 (Ref 99-I/mis/2007/10) informed that MEEW requested to submit a full EIA for the project, however, agreed to accept the report in two parts, where the first part should include the geotechnical aspects of deep piling and the second part would be the rest of the EIA components such as water, sewage, energy, waste management etc. Hence, this report has been mainly focussed on the environmental impacts associated with the geotechnical and geo-environmental aspects of the project. Major findings of this report are based on assessments and studies undertaken from the project site as well as the following reports that have been prepared for the project at various stages of project development:

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This document has been produced in accordance with the EIA regulations published by the MEEW in 2007 as well as the Terms of Reference (ToR) provided by the Environment Research Centre (ERC) of the MEEW to the proponent on 23rd October 2007.

1.2 Terms of Reference for the EIA

This is the part one of the full EIA report and covers the geoenvironmental, and geotechnical impact assessment arising from the proposed development work at Ameeneege under the management of Male` Hotel Associates Pvt. Ltd. Terms of Reference (Appendix 2) provided by the Environment Research Centre (ERC) of the MEEW to the proponent on 23rd October 2007 involves:

1. Description of the proposed project
2. Description of the existing Environment, a geotechnical investigation of the site and ambient noise was mandated to be determined
3. Legislative and regulatory considerations
4. Determination of the potential Impacts of the proposed project, particularly land preparation and deep piling work, noise, fugitive dust traffic etc.
5. Analysis of alternatives for the project
6. Mitigation and management of negative impacts
7. Monitoring plan.

2 Project Description

2.2 The Proponent

The project is proposed by Hotel Associates Pvt. Ltd., a joint venture company. The land area proposed for the development of Holiday Inn is a property of Farahanaz Faisal of Ameeneege, and has been leased to Hotel Associates Pvt. Ltd.

2.3 Project Location and legal status of the land

The original land proposed for the project is part of the greater land plot known as Athireege, which was the private land register in the name of Ameenaa Mohamed Ameen, was gifted by her, to her four children: Ibrahim Faisal, Ameen Faisal, Farahnaz Faisal and Aishath Shuwaikar. Original Athireege land was subdivided into four part, upon the request of her children, now the eastern most part (land plot for hotel building) has been registered to Farahanaz Faisal as a separate piece of property (5711 sq.ft.,530.56m^2) under the name of Ameeneege .

Ameeneege is located on the northern part of the Henveyru district, which is also known as the commercial area in the capital city where most of the government offices and other important commercial buildings are located in this area. Ameeneege is located at the corner of Nasreenu Goalhi where it meets with Ameeru Ahmed Magu (Fig 1.).

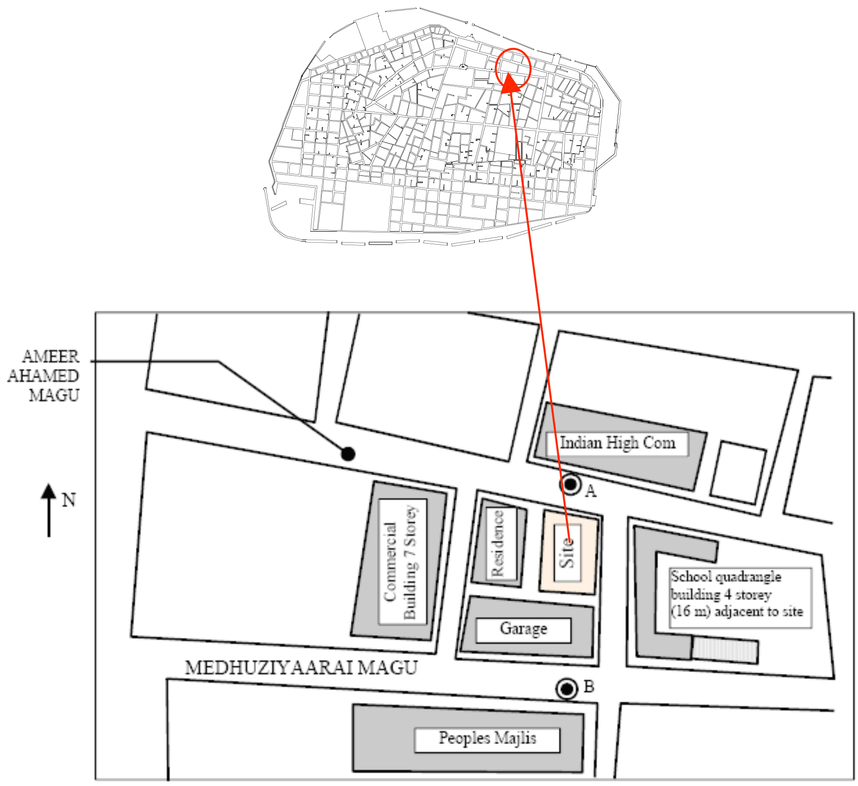


Fig 1. Location map of the project site.

2.4 Project Scope

The project involves building a 15-storey hotel, (Holiday Inn) in Ameeneege, and operate it at international 4-star standard hotel. The proposed building consists of RC (Semi-Basement & 1st Storey) System & Steelwork System (from 2nd Storey to Roof) with profile steel slab construction. The building will be sitting on a Steel, 'H' pile of 250 x 250 x 64.4 kg/m, foundation system. The pile capacity is estimated to be 405 kN, 465 kN, 525 kN and 585 kN with corresponding pile depth of penetration of 30m, 33m, 36m and 39m (Fig 2). A total of 85 piles will be penetrated to 36m depth, 153 piles to 39m, 8 piles to 30m and 16 piles to a depth of 33m, making the total number of piles that will be derived into the ground 256 H pile (Fig 3).

As mentioned earlier, this is the first time in the Maldives a deep pile foundation structure is constructed. Given the nature of pile driving the noise and vibration caused during the work has led to file number of complaints from the community and the neighbours against the developer as soon as the work started at the site. Considering the environmental conditions of the Maldives and the subsurface geology of Male island people's perception was that the process of pile driving might cause damage to the neighbouring buildings and structures. Therefore the scope of this document is only limited to assess and evaluate Environmental (mainly geotechnical and geoenvironmental) impacts that may have from the construction and operation of the hotel. Therefore this document is will mainly focus on environmental impacts associated with pile driving into the bed rock, physical damage to buildings in the vicinity as well as other relevant impacts related to construction of the building.

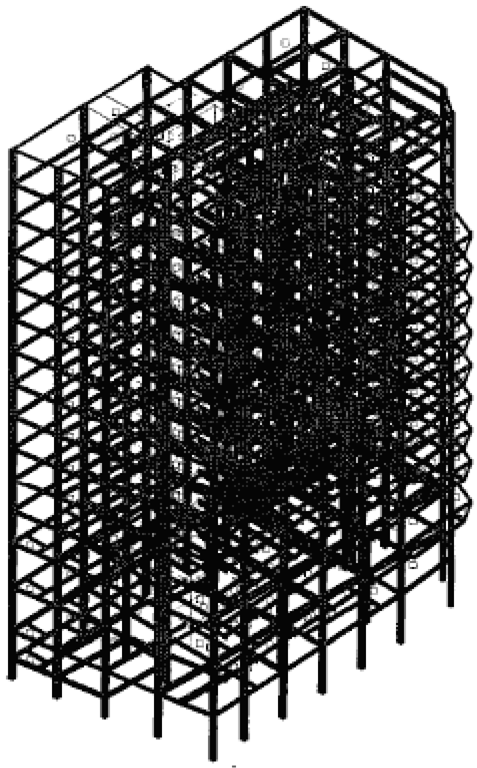
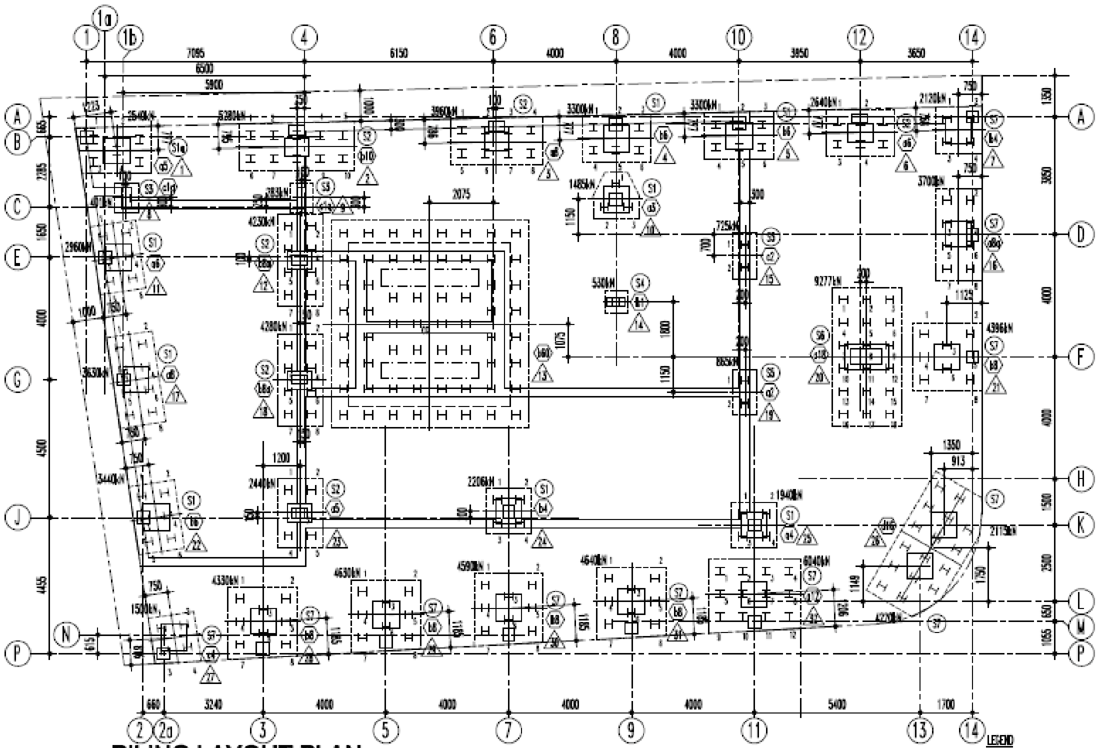


Fig 2. Steel frame of the proposed 15-storey Holiday Inn building at Ameeneege.



PILING LAYOUT PLAN

LEGEND	GRADE 45 CONC. PILE SIZE	PILE CAPACITY (kN)	NEGATIVE SKIN FRICTION (kN)	PILE ALLOWABLE (kN)	WORKING LOAD TEST (kN)	PENETRATION DEPTH FROM C.G.L (m)	TOTAL NO. OF PILE	NO. OF ULT LOAD TEST	NO. OF WORKING TEST	NO. OF PDA TEST
H (a)	250X250X64.4kg/m H-PILE	-	-	525	787.5	36	85	-	-	-
H (b)	250X250X64.4kg/m H-PILE	-	-	585	877.5	39	153	-	-	-
H (c)	250X250X64.4kg/m H-PILE	-	-	405	607.5	30	8	-	-	-
H (d)	250X250X64.4kg/m H-PILE	-	-	465	697.5	33	16	-	-	-

LEGEND

- ○ —— DENOTES COLUMN MARKING
- △ —— DENOTES PILEGROUP
- ⬡ —— DENOTES TYPE OF PILECAP

NOTES :

1) ONE NUMBER STATIC LOAD TEST TO BE CARRIED OUT.
2) H-PILES ARE TO PILE TO SET.
PILE SET CALCULATION BASED ON 2.5 TIMES THE PILE CAPACITY

Fig 3. Pile layout plan, a total 256steel H-piles will be driven into the ground.

2.5 Project Justification

The economic growth and the development that took place in last couple of decades in the Maldives have made the capital city of Male` centre of all socio-economic and financial activities of the Maldives. Apart from the tourists visiting the exotic resorts, there are large number of visitor to Male to do business, to visit local islands and to attend conferences, seminars and meetings. For these category of people it is always hard to get accommodation in a nearby resort also to travel back and forth for meeting in Male`. Beside this, travelling from nearby resort to Male by a speed launch is extremely expensive and in rough weather condition it is painful. Lack of appropriate halls and banquette facilities in Male makes the cost of arranging and organising meetings expensive and unattractive for organisers. Therefore there is a need develop such a facility in Male to cater not only for the foreigners who visit Maldives but also for the Maldivians who wants to hold meetings conferences, parties, weddings, banquettes etc. in Male.

The overall investment of the project is estimated to be 20 million US$, the following is breakdown of costs is US$:

- 1 million Piling
- 6.4 million General building works
- 2 million Structural works
- 2 million Interior Design and Fittings
- 0.8 million Hotel Operating Equipment & Supply
- 2 million Consultants Fees etc
- 5.8 million various other fees including Banking ,Legal, miscellaneous

The proposed Holiday Inn will be designed, built and operated to the world wide standard of the Intercontinental Hotel Group (IHG), including the 2007 standard “green line” IHG’s Response to Global Warming. The hotel is and international 4 star property which will contribute much to the country’s economy establish new standards for the Male` Hotel scene and satisfy the needs of the local population for good quality food and beverages and provide full conference and banquette facilities.

2.6 Project Workforce

During the construction phase the project will have 20-50 direct employment positions. In employing people priority will be given for the Maldivians. During the operational phase the Hotel will have approximately 50-70 direct and indirect employment opportunities.

2.7 Project development data

a)Site area 530.56sqm
b) Total built-up area 7299.30.sqm
Excluding roof, part pool Deck, Swiming pool area)
(part pool deck 93.80 sqm & swimming pool 118.00sqm)
c) Total area (including roof) 7511.10sqm
d) No. of guest rooms 119

Table1. Shows area allocation in each storey of the building

storey	Allocated for	Area in (m^2)

Basement	Water and fuel storage tank and Pump room	226.1
1st storey	Hotel lobby/ Reception/ pastry counter/ Admin office/ M&E service and BOTH	481.60
2nd storey	Restaurant/ Kitchen & Toilets	458.80
3rd storey	Banquet/meeting room Kitchen and Toilet	500.70
4th Storey	Guest room (3 nos) SPA and BOTH rooms	501.60
5th storey	Guest rooms (12 nos) & Bakery	501.60
Typical 6th-10th Storey (501.60x5 floors)	Guest rooms (13x5 storey)	2508.00 in 5 floors
11th storey	Guest rooms (13 nos)	501.6
12th storey	Guest rooms (13 nos)	456.90
13th storey	Guest rooms (13 nos)	456.90
14th storey (M&E space)	M&E service	462.70
15th storey / pool deck	Reataurent/ Gym/ Changing room/ Pool deck and pool	454.60
Total area		**7511.10**

2.8 Structural system of the building

2.8.1 Design concept

Proposed development consists of 15-Storey Structure. Semi-Basement & 1st Storey consists of RC System., while 2nd to Roof consists of Steelworks with profile Steel slab construction. Temporary propping is required for bondek slab construction (1.0mm thick metal sheet from Bondek II or approved Equivalent). All steel columns are in filled with minimum Grade 30 concrete, with opening for vapor built up release.

To allow for column-free banquet hall at the 3rd Storey, transfer beams comprising of steel box girders are provided at the 4th Storey. Temporary propping is required during construction stage to avoid additional stresses to the steel beams supported on the transfer columns.

Estimated design wind load for the structure is 74mile/hr, based on the strongest wind Male` has experienced in last 20 years, and is analysed using 3-D modeling to check the core wall and columns. Wind analysis show that the maximum lateral displacement and inter-storey drift are within the allowable lateral displacement of H/500 and L/500.

2.8.2 Stability of the frame structure

All loads from the horizontal element are supported on steel columns which transfer the load to pile. Pilecaps are designed to transfer the load from columns to piles. Vertical loads at base level would be transfer directly to pile from pilecaps.

2.8.3 Foundation system

Both raft and deep pile foundation and has been considered during the design stage but due to the high bearing stress in raft foundations, deep foundation system has been preferred and adopted. Steel 'H' pile of 250 x 250 x 64.4 kg/m is used for the foundation system. The pile capacity as computed are 405 kN, 465 kN, 525 kN and 585 kN with corresponding pile depth of penetration of 30m, 33m, 36m and 39m. Geotechnical capacity of the pile is computed using Meyerhof Method. The pile capacity was validated by pile load test conducted in the site.

2.8.4 Material specification and load estimations

The building has been designed to meet the British building cord standards. Therefore all the materials used in the project will meet the specifications set out in the building code of the United Kingdom. The following are the material specification and load estimations for Holiday Inn.

I- Material Specification

a) Concrete Grade	fcu = 30N/mm2
Concrete Grade (Sub-structures)	fcu = 35N/mm2
b) Yield Strength of steel bars	fy = 460 N/mm 2
c) Mild-Yield Bar – (R)	fyv = 250 N/mm 2

d) Structural Steel members to comply to standards BS EN 10025-2, BS EN10210-1 for steel grade S355
e) All Structural steel section to be hot-rolled
f) All Welding to be 8 FW U.O.S (fillet weld all round)
g) Weld Strength (E51 Electrodes) = 255 N/mm2
h) All Bolts to be of Grade 8.8 U.O.S
i) Bondek System to be 1.0mm thick bondek sheet of Bondek II or other approved Equivalent.

II- Material Dead Load

Density of Concrete -	2400 kg/m^3
Density of Steel -	7850 kg/m^3
Finishes (25mm thick) -	0.6 kN/m^2
Finishes (50mm thick) -	1.2 kN/m2
Partition -	0.5 kN/m^2
M&E/Ceiling -	0.5kN/m^2
Brick wall (100mm thick) -	2.7 kN/m^2 height
Brick wall (200mm thick) -	5.4 kN/m^2 height
Steel Roof DL -	0.5 kN/m^2
Wind Load - (Based on 74mile/hr)	1.03kN/m^2

III- Super-Imposed Live Load

	Live Load (kN/m^2)
Hotel Rooms	2.0
Kitchen/Laundries	2.0
Toilets	2.0
Office	4.0
Lift Lobby/Staircase	4.0
Hotel Lobby	5.0
Pool Deck	5.0
Lounges/Gym/Bar	5.0
Restaurant/Banquet Hall	5.0
M&E Equipment Room (or by weight specification of Equipment)	7.5
LT& HT / Transformer Room (or by weight specification of Equipment)	16
Genset Room (or by weight specification of Equipment)	10
Glass Canopy /Steel roof	0.5
Retractable Roof	No access

2.9 Hotel Facilities and Components

2.9.1 Energy Generation

Maximum Demand for energy for the Holiday Inn is estimated to be 956 kVA. Two diesel generators will be installed to provide the full power supply to the hotel. All the energy needed for project will be produced from 2 diesel generator 500kVA (400kW) sets installed at the basement of the building. The two generators will be synchronised to give flexibility in the operation. In addition, the mains supply will be used as back up, as and when required.

The switchboard serving the essential building services which includes homing of lifts, fire pumps, emergency lightings, staircase/car park ventilation fans, smoke extract fans, domestic water booster pumps will be segregated from the switchboard serving the normal building services loads for ease of maintenance.

Fuel needed for the generators will be stored in an underground fuel storage tank, which is 23000 litres and it is adequate for 3 to 4 days. The storage take will meet local and international regulations and standards.

2.9.2 Illumination

Generally the lighting source and control gears will be selected on the basis of energy efficiency, aesthetics, good colour rendition and ease of maintenance/re-lamping. Low glare double parabolic mirror louvered fluorescent fittings with low loss ballast will be provided in the back of house area. Emergency lighting will be provided to light up the exit path as per British Standards.

2.9.3 Fire safety and Emergency Communication systems

All the areas of hotel will be provided with sprinkler, wet riser, hose reel and private hydrant system.

Water for sprinkler, wet riser, hose reel and hydrant system will be tapped from the roof swimming pool with pumps located at L14 Two electrical fire pumps (one operating and one standby) with power back up by generator will be provided. One jockey pump will be provided. Common pump to serve sprinklers, hose reel, wet riser and private hydrant will be used.

Fuel will be handled and stored with maximum precautionary measures. All diesel fuel tanks will be completely bonded to protect against accidental spill or partial or even total collapse of the tank

Fire fighting system will meet the standards set out by the National Fire Code.

Addressable fire alarm system will be provided throughout the hotel. Smoke detectors will be provided at guest rooms and front of house areas. Kitchen will be provided with heat detector. Main alarm panel will be provided at the fire command centre and a repeater will be provided at the chief engineer's office

An emergency voice communication system comprising a public address system and a firemen intercom system will be provided to facilitate broadcasting and evacuation of occupants during emergency and fire in compliance with British Standards.

In-house radio and music system will be interlinked to the emergency voice communication system for normal paging and play of background music to the public areas, toilets, lobbies, lift cars etc. during normal operation. Two operator control panels will be provided (one at the Fire Command Centre and the other at the Telephone Operator Room) for paging through the Public Address System. Firemen intercom phones will be provided at each smoke free lobby.

2.9.4 Building Security System

Building Security System comprises of closed circuit television system for selected areas and watchman tour system is contemplated for security control and surveillance of the building.

2.9.5 Air conditioning and ventilation system

Guest rooms will be air-conditioned by ceiling suspended DX fan coil units. Fan coil units will be connected to VRV condensing unit. Each Guest room will be controlled by wall-mounted thermostat with 3-speed switch.

Guest room corridors will be air conditioned by VRV DX fan coil units. Fresh air supply to guest room will be by pre-cooled fresh air AHU(DX) located at roof. Fresh air ducts will run inside vertical risers and branch off to each guestroom FCU. The air supply to corridors will be adequate to keep corridors slightly pressurised compared to guest rooms. Air from corridor will be allowed to seep through the door undercuts into guest room toilets. Return air grille will be located inside the wardrobe. Air gaps to be provided in the doors of wardrobe for return air to fan coil units.

Toilet exhaust for each guest room will be routed through ducts in vertical risers to exhaust fans located at roof. Guest room thermostats will be linked to card key system to reset to higher temperature (27 degree C) and the fan speed to low speed automatically once the card key is removed from the holder.

Public areas like ball rooms, Restaurants, lobby, meeting rooms will be air conditioned by ceiling suspended VRV DX FCUs. Condensers will be located at L14. Ballroom/function rooms/pre function lounge will be provided with VRV DX FCus condensers located at L14. Business centre/admin office/lobby lounge/reception area will be provided with VRV DX FCUs condensers located at L14. Wall mounted temperature sensors to be controlled by BAS. Front of house areas will be provided with linear diffusers.

Kitchen will be air conditioned. To condition at around 27º dB. All the air conditioned air will be exhausted through kitchen exhaust system. Kitchen ventilation fan will be located within respective kitchen.

Back of house areas like staff changing rooms, Linen stores, toilets, plant rooms, lift motor rooms will be mechanically ventilated. Other back of house areas like security rooms, food stores, engineering rooms, building control rooms will be air-conditioned

2.9.6 Plumbing and sanitary pipe installation

All the water needed for the Hotel will be obtained from the local water company (MWSC) public pipelines. Estimated water consumption in the hotel is 175m3/day. Beside that underground RC tank will be designed to store one-day water consumption of hotel and roof FRP tank will be designed to cater for one-hour peak demand of hotel and for emergency purposes. Booster pumps located at roof will serve all guest rooms. Maximum pressure estimated at the lowest guest room floor will be 5 bars, which will be good for massaging type showers. Hot water will be generated by electric heat pumps and calorifiers. 2 nos. below each heat pump and 3 nos. 2500 litres calorifier will be provided at L14 for guestrooms. 2 nos. 18kW each heat pump and 2 nos. 1500 litres calorifiers will be provided at basement for serving L3 and below. Guest rooms will be provided with re-circulating hot water system

The sewer system of the hotel will be connected to the public sewer system. Guest rooms will be provided with fully ventilated stack system comprising of soil/waste and vent pipes. Soil/Waste will be discharged into city sewer. Kitchen waste will be passed to grease trap before discharge into city sewer. Condensate water from air conditioning system will be collected in a dedicated insulated pipe and discharge into storm water system. Generally two guest rooms will share a vertical riser consisting of pipes like cold water, hot water, and condensate water.

2.10 Project Activities – Construction phase

2.10.1 Site clearance and preparation

The site has already been cleared and the building existed there has already been demolished. Demolition waste was disposed off at Male` Kuni Koshi. Three boreholes were made to study the geotechnical aspects and subsurface geological condition of the site. Data collected from those boreholes were used for designing the building foundation.

2.10.2 Pile driving

As mentioned in the structural details of building the whole building will be standing on a pile foundation. A total of 256 piles, 250x250mm steel H piles, will be driven into the bed rock, 85 piles will be penetrated to 36m deep, 153 piles to 39m, 8 piles to 30m and 16 piles to a depth of 33m. The piles shall be driven with a hydraulic drop hammer. The drop hammer has a 3-tonnes ram and ram stroke of up to 1m shall be used for driving the piles.

High strain dynamic pile test has been conducted in the site by the ABV Technology Pte. Ltd. A Singaporean company and a report on 4 test pile have been produced. The result shows that the rock resistance to pile driving was very low, less than 10kPa at 8m depth and 20-30kPa below 14m depth. Therefore it is anticipated that the proposed pile driving would not be faced with much resistance during the construction.

2.10.3 Excavations & Dewatering

The central area within the ring of H pile will be excavated to a depth of 1.1 to 1.5m. The ground from the edge of this excavation area up to the pile boundary is left as a sloping section providing support to the wall. Then the raft slab is constructed from the boundary of the pile. So far a method for dewatering has not been selected because the water lens was found at a depth 1.57m, therefore, the excavation will not reach the water lens. If water lens is reached and dewatering becomes necessary, the de-watering method will be based on estimates of

Discharge based on depth of pile wall
Pump capacity required; and
Safety against piping

Given the present status of the ground water lens of Male`, during the dewatering process water will not be pumped out to the sea it will be sunk back into the ground in a different location if possible.

3 Existing Environment

This section describes the soil and geological condition of the site, ambient noise level in Male` and structural assessment of buildings nearby the proposed project site. Much of the information used in this section are based on the Geotechnical Report by ELS-Amin International (Pvt) LTD, Existing Structural Conditions Assessment Report on ADK Tower, Asters Building, Athiriveli and Dharumvantha School by CIVENG Pvt. Ltd (Maldives), Acoustic Report by ViPAC Engineers and Scientists Pte. Ltd. (Singapore) as well as ambient noise level measurements conducted from 3-6 November 2007.

3.1 Location

Ameeneege (project site) is located on the northern part of Male` approximately 66m from the shoreline. It is located at the corner of Nasreenu Goalhi- Ameeru Ahmed Magu corner. Figure 4 is a Google earth picture showing the location of Ameeneege and buildings in the vicinity.

Fig 4. Google Earth™ map of Male` showing the location of Ameeneege and the neighbouring buildings.

3.2 Geology

Subsurface geology information on site and area conditions is based on a review of geotechnical borehole logs conducted by ELS Amin International Pvt. Ltd. from 12-24th September 2006. Summary of borehole investigation is shown in Table 2. and (Fig 5) shows the location of boreholes.

Table 2. Summary of the borehole investigation

Borehole No.	Drilling in overburden (m)	Rock (m)	Total Depth (m)	Groundwater Level (m)
BH-01	25.70	9.30	35.00	1.53
BH-02	24.00	26.00	50.00	1.57
BH-03	22.50	12.50	35.00	1.62

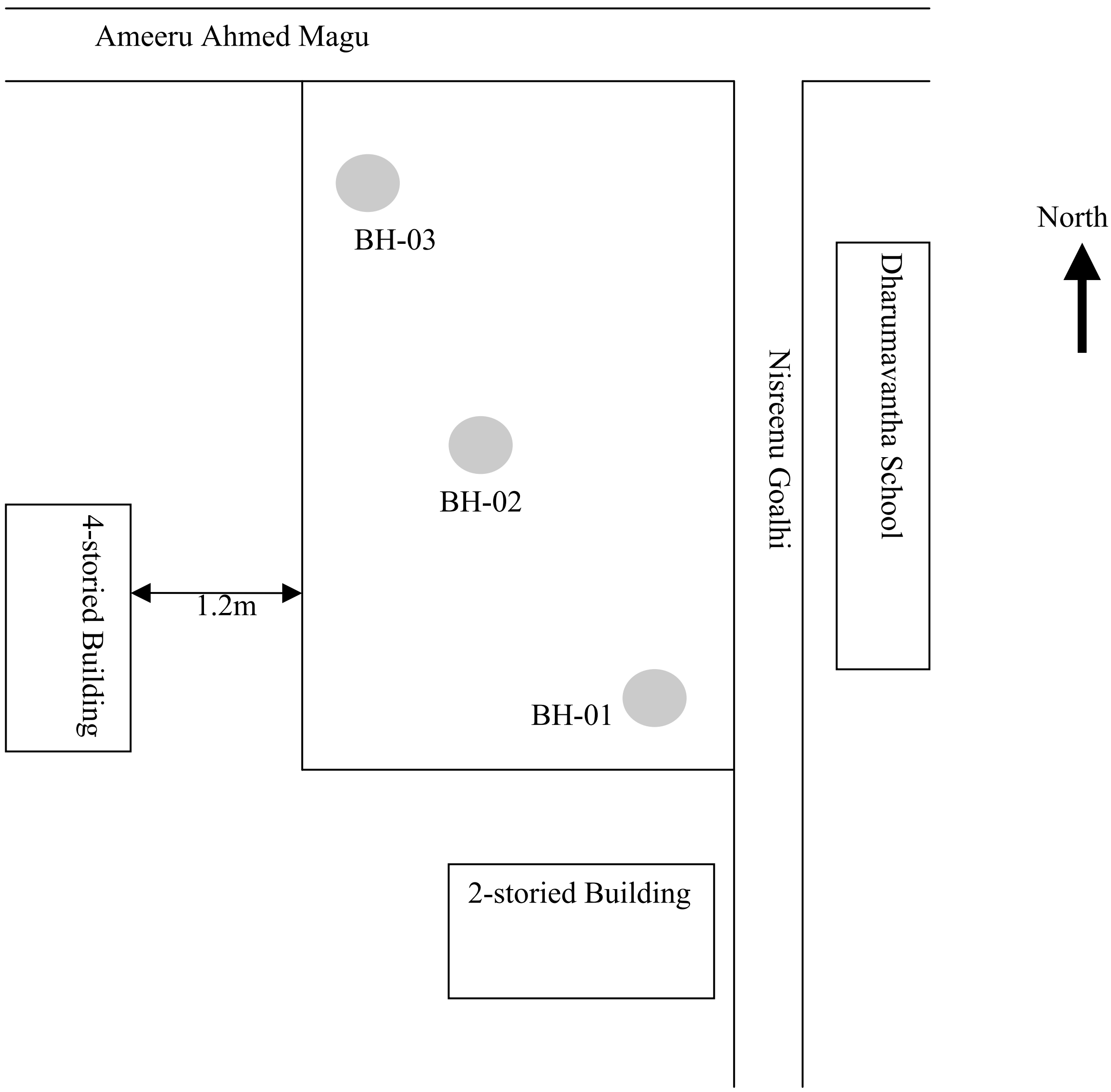


Fig 5. Location of boreholes in the site. Note that the northern and eastern boundary of the site consist of main roads, on the southern boundary there is a 2-storey building adjacent to the common property line, and on the western side a 4-storey building about 1.2m from the common property line.

3.2.1 Subsurface conditions

Using the results of the Borehole Investigation, a profile of the sub-surface conditions across the boreholes has been constructed and this is shown as figure 2. These results show that;

- The ground water level (GWL) was at a depth of around 1.57m at the time of investigation;
- The surface horizon above GWL was a surface layer of top soil containing medium dense, slightly silty fine coral sand with coral rock fragments, shell fragments and demolished building materials.
- The soils below GWL consist of medium dense coral sand with coral fragments, with occasional intrusions of thin layer of loose coral sand which is consisting with coral rock fragments and shell fragments. (e.g. between depths of 1.0m and 3.0m at BH-02).

- In between the basement coral rock and the above mentioned medium dense coral sand layer there is an intermediate layer of dense coral sand with coral fragments. Detail log of each borehole is summarised in the Table 3.
-

Table 3. Detail borehole logs of Ameeneege.

BH No	Depth (m)	Detail description of the strata
BH-01	0-3.45	Medium dense light brown, slightly silty fine coral sand with coral rock fragments and shell fragments, water table at 1.53m.
	3.45-16.50	Medium dense whitish yellow, silty-fine sand with coral fragments and shell fragments
	16.50-25.75	Dense whitish yellow, silty-fine sand with coral fragments and shell fragments
	25.75-35.00	White medium grained highly fractured porous coral rock
BH-02	0-1.00	Light brown clayey, fine sand, top soil, ground water level at 1.57m
	1-3.45	Loose light gray slightly silty fine coral sand with coral fragments and shell fragments
	1.45-10.50	Medium dense light brown silty coral medium sand with coral fragments and shell fragments
	10.50-23.00	Medium dense whitish yellow, silty-fine sand with coral fragments and shell fragments
	23.00-24.00	dense whitish yellow, silty-fine sand with coral fragments
	24-50.00	White medium grained highly fractured porous coral rock
BH-03	0-1.45	Medium dense light brown fine coral sand with demolished building materials, top soil Ground water level 1.62m.
	1.45-21.00	Medium dense yellowish white , silty-fine coral sand with coral fragments and shell fragments
	21-22.5	Dense whitish yellow, slightly silty-fine – medium coral sand with coral rock fragments
	22.5-35.00	White medium grained highly fractured porous coral rock.

3.2.2 Rock Quality Designation index (RQD)

The Rock Quality Designation index (RQD) was developed by Deere (Deere et al 1967) to provide a quantitative estimate of rock mass quality from drill core logs. RQD is defined as the percentage of intact core pieces longer than 100 mm (4 inches) in the total length of core. RQD is intended to represent the rock mass quality in situ. From the borehole logs of Ameeneege it shows that the RQD of all three cores has 0%, which means that the in situ rock has a very poor quality.

3.2.3 Rock Mass properties

By reanalyzing the borehole log data, rock mass properties of the area was determined. From the borehole logs it indicates that the coral rock that lies in the subsurface is highly fractured and very porous, therefore for the calculation of rock mass properties Geological Strength Index of 20 is assigned for the calculation. Figure 6 shows rock strength analysis using Rocklab^{TM} software. The analysis shows that Ameeneege pile foundation is on a weak rock mass in geological terms, but that does not mean the rock doesn’t have the capacity to hold and support the building because the rock has strength of 1GPa.

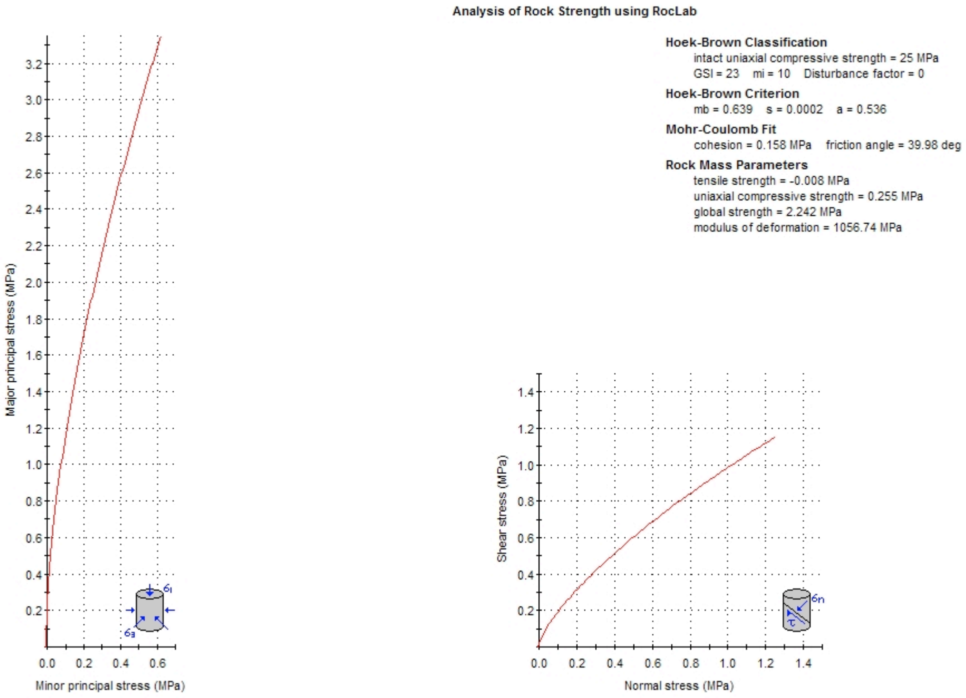


Fig 6 .Showing the rock strength analysis, Ameeneege samples, by using Rocklab™ .

3.2.4 Subsurface soil

The subsurface soil at the site can be briefly described as follow:

- from surface to a depth of 17m consists of medium dense silty coral sand and has a Standard Penetration Test blowcount value, "N" or SPT N-value between 11 and 27.
- From 17-26m depth is a dense silty coral sand with SPT N-value between 31-50
- Below 26m was medium grained highly fractured porous coral rock.

3.2.5 High Strain Dynamic Pile Test

High strain dynamic pile test was performed by ABV Technology Pte. Ltd (Singapore), at the site to evaluate the performance and integrity of steel piles and to test the penetratebility of piles in to the ground. The test was conducted according to the American Society for Testing and Materials (ASTM D 4945-2000), the test was accomplished with the use o f a Pile Driving Analyzer® (PDA) detail analysis were carried by using a computer Program CAPWAP ® Case Pile Wave Analysis Program). Four test piles were derived, summery results of the test are shown in Table 4. The result of test showed that shaft resistance above 8m is about 10kPa and 10-19 kPa between 8and 14m and below 14m the resistance was between 20-35kPa. This shows that the pile could be easily driven into the ground without much resistance.

Table 4. High strain pile test summery of CAPWAP® results.

Pile no.	Toe dept	Soil Damping		Soil Quake		Static soil resistance		
		Shaft (s/m)	Toe (s/m)	Shaft (m/m)	Toe (m/m)	Shaft (ton)	Toe (ton)	Total (ton)
1	30	0.39	1.33	2.5	13.0	56	8	64
2	26.3	0.42	1.26	2.5	10.0	40	8	48
3	26.2	0.53	1.71	2.5	9.5	41	6	47
4	24.2	0.50	1.59	2.5	7.0	47	6	53

3.3 Status of Existing buildings in the vicinity

The Ministry of Construction and Public Infrastructure requested in an official communication with the developer to conduct a survey to assess the status of the building at 70m radius from the proposed Holiday Inn development site. The letter also stated that priority in assessment should be given to the 4 buildings in the immediate vicinity of the site; they are The Athitirveli, Asters Building and AD K Tower are on the west of the site Dharumawantha School (east of the site). The developer hired an engineering firm (CIVENG Pvt.Ltd) to conduct the assessment. Assessment report will be available for the concerned authorities. The following section will briefly discuss the methodologies used for the survey and major findings of the assessment of four buildings.

3.3.1 Survey methodology

Status assessment was based on visual inspection. As understood by the structural failure mechanism, building structures give number of visual warnings in the form of cracks before the structure fails and this failure ultimately leading to collapse of the building. Usually the location and the form and the crack indicate structural severity.

The scope of status assessment includes description of the building and comprise, class of use, age of the building, type of primary and secondary structure, structural material, type of secondary elements such as walls, cladding material and if possible, estimated depth of foundation.

Field observations of existing damages to the building in terms of distress, cracks, sealant damages, water leakages; width of cracks have been estimated based on digital imaging of the cracked area by capturing the area with high resolution digital camera and comparative analysis with a reference scale. Wherever possible, observations were made on the interior as well exterior surface of the building.
The survey was conducted between 28th September 2007 and 15th October 2007.

The following sections give a brief description of major findings of the structural assessment of building in the vicinity of the site:

i) **ADK Tower**

ADK tower building, shown in (Fig 7), is built to 10 storey, constructed with reinforced concrete frames as primary structure on raft foundation. Exterior cladding was masonry walls, glass curtain wall, aluminium framed glass windows and solid timber doors. This building is approximately 12-30m west of the site.

Fig 7. ADK tower 12-30m west of the site.

The report states that during the observation about 130 locations in the building have been found to have some form of defects. Most of the defects were in the form cracks on the masonry walls and some are on masonry to concrete joints or masonry to timber door frame joints risk of structural failure was not observed from the building. Table 5 . shows the distribution of defect in the building, each floor separately.

Table 5. Distribution of locations of defects compared for floor levels ADK tower.

Floor level	Locations of defects	%
Ground floor Level	10	7.7%
First floor Level	11	8.5%
Second Floor Level	12	9.2%
Third floor Level	6	4.6%
Fourth floor level	13	10.0%
Fifth floor level	10	7.7%
Sixth floor level	12	9.2%
Seventh floor level	7	5.4%
Eighth floor level	13	10.0%
Ninth floor level	21	16.2%
Tenth/terrace floor level	13	10.0%
Roof top level	2	1.5%

ii) Asters Building

Asters building (Fig 8) is generally built to four storey blocks with one block with two storey constructed with reinforced concrete frames as primary structure and exterior cladding with masonry walls, aluminium framed as well as timber framed glass windows and doors. This building is 10-25m west of the site.

The report found about 147 defects in the building. Most of the defects were in the form cracks on the masonry walls and some are on masonry to concrete joints or masonry to timber door frame joints. Few cracks have been observed on structural elements. No indication of structural failure were observed, however, the report recommends to check the existing vertical crack in the columns in ground floor by a maintenance structural engineer. Table 6 shows distribution of defects in Asters Building.

Table 6 . Distribution of locations of defects compared for floor levels Asters building.

Floor level	Locations of defects	%
Level 1	19	12.9%
Level 2	15	10.2%
Level 3	26	17.7%
Level 4	20	13.6%
Level 5	44	29.9%
Level 6	23	15.6%

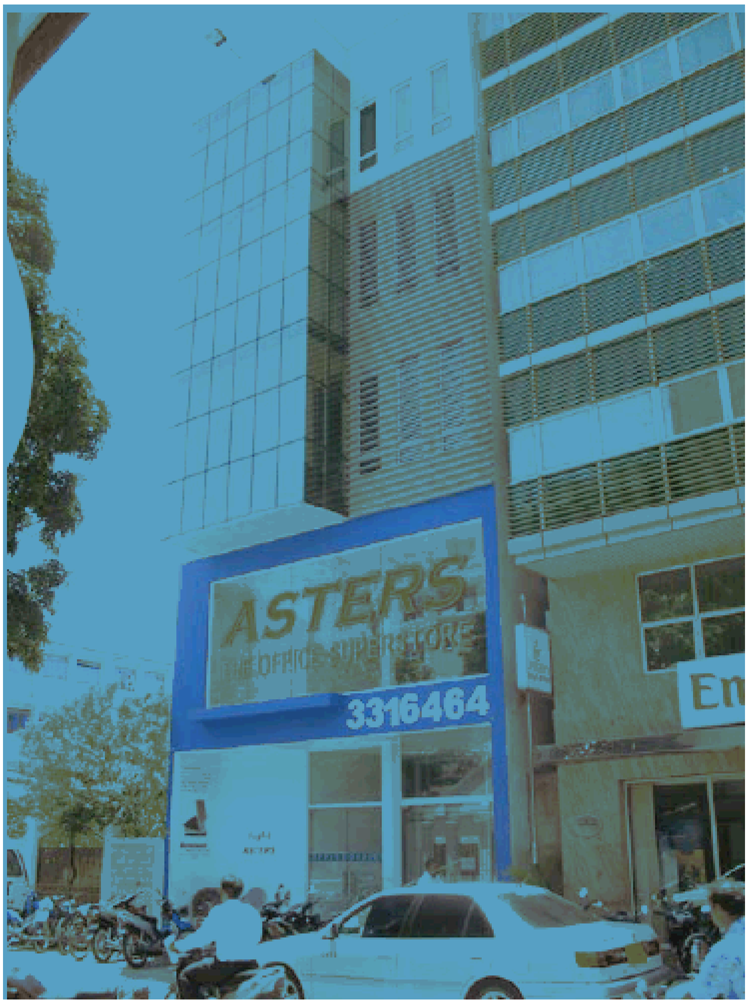


Fig 8. Asters building 10-25m away from the site.

iii) Athiriveli

H. Athiriveli, shown in (Fig 9) is a four storey residential building constructed with reinforced concrete frames as primary structure and exterior cladding with masonry walls, aluminum framed glass windows and doors. Proposed site for hotel development and the Athiriveli are in the property line and share single boundary line at west. The distance measured from the centre of the plots gives about approximately 13 m.

Building defects were noted in about 50 locations in the building. Most of the defects were in the form of cracks on the masonry walls and some susceptible area of water leakage was observed. Risk of structural failure was not observed in the building during the survey. Table 7 shows distribution of building defects in Athiriveli.

Table 7. Distribution of locations of defects compared for floor levels Athiriveli

Floor level	Locations of defects	%
Basement Level	0	0.0%
Ground floor Level	10	20.0%
First floor Level	4	8.0%
Second Floor Level	22	44.0%
Terrac/roof Level	14	28.0%

Fig 9. Athiriveli Residence at the property boundary line with the site approximately 1.2m west of the site.

iv) Dharumvantha School

Dharumavantha school (Fig 10) is generally built to four storey blocks with one with one block with two storey constructed with reinforced concrete frames as primary structure and exterior cladding with masonry walls, aluminium framed as well as timber framed glass windows and doors. The school is located 50m east of the site.

Building defects were noted in 162 locations and most of the defects were in the form cracks on the masonry walls and some are on concrete primary structure. Structural elements had cracks at some area and the report recommends to monitor them during the progress of proposed construction works. Table 8 Distribution of defects in Dharumavantha School.

Table 8. Distribution of locations of defects compared for floor levels Dharumawantha School.

Floor level	Locations of defects	%
Ground floor Level	75	46.3%
First floor Level	37	22.8%
Second Floor Level	30	18.5%
Third Level	15	9.3%
Terrace/roof Level	5	3.1%

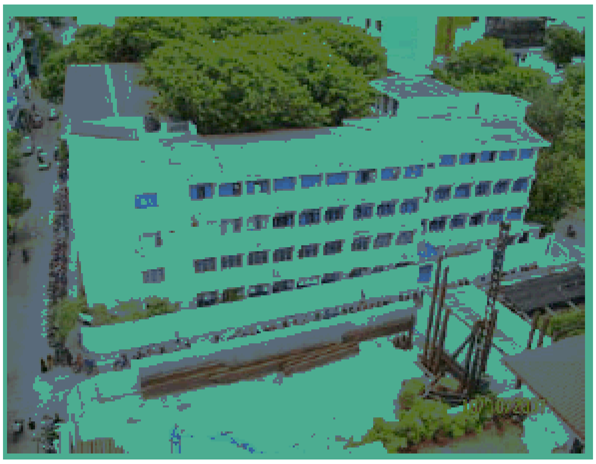


Fig 10. Dharumavantha school 50m east of the site

3.4 Ambient noise level in Male`

During the field visit 2nd -6th of November sound level was measured in 59 station around Male, during daytime from 13-15.00 hours and early morning from 1-3. 00 hours by using a BK 732 Sound Level Meter to record the ambient sound level in the city. ViPAC Engineering and Scientist have carried out sound level measurent from 16-17th July during the desinigning stage of Holiday Inn to ensure that the archtectual designing takes account of ambient sound level in Male and the sound level in the hotel will meet the requirement and standards of Intercontinental.

For the purpose of this EIA report ambient sound level all around Male` has been determined and the Table 9 shows summary statistics of dBA levels, and (Fig 11 and 12) shows street level ambient noise level in Male`.

Table 9 . Ambient noise level in Male`, recorded maximum, minimum and average during day and night time.

	Day dBA	Night dBA
Maximum	70.2	65.7
Minimum	54.4	44.7
Average	63.38475	52.35424

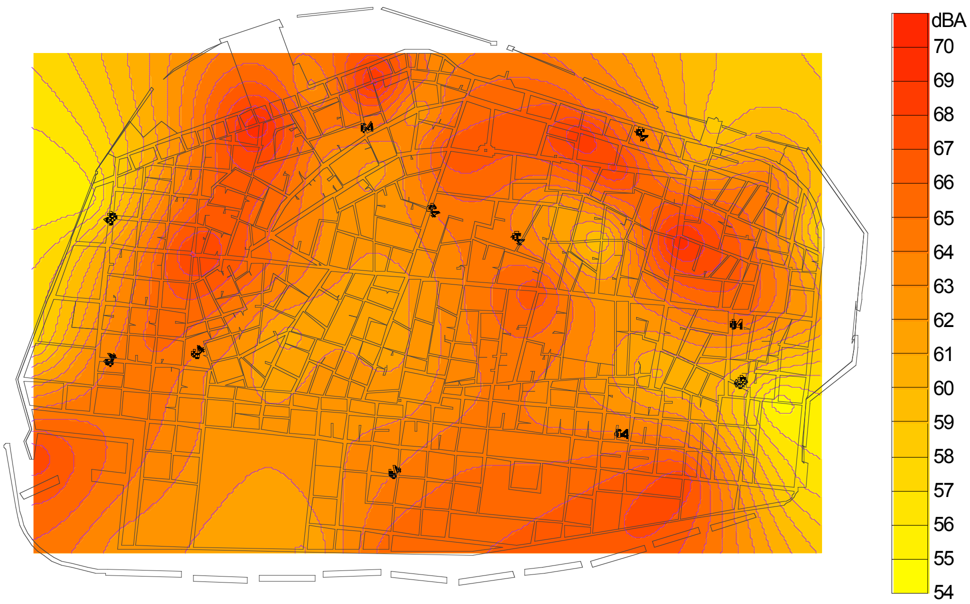


Fig 11. countours of ambient noise level at day time in Male.

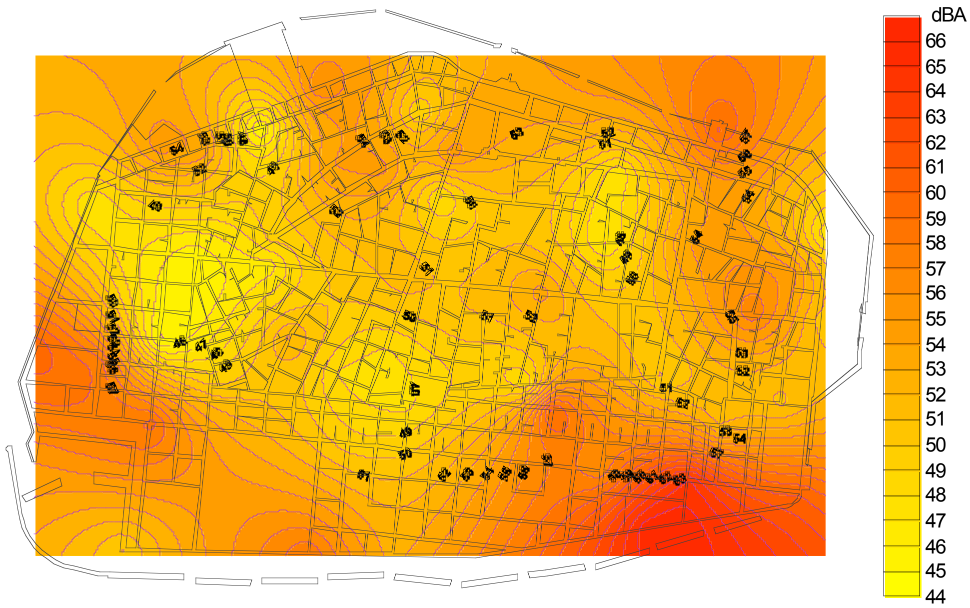


Fig 12. Countours of ambient noise level at night time in Male`

3.5 Vibration

During the SPT test pile driving on the site, vibration were measured using a minimate® Vibration and Overpressure Monitor, placed at the top floor of some of the aforementioned buildings on the 20th 2nd and 23rd of September 2007. Maximum Peak Particle Velocity PPV recorded was 2.98mm/s and the maximum frequency recorded was 18Hz. Sample vibration record obtained from the site during the test pile driving operation, compared with standard DIN 4150-3, is shown in (Fig 13).

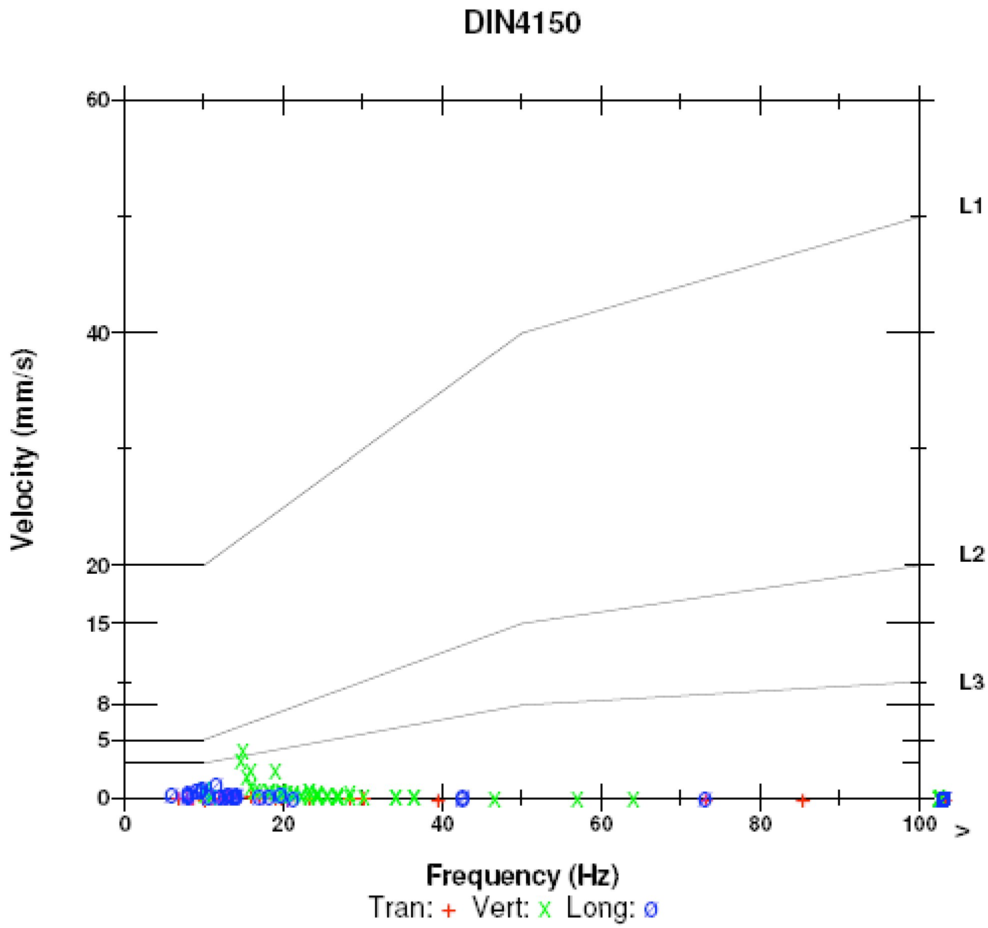


Fig 13 . Vibration level reorded at ADK tower at the time of test piles driving, vibration levels PPV are as low as 2mm/s.

3.6 Groundwater

The primary groundwater system in Male consists of a shallow, unconfined aquifer island water lens. Information regarding groundwater levels at the site was obtained from previous subsurface investigations. In general, groundwater has been reported at about 1.57m below the ground level. Ground water fluctuations have been monitored in three boreholes, water level was recorded in the evening and morning every day. The graph in (Fig 14) shows typical ground water fluctuation recorded in borehole 1 (BH-01) recorded from 12-30th September 2007 twice a day at 8am and 5pm. The graph shows that ground water level was generally high at 5pm and has a water level difference between morning and evening within a range of 13-190mm during the recording period.

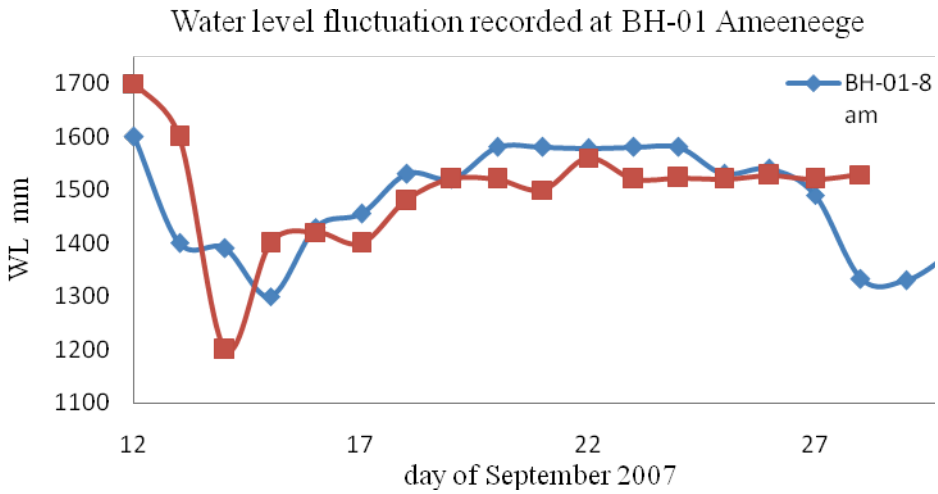


Fig 14. Ground water level fluctuation recorded at BH-01, project site from 12-30th September 2007

3.6.1 Ground water quality

Certain physico-chemical parameters that would enable predictions on the quality of groundwater on the project site was conducted. A water sample obtained from the project site on the 17th of September 2006 was analysed at the Public Health Laboratory of the Ministry of Health. The measurements were compared with standard values for these parameters specified by the WHO guidelines for human consumption. The result of ground water analysis is shown in Table 10. Results shown that the ground water in Ameeneege is good and falls within the limits of WHO guidelines for human consumption, and no heavy metal contamination or any other sort of chemical contamination were observed from the sample.

Table 10. Analytical result of ground water sample tested from the project site.

Parameter tested	Level of presence	Test method
Phosphate	0.01 mg/l	photometric test
Dissolved Oxygen	6.1 mg/l	photometric test
Sulfate	13 mg/l	photometric test
Salinity	300 mg/l	photometric test
Lead	0.00 mg/l	photometric test

4 Legal and Regulatory Consideration

The Male' Municipality is the municipal authority of Male' which is an office administered under the Ministry of Home Affairs, is mandated for management of land in the Capital of Maldives. As such management and regulation of building permission, land plot boundary delineation, land registration construction permission and monitoring comes under purview Male` Municipality. Ministry of Housing and Urban Development together with the Male` Municipality and other relevant ministries manages and plan urban development of state owned land plots. Male Municipality has a more of an implementation and enforcement role of the urban development plans in Male`. Ministry of Tourism and Civil Aviation is the licensing authority to tourist hotels and guest houses.

The Ministry of Tourism and Civil Aviation has informed the proponent that they have no objection in principle to the development of the proposed Hotel in Male provided that the project complies with the rules and regulations and the existing practices of the concerned agencies of the government of the Maldives. Similarly the Male` Municipality has issued a building permit to the proponent to go ahead with the construction.

The authority for regulating the environmental affairs is the Ministry of Environment, Energy and Water. Under the Environmental Protection and Preservation act, MEEW is mandate to implement the EIA process for the development projects. According to the Environmental Protection and Preservation Act (EPPA) (law 4/93) of the Government of the Republic of Maldives has the authority to terminate projects that has any undesirable impact on the environment without compensation.

The revised guideline for EIA process has been published early this year. EIA regulations are implemented by the Environment Research Centre of the MEEW. All EIA are evaluated by the MEEW and the responsibility of implementing the EIA recommendations falls under the MEEW. Main EIA related licensing and responsible agencies and their authority is given in Table 11.

Table 11. Main EIA related licensing and responsible agencies and their authorities of the proposed project

Licensing/Responsible Agency	Relevant EIA required project
Ministry of Health	Any project relating to public health
Ministry of Environment Energy and Water	Construction, infrastructure development, any project related to energy generation (diesel solar bio-gas etc)
Maldives Water and Sanitation Authority	Projects related to drinking water issues, watering, dewatering and swage.
Ministry of Tourism and Civil Aviation	All projects related to tourism development and tourism re development
Ministry of Construction and Public Infra Structure	Project related to infrastructure design Harbours buildings, structural design
Ministry of Housing and Urban Development	Projects related to urban development, and developments in urbanized areas
Male Municipality	Projects related to developments in Male,
Ministry of Economic Development and Trade	Import of raw materials/ final products for wholesale and retail.

5- Assessment of Impacts and Mitigation Measures

Assessments and prediction of environmental impacts involves certain degree of uncertainty as natural and anthropogenic impacts can vary from place to place due to differences in subsurface geological or socio-economic conditions in a particular place. Particularly in this case where this is the first time such an EIA on a building being prepared therefore, there is no data on similar cases in the Maldives. However, building and construction being extremely high-tech field, number of computer programs can be used to model buildings ground settlements and vibrations to predict the environmental impacts over time. For the Ameeneege deep pile foundation, the EIA team was able to fully model the impacts related to ground settlement, vibration and pile driving. Therefore most of the impact prediction used in this report is based on Plaxis® (most widely used software to model the geotechnical aspects of structures, especially piles) 3D modeling program as well as the existing literature on similar cases elsewhere. The input data for Plaxis® was obtained from the geotechnical assessment report, and high strain dynamic pile test report. By using these data Plaxis® was able to do the static and dynamic analysis, which uses finite element method as the basis for analysis. Experience and opinion of engineers who are involved in the construction industry of Maldives and the outcome of assessments of the buildings in the vicinity are used as the basis to evaluate the condition of the nearby structures. The impact of vibration and ground settlement will differ from building to building depending on the structural elements and the proximity to the site.

5.1 Definition & Classification of Environmental Impacts

An environmental impact is any change to the existing condition of the environment caused by human activity or an external influence. Impacts may be positive (beneficial) or negative (adverse). They may also be direct or indirect, long-term or short-term in duration, and wide-spread or local in the extent of their effect. Impacts are termed cumulative when they add incrementally to existing impacts. In the case of Ameeneege project, potential environmental impacts would arise during the construction mainly due to pile driving vibration and ground settlement that may be short-term or long-term depending on the magnitude and nature of the effected structure.

5.1.1 Impact Significance

The purpose of an EIA is, *inter alia*, to identify the significant impacts related to the project or activity under consideration and then to determine the appropriate means to avoid or mitigate those which are negative. Significant impacts are defined, not necessarily in order of importance, as being those which:

1. Are subject to legislative control;
2. Relate to protected areas or to historically and culturally important areas;
3. Are of public concern and importance;
4. Are determined as such by technically competent specialists;
5. Trigger subsequent secondary impacts;
6. Elevate the risk to life threatening circumstances; and
7. Affect sensitive environmental factors and parameters.

5.1.2 Impact Description & Mitigation

The following sections discuss the major project activities and the potentially significant impacts related to those activities. For ease of discussion and presentation, the corresponding impact mitigation measures are presented after the discussion of each impact.

5.2 Building Demolition Impacts

5.2.1 Site clearance – creation of demolition waste, dust and noise

Impact: At the time preparation this report the existing building has been demolished and the resulting debris and other materials removed and the site has been cleared. Therefore there is no need to address the issue here. Apparently there was no specific issue with regard to building demolition as all the debris and waste are being treated according to the local regulations.

5.3. Construction Phase Impacts – Building Works

5.3.1 Vibration

Impact: Pile driving can excite the adjacent ground, creating vibration waves that propagate (or move) through the various soil and rock strata potentially reaching the foundations of nearby buildings and then throughout the parts of the building structure. The effects of ground-borne vibration can include perceptible movement of the building floors, rattling of windows, shaking of items on shelves or hanging on walls, and rumbling sounds. In extreme cases, such vibration can cause damage to buildings and other structures.

Differences in these vibration outcomes is related to the magnitude of the vibration that propagates to nearby structures. Vibrations of greater magnitude may cause building damage but vibrations at much lower levels may be felt by humans but be too low to cause building damage.

Evaluation criteria for determining vibration impacts due to construction activities include thresholds for (1) human perception, annoyance, and interference and (2) damage to fragile and historical buildings.

The Peak Particle Velocity (PPV) is appropriate for evaluating impulsive vibration associated with such vibration sources as blasting or pile driving, and the resulting stresses that potentially are damaging to buildings. PPV represents the maximum instantaneous positive or negative peak motion of a vibrating surface.

Ground vibrations from construction activities very rarely reach the levels that can damage structures, but can achieve the audible and perceptible ranges in buildings that are very close to the active work area.

According to the most widely used structural vibration standard (DIN 4150-3 Appendix 3) and also existing literature the damage threshold for normal buildings and are well below vibration levels (50mm/s PPV) at which damage might be expected to occur. However humans may be able to feel Vibration levels as low as in the range of 0.017 to 0.035 PPV which are much lower than levels that could cause damage to buildings (example hair cracks in the buildings).

In the case of Ameeneege vibration modeling at various depth found that PPV reaches to 50 PPV at distance less than 2m (Fig 15a-d). Therefore it is possible to impact buildings that are closer than 2m from pile tip (example Athiriveli) to be effected from pile driving. Athiriveli is less than a pile length from the pile driving area on the western side. At this stage we are not about the magnitude of impacts, could be number of hair-crack, or even more, surely the building needs to be monitored during the pile driving process.

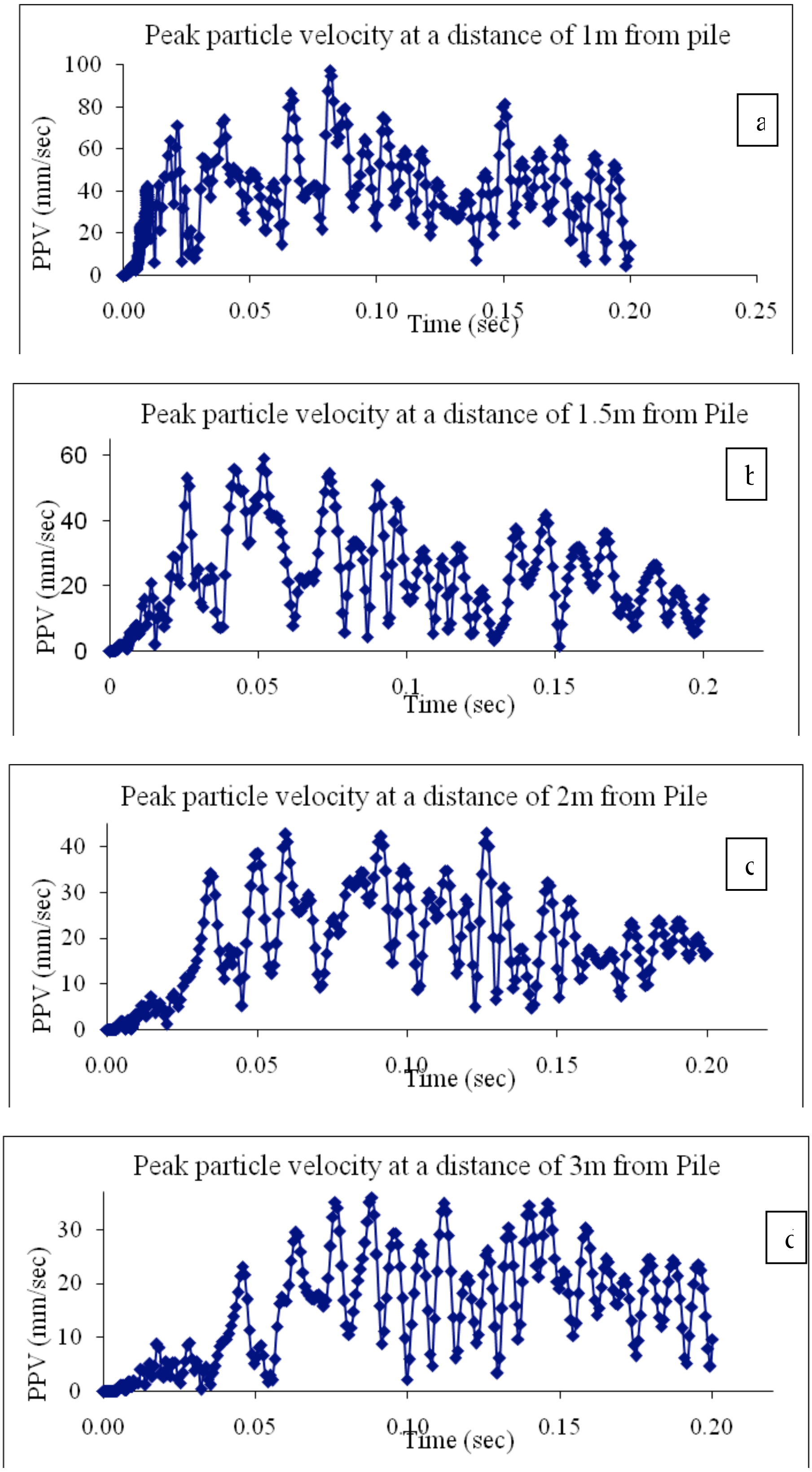


Fig 15. Graphs a-d shows modeled peak particle velocity, Ameeneege development, at different distances from pile tip. The figures shows that the safe distance for vibration is more than 2m, if less than that PPV reaches 50, DIN limits, potential risk of damage for nearby structures.

Mitigation: Studying the energy and frequency from pile driving can help to determine if the vibration will be a nuisance to occupants or a damaging force. Vibration measuring equipment to be installed at least in two locations, one would be Athiriveli and the second would be the Asters building. Athiriveli because it is the closest to the pile driving area. The structural assessment report shows that the Asters building has serious cracks. Crack monitoring devices should be installed in buildings in the vicinity "Telltale" monitoring devices would be enough. Consultation with a structural engineer is important to select the location for crack monitoring.

The second option to minimize the vibration and noise level would be to minimize the hydraulic hammer ram from 3 tons to 2 tons or less. However modeling the hammer ram with Plaxis ® show that 3 tons is the right size. If the ram is reduced to two tons time taken to drive a pile is extremely long (Fig 16).

Raising awareness on construction induced vibration and its impact would be an important mitigation measure. Generally human being can feel vibration as low as 0.2mm/s but vibration that cause damage to the buildings are or cause minor hair cracks has a PPV of 50mm/s. Therefore the public needs to be aware of such information. Vibration mitigation action flow chart is shown in (Fig 17).

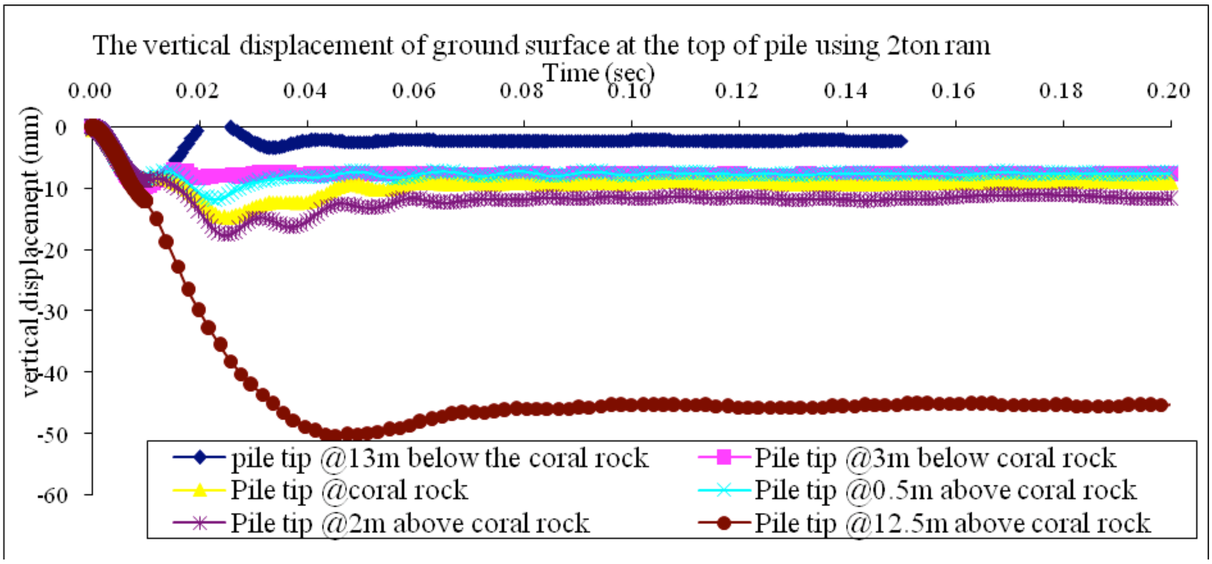


Fig 16 .Showing the time taken by 2 ton ram to drive the pile in various depths.

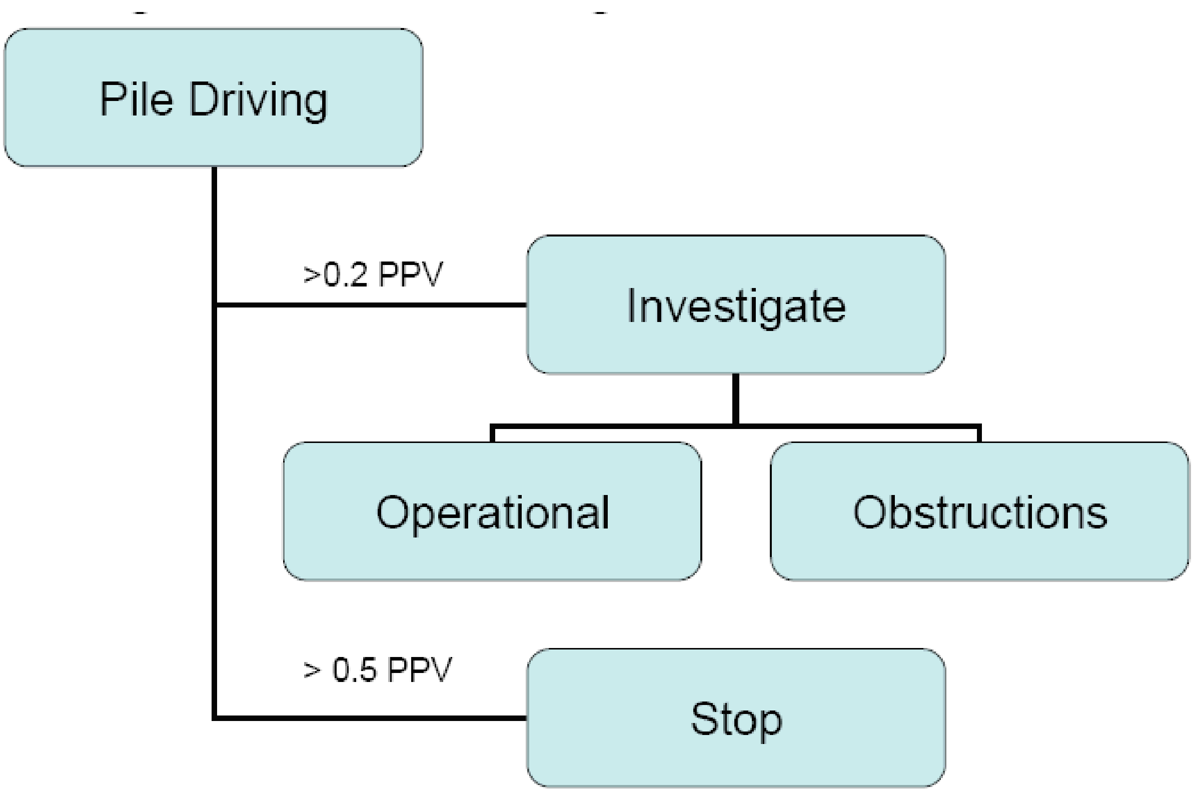
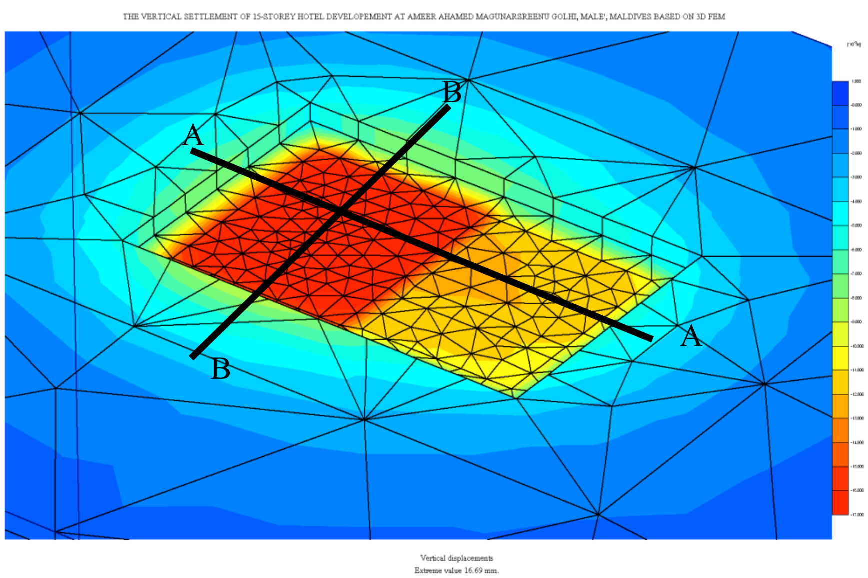


Fig 17. Vibration mitigation action flow chart, PPV in inches.

5.3.2 Ground Settlement

Impacts: Pile driving and construction of the 15 storey building at Ameeneege would cause ground settlement, and lateral movement to some degree. So far the calculated values of settlement are within allowable limits. For the purpose of this EIA ground settlements near the proposed 15-strey hotel was modeled in Plaxis® software. The model shows ground settlement within the range 0f 12-17mm (Fig 18).



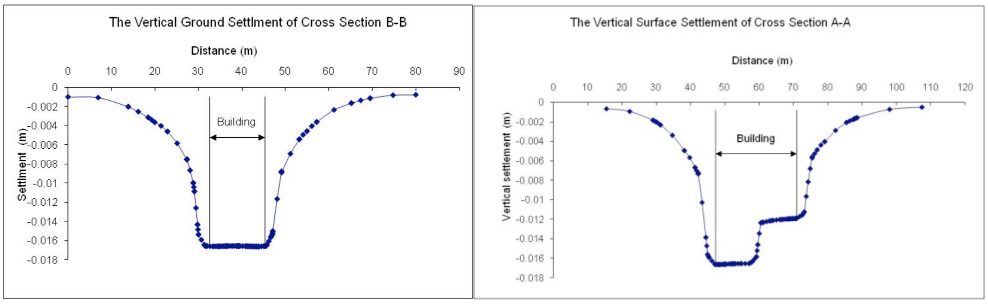


Fig 18. 3D Plaxis ® image showing the vertical settlement from Ameenege building (top) and cross sections A-A and B-B (bottom), the amount of settlement will not exceed 17mm.

Mitigation: Ground subsidence impacts related to preload and surcharge fills would be mitigated by site-specific analysis and design of the preload fill to control adjacent settlements. The extent of potential ground settlements and mitigation needed would be dependent on the depth of poor soil, the height of the preload fill, the proximity of existing structures and utilities, and the sensitivity of the existing structures and utilities to settlement. Mitigation measures conducting pre- and post-construction surveys of nearby structures, and monitoring of ground movements to verify that no adverse settlement occurs during the construction period.

5.3.3 Earth excavation

Impact: The basement flow will be at 1.5 below and the ground, some of these are temporary excavations that would be required for the installation of future structures and infrastructure such as basement floor, elevator pits, etc. Without mitigation, these excavations could have a potentially adverse effect on immediately adjacent existing and future structures (i.e., structures within a distance equal to about the depth of the excavation), utilities, and other improvements. However, standard construction measures, such as use of properly designed and installed temporary shoring systems, would reduce the potential for such adverse impacts.

Mitigation Measure: Impacts from temporary construction excavations would be mitigated through the use of properly designed and constructed excavation shoring systems, which is expected to reduce the impacts.

5.3.4 Dewatering

Impact: Dewatering would reduce the available water lens of the island also dewatering would be potentially be related to differential settlement. According to the present plan the area would not need dewatering because the excavation would not reach the water lens at the depth of 1.57m. However if dewatering becomes necessary the following mitigation measure will be implemented.

Mitigation: Site-specific analyses have already being carried out. Selection of dewatering method would be based on estimates of discharge based on depth of pile wall, pump capacity required; and safety against piping. According the existing local regulation water will not be pumped out into the sea. Mitigation measures to control the potential impact of excavation dewatering could also include minimizing the extent and duration of dewatering, monitoring for settlement, and installing groundwater cut-off walls.

5.3.5 Noise

Impacts: Noise associated construction equipment and various construction activities. Equipment utilized for pile driving will include a crane, front-end loaders, backhoe, and other construction-related vehicles and equipment. The equipment generates noise from diesel engines, high-pressure air compressors, and mechanical equipment movement in general. The most widespread source of noise from typical construction equipment is generally due to internal combustion engines, usually diesel, which provide operating power. Engine-powered construction equipment includes earthmoving equipment that is highly mobile, handling equipment that is partly mobile and stationary equipment. Earthmoving equipment includes machinery such as drill rigs, dump trucks, and jet grout drills. Their internal combustion engines are used both for propulsion and for powering working mechanisms. Engine sound typically predominates, with exhaust noise normally being the major source, and inlet sound level and structural sound level being of secondary importance. Other sources of noise associated with the equipment include the mechanical and hydraulic transmission actuation systems and cooling fans that can sometimes produce relatively high sound levels.

Stationary equipment such as air compressors, cranes, and generators generally run continuously at relatively constant power and speed, although sound levels may vary according to the work cycle (e.g., loading). Construction related noises are usually of a temporary duration and can be, relatively intermittent.

At present the ambient noise level at daytime at the site is 64dBA and 47dBA at early morning. Since there are no clear guidelines on noise levels in working area in the Maldives. Due to the size of the site, and the site being located near a school and the commercial area noise emissions from construction and operation activities of the facilities would be expected to cause annoyance to the people nearby. Therefore, noise impacts associated with construction would expected to be within 65-70dBA particularly during the operation of hydraulic pile hammer.

Mitigation: Workers operating equipment that generate noise should be equipped with noise protection gear. Workers operating equipment generating noise levels greater than 80 dBA continuously for 8 hours or more should use earmuffs. Workers experiencing prolonged noise levels of 70 – 80 dBA should wear earplugs. Apart from this there are available technologies to reduce the sound such as, fence- acoustic insulation, moveable sound barrier curtain and temporary sound barriers. If the sound emission is higher than 80dBA f at 50m radius fromf the source such option could be considered. Figure 19 shows noise mitigation action flow chart.

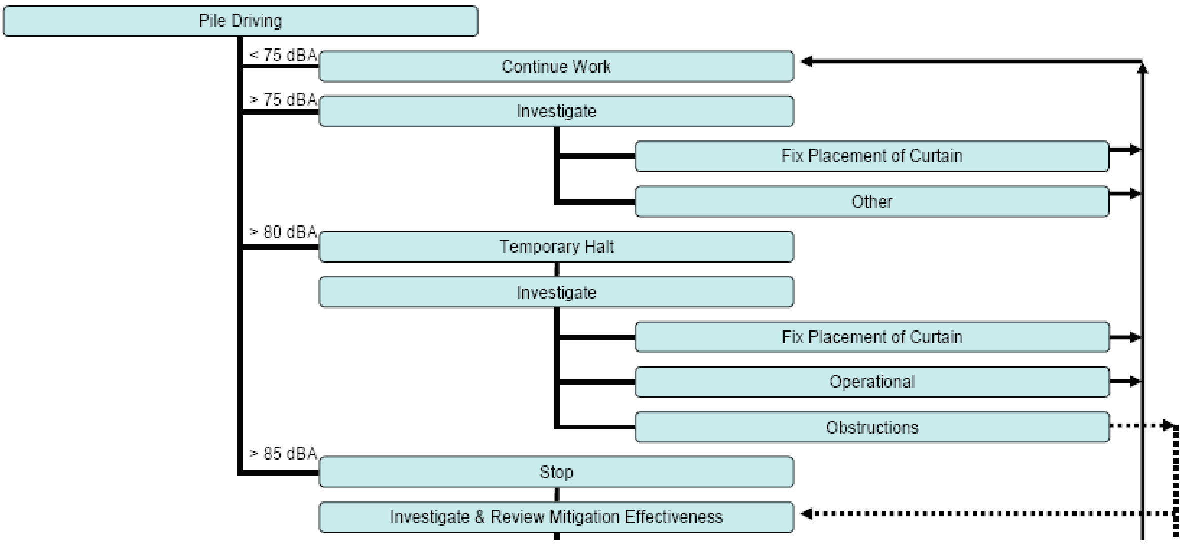


Fig 19. Noise mitigation action flow chart.

5.4 Fugitive dust

Impact: The building structure frame is from steel therefore the amount of fugitive emission from the site would be much lower than the concrete foundation buildings. However, concrete will be used to some extent and the major environmental impacts related to concrete mixer are:

- Dust (air pollutant) - resulting from the transport, handling and storage of the raw materials.
- Waste water – alkaline wash out water, which is toxic to fish and other aquatic life, is generated during the cleaning of mixer;
- Solid waste – may be generated from unpacking bagged cement;

- Noise – produced by various pieces of equipment and machinery;
- Other environmental impairments – soil pollution (e.g. oil and grease spillage)

Mitigation:

- Carefully unpack and unload cement to avoid dust production.
- Prevent disposal of wastewater to open environment.
- Use water carefully during all stages of production.
- Re-use wash water as mix water in concrete manufacture.
- Provide workers with appropriate personal protective gear (e.g. gloves, masks, etc.)
- Apply good house-keeping practices.
- Train staff in environmentally friendly behavior and production.

5.5 Construction waste

Impact: Considerable volumes of solid waste will be generated during site preparation and construction works, which would include typical construction waste such as wasted concrete, steel, wooden scaffolding and forms, bags, waste earth materials, etc. This waste will negatively impact the site and surrounding environment if not properly managed and disposed of at an approved dumpsite. Solid waste, if allowed to accumulate on the ground, could cause localised pooling and flooding. Pooling of water, in turn, would create conditions conducive to the breeding of nuisance and health-threatening pests such as mosquitoes. Poor construction waste management constitutes a short term negative impact.

Mitigation:

- A site waste management plan should be prepared by the contractor prior to commencement of building. This should include designation of appropriate waste storage areas, collection and removal schedule, identification of approved disposal site, and a system for supervision and monitoring. Preparation and implementation of the plan must be made the responsibility of the building contractor with the system being monitored independently.
- Reusable inorganic waste (e.g. excavated sand) should be stockpiled away from drainage features and used for in filling where necessary and/or possible.
- Unusable construction waste, such as damaged pipes, formwork and other construction material, must be disposed of at an approved dumpsite

5.6 Cumulative Impact

Cumulative impact from pile driving and during the construction work would be short term increase in noise and vibration level in the area during the working hours, increase traffic and other short-term impacts arises from any similar construction site.

The long-term impact of the project would be ground settlement in that area, modeled data shows various degree of ground settlement could be reached to 110m radius from the building. The highest level of settlement will be about 17mm near the building. This is within the allowable lateral movement of the buildings and ground, therefore this could not be visually observed neither it would have physical damage impact on the buildings in the vicinity. Small hair cracks might appear on the wall of buildings within a distance of pile length.

Short-term exposure of building and structures within the range of 2m radius to vibration might cause minor cracking, but if appropriate monitoring is done, as suggested in the monitoring plan, it could be prevented or mitigated before it occurs.

6 Summary Evaluation of the Alternatives

The exploration and analysis completed for Ameeneege development indicates that, from a geotechnical standpoint, the site is suitable for development with or without Alternatives, provided the proposed mitigation measures are implemented

Alternative 1. Assume changing the location of the site and shifting the hotel somewhere else in Male`. Given the present land availability condition in Male` this seems to be an impossible option. If such an option is available the developer would definitely prefer to move the hotel to a less congested beach front location in Male.

Alternative 2. Assume changing the deep pile foundation to a raft foundation, like many buildings in the Maldives. Significant features that effected selection of type of foundation are: a)ground water level, b)existence of medium dense coral sand with coral rock fragment at the top 16-23m in the site, c) the highly fractured porous rock was found at a depth of 21m, d) provision for the basement for the structure and the need to protect foundation of the adjacent building foundations, e) also the magnitude of loads from the proposed 15-storey building f) bearing pressure of raft is estimated to be 250kN/m2 which will also cause a ground settlement in the order of 40mm which is extremely high compare to 17mm now.

Alternative 3. Assume using a 2ton or 1.5 ton ram in the hydraulic hammer used for pile driving to reduce the sound and vibration. This option has been modeled and it shows that 2ton ram might reduce the sound emission and vibration to some extent but the amount of taken to drive the pile would be longer hence exposure to sound emission and vibration sound be longer. Also the construction schedule could be longer and the cost would be higher.

7 Environmental Management Plan

7.1 Environmental Specifications for Construction Works

- The contractor is required to conform in all respects to the requirements for environmental management of the construction site and works as specified below and to make provision in his/her tender for all costs associated therewith.

- Public/worker safety: The work site shall be adequately fenced so as to ensure the exclusion of persons from potentially hazardous site activities and situations.

- The contractor shall ensure that workers on the site are provided with the appropriate safety gear, e.g. hard hats, safety boots, nose masks and ear muffs, etc., as appropriate.

During construction, temporary **erosion and sedimentation control measures** and Best Management Practices to control erosion would be implemented. These measures should be consistent with the local regulations, and could include the following:

- Minimize areas of exposure.
- Schedule earthwork during drier times.
- Route surface water through temporary drainage channels around and away from
- disturbed soils or exposed slopes.
- Cover exposed soil stockpiles and exposed excavations with plastic sheeting, as
- appropriate.
- Intercept and drain water from any surface seeps, if encountered.
- Incorporate contract provisions allowing temporary cessation of work under certain,
- limited circumstances, if weather conditions warrant.
- Soil contamination, dusting and noise: Oils and lubricants shall not be spilled on the ground under any circumstances and proper provision shall be made to avoid such occurrences during vehicle maintenance. Oil leaks must be collected in drip pans and these emptied into larger containers for storage and later disposed.

- Turbid water from cement mixers shall first be discharged to a sediment settlement basin and only clarified water allowed overflow to open ground.

- Exposed dry soils on the work site shall be kept properly wetted such that there is no fugitive dust. Soil wetting shall apply particularly to areas where there is vehicular movement.

- Solid waste management: All hazardous materials encountered on the site shall be disposed of appropriately and in accordance with government requirements.

- Construction wastes shall be collected from the site each day, stored and contained in a designated area on the work site.

- Construction wastes and garbage shall be removed from the site at least three times a week and disposed of appropriately.

7.2 Compensation plan

Since the development project is taking place in a semi-residential-commercial area, all the buildings and property nearby are very valuable. There were some concerns on vibration induced building defects that may occur due to the project. Since there are no other alternative available for the project the developer must try his best to keep the loss to a minimum. If this proves impossible, the loss must be compensated.

The compensation obligation means that the affected nature must be replaced on a one-to-one basis, in terms of quality, quantity and physical appearance.

The developer agrees to compensate any defect that may cause due to his activities during construction and operation of the proposed facility in accordance with the laws and regulation of the Maldives.

8 Monitoring Programme

The monitoring progamme proposed here is acceptable to the proponent taking into consideration of the costs involved. The cost implication of the monitoring programme was discussed with the proponent. The main objective of the following monitoring program is to document and record building vibration due to pile driving in Ameeneege and monitor the already documented existing crack in some of the buildings, particularly in Athiriveli, Asters building, ADK building and Darumantah school . The main objective of the monitoring is to continuously monitor the adjacent buildings for structural damage during operations and compare with the documented building defects. Monitoring would also measure the effectiveness of the selected methods and procedures and will be sensitive enough to detect any movement or impending damage before it is apparent to the eye. The aim is to take necessary corrective action before damage spreads.

Crack monitoring: "telltale" crack monitoring instrument will be installed over existing deficiencies in Athitiriveli and Asters building and ADK tower to monitor movement of existing cracks caused by vibration. Another way to monitor crack is using Brittle patches. Placing dime-sized patches of any weak, brittle material over a crack, movement along or across the crack will cause the patch to rupture. Generally "telltale" ruler like crack monitors will be installed before the start of pilling and crack movement will be monitored regularly.

Vertical movement: Level circuit will be used to monitor vertical movement by establishing turning points on the exposed structure and on the ground surface adjacent to the structure to monitor vertical movement. Benchmarks used in this circuit will be located far away from the construction operation to ensure their reliability. Periodic measurements will be conducted by using ortheodolite

Lateral movement: by using a reference transit line—placed parallel to the structure and offset by one foot or less— horizontal movements in the structure will be monitored. Periodic offset measurements will be made with ortheodolite.

Ground Vibration monitoring: Vibration will be monitored in buildings using a Minimate® Vibration and Overpressure Monitor, at present there is only one device, it is recommended to install two, one in Athiriveli and another in Asters building and periodically check other buildings.

Sound Emissions: Sound emission could be monitored from any sound level measuring meter. It is recommended to take two to three readings per day within 50m radius from the construction site regularly.

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Following reports prepared for the project

- Geotechnical Report by ELS-Amin International (Pvt) LTD.
- Structural Design Report CPLIM and Partners (Singapore)

- Concept Report of Mechanical and Electrical Engineering Services PCR Consulting Pte. Ltd. (Singapore)
- Acoustic Report by ViPAC Engineers and Scientists Pte. Ltd. (Singapore)
- High Strain Dynamic Pile Test Report by ABV Technology Pte. Ltd (Singapore)
- Existing structural conditions assessment report on ADK Tower, Asters Building, Athiriveli and Dharumvantha School by CIVENG Pvt. Ltd (Maldives)

Appendix 1: Building permission given by Male` Municipality on the 18th of July 2007

Appendix 2: Terms of Reference provided by the Environment Research Centre (ERC) to the proponent on 23rd October 2007

Appendix 3: Structural Vibration, part3. Effects of vibration on structures DIN 4150-30 Standards

بسم الله الرحمن الرحيم

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Environment Research Centre

Ministry of Environment, Energy & Water

Male', Republic of Maldives

Terms of Reference for Environmental Impact Assessment

The following is the TOR for undertaking the EIA of the **proposed fifteen-storey hotel development project at Ameeneege**, Henveiru, Male'.

1. Introduction - Identify the development project to be assessed and explain the executing arrangements for the environmental assessment. Describe the rationale for the development and its objectives.

2. Study Area - Specify the boundaries of the study area for the assessment as well as any adjacent areas that should be considered with respect to the project.

3. Scope of Work - The following tasks will be performed:

Task 1. Description of the Proposed Project – Description of the location, legal status of the land, building structure, construction methodology, construction materials, maximum occupancy, employment, water supply requirement, sewage management, duration of construction works, project life cycle.

Task 2. Description of the Environment - Assemble, evaluate and present baseline data on the relevant environmental characteristics of the study area, including the following:

a) Physical environment: A Geotechnical investigation of the site should be conducted and ambient noise shall be determined.

b) Socio-cultural environment: traffic, land use, planned development activities in the area, employment, and community perception of the development. Building architectural design and integration with the character of the area should be addressed.

Task 3. Legislative and Regulatory Considerations - Describe the pertinent legislation, regulations and standards, and environmental policies that are relevant and applicable to the proposed project, and identify the appropriate authority jurisdictions that will specifically apply to the project.

Task 4. Determine the Potential Impacts of the Proposed Project – Identify impacts related to dredging, spoil disposal and possible land filling. Distinguish between significant impacts that are positive and negative, direct and indirect, and short and long term. Identify impacts that are cumulative, unavoidable or irreversible. Identify any information gaps and evaluate their importance for decision-making. Special attention will be paid to:

a) Visual intrusion (Construction phase).
b) Land preparation and piling works (Construction phase).
c) Water supply and demand (Construction & operation phase).
d) Sewage and waste water treatment (Construction & operation phase).
e) Solid waste management (Construction & Operation phase).
f) Impacts related to construction works on land including materials.
g) Sourcing, transport and storage, building construction methodology & piling.
h) Noise, fugitive dust, traffic obstruction (Construction phase) and employment (Construction & operation phase)

i) Impacts related to vehicular traffic induced by the project (Construction & operation phase).
j) Potential impacts of the development on adjacent properties and residential areas (Construction & operation phase).

Task 5. Analysis of Alternatives to the Proposed Project. – Describe the alternatives examined for the proposed project that would achieve the same objective including the "no action alternative. This should cover alternative piling technologies. Distinguish the most environmentally friendly alternatives.

Task 6. Mitigation and Management of Negative Impacts – Identify possible measures to prevent or reduce significant negative impacts to acceptable levels with particular attention paid to dredge spoil disposal and dispersal/sedimentation control. Cost the mitigation measures, equipment and resources required to implement those measures. A compensation plan should also be included.

Task 7. Development of a Monitoring Plan – Identify the critical issues requiring monitoring to ensure compliance to mitigation measures and present impact management and monitoring plan for construction & operation phase.

Task 8. Assist in Inter-Agency Coordination and Public/NGO Participation – Identify appropriate mechanisms for providing information on dredging activities and progress of project to stakeholders. Assist in co-ordinating the environmental assessment with the relevant government agencies and in obtaining the views of local stakeholders and affected groups. (It is anticipated that there will be considerable public interest concerning issues of noise, vibration and the economic benefits to be derived from the project).

Presentation - The environmental impact assessment report, to be presented in digital format, will be concise and focus on significant environmental issues. It will contain the findings, conclusions and recommended actions supported by summaries of the data collected and citations for any references used in interpreting those data. The environmental assessment report will be organized according to, but not necessarily limited by, the outline given in the Environmental Impact Assessment Report, 2007.

…………………………………………………….

(22 October 2007)

February 1999

Structural vibration

Part 3: Effects of vibration on structures

DIN 4150-3

ICS 91.120.25

Supersedes May 1986 edition.

Erschütterungen im Bauwesen – Teil 3: Einwirkungen auf bauliche Anlagen

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

Contents

Foreword

This standard has been prepared by Technical Committee *Schwingungsfragen im Bauwesen; Einwirkungen auf bauliche Anlagen* of the *Normenausschuß Bauwesen* (Building and Civil Engineering Standards Committee).

Amendments

The following changes have been made to the May 1986 edition.

a) The standard now also covers the effects of vibration on buried pipework.

b) The standard has been revised in form and content to reflect the current state of the art.

Previous editions

DIN 4150-3: 1975-09, 1986-05.

Continued on pages 2 to 11.

Translation by DIN-Sprachendienst.

In case of doubt, the German-language original should be consulted as the authoritative text.

1 Scope

This standard specifies a method of measuring and evaluating the effects of vibration on structures designed primarily for static loading. It applies to structures which do not need to be designed to specific standards or codes of practice as regards dynamic loading.
This standard gives guideline values which, when complied with, will not result in damage that will have an adverse effect on the structure's serviceability. In some cases, guideline values for a simplified evaluation are also given.

2 Normative references

This standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the titles of the publications are listed below. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

DIN 1311-1	Vibration and shock – Vibration systems – Concepts, classification *)
DIN V 4150-1	Structural vibration – Principles and measurement of vibration parameters *)
DIN 4150-1	Structural vibration – Preliminary measurement of vibration parameters **)
DIN 45669-1	Mechanical vibration and shock measurement – Measuring equipment
DIN 45669-2	Mechanical vibration and shock measurement – Measurement procedure
DIN EN 1594	Gas supply systems – Pipelines – Maximum operating pressure over 16 bar – Functional requirements *)

3 Concepts

For the purposes of this standard, the following definitions apply in addition to those defined in DIN 1311-1.

3.1 Vibration

Mechanical vibration of solid bodies which may cause damage or discomfort.

3.2 Damage

Any permanent effect of vibration that reduces the serviceability of a structure or one of its components.

3.3 Guideline value

A value obtained through experience; compliance with this value ensures that damage will not occur.

3.4 Short-term vibration

Vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.

3.5 Long-term vibration

All types of vibration not covered by the definition of 'short-term vibration' in subclause 3.4.

4 Principles of evaluating the effects of vibration on structures

4.1 General

Clauses 5 and 6 specify methods of measuring and evaluating vibration parameters. If these methods are not used, then the dynamic stresses occurring in the structure are to be determined by measurement or analysis (e.g. as in subclauses 4.2 and 4.3, respectively) and the results then compared with the permissible stresses, taking their frequency of occurrence into account. Note that the methods described in subclauses 4.2 and 4.3 are not suitable for assessing minor damage as defined in subclause 4.5.
Sometimes, vibration cannot be classified as being only short-term or only long-term as defined in subclauses 3.4 and 3.5, respectively. In such cases, it shall be evaluated on the basis of both clause 5 and clause 6.

*) Currently at draft stage.
**) 1975 edition.

Where necessary, foundation displacement as an indirect consequence of vibration shall also be taken into consideration (cf. Appendix C).

4.2 Determining stresses by measurement

By measuring the strain in a vibrating building component and applying the mass law, the stresses present can be inferred.

The amplitude and frequency of the measured vibration displacement, velocity or acceleration can be used in stress/strain calculations.

The stresses in beams and slabs vibrating close to resonance can be approximated on the basis of the vibration velocity amplitude, provided the measurement is made at the point of the greatest amplitude. In this case, the boundary conditions and stiffness of the component need not be known (cf. subclause 6.2).

4.3 Determining stresses by analysis

The analysis of stresses shall be performed using state-of-the-art methods. Values used in the analysis may be obtained by means of the predictive method described in DIN V 4150-1 or DIN 4150-1.

4.4 Permissible stresses

Verification of stability shall be carried out using the safety factors specified in the relevant standards and regulations for additional dynamic loading, taking into account the type and duration of the dynamic loads imposed, the measurement method, the characteristics of the building materials and the type of construction. If necessary, fatigue strength shall also be verified. Stress-number curves may be used to establish, as a function of the number of expected stress reversals, the stress limits, stress amplitudes, limits of strain and similar parameters for the building materials, building components and junctions.

A detailed analysis of fatigue strength may be dispensed with if, for the stability analysis, the dynamic load components are multiplied by a factor of 3.

Fatigue analysis is not required if the dynamic load component is less than 10 % of the permissible static stress.

4.5 Evaluating serviceability

Examples of a reduction in the serviceability of a building or building component due to the effects of vibration include:

- the impairment of the stability of the building and its components;
- a reduction in the bearing capacity of floors.

For structures as in lines 2 and 3 of table 1, the serviceability is considered to have been reduced if

- cracks form in plastered surfaces of walls;
- existing cracks in the building are enlarged;
- partitions become detached from loadbearing walls or floors.

These effects are deemed 'minor damage'.

4.6 Effects of vibration on soil

Strong vibration can cause settlement of soil, primarily in the case of loose to medium-dense, non-cohesive soil such as sand and gravel; this can also lead to foundation settlement, especially where there is frequent vibration or uniformly graded sand or soil beneath the groundwater level. For more information, see Appendix C.

5 Evaluating effects of short-term vibration

5.1 Effects on the structure as a whole

Numerous measurements of vibration velocity in building foundations have provided empirical values which give guidance on the evaluation of short-term structural vibration. Evaluations as in this standard are based on the maximum absolute value of the velocity signals, $|v|_{i,max}$, for the three components (where $i = x$, y or z) of the unweighted velocity signals, $v_i(t)$, measured on the building foundation (this parameter is referred to below as v_i for short). See subclause 5.4 for details of measurement.

The vibration measured in the plane of the highest floor resting on external walls also provides significant information for this evaluation, taking the maxima of the two horizontal components as a basis. Measurements taken at this point in accordance with subclause 5.4 may be used to determine the horizontal response of the structure to the excitation at the foundation.

Table 1 and figure 1 give guideline values for v_i at the foundation and in the plane of the highest floor of various types of building. Experience has shown that if these values are complied with, damage that reduces the serviceability of the building will not occur. If damage nevertheless occurs, it is to be assumed that other causes are responsible. Exceeding the values in table 1 does not necessarily lead to damage; should they be significantly exceeded, however, further investigations are necessary.

Table 1: Guideline values for vibration velocity to be used when evaluating the effects of short-term vibration on structures

Line	Type of structure	Guideline values for velocity, v_i, in mm/s			
		Vibration at the foundation at a frequency of			Vibration at horizontal plane of highest floor at all frequencies
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz*)	
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20	15
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings under preservation order)	3	3 to 8	8 to 10	8

*) At frequencies above 100 Hz, the values given in this column may be used as minimum values.

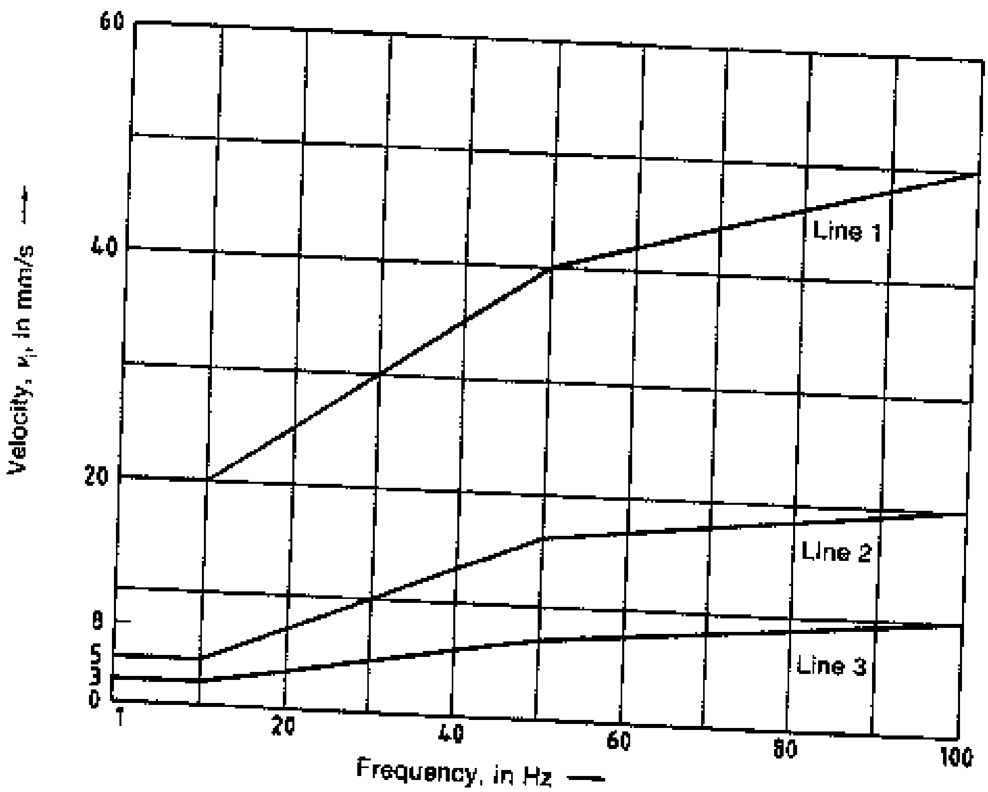


Figure 1: Curves for guideline values specified in table 1 for velocities measured at the foundation

To determine which frequency ranges shown in table 1 apply, take the frequency which occurs within the relevant velocity range, special care being necessary in the measurement of low frequencies. For analytical purposes, the character of the signal shall also be taken into consideration, for instance by means of suitable data windows (cf. Appendix D).

For civil engineering structures (e.g. reinforced concrete constructions used as abutments or foundation pads), the values in line 1 of table 1 may be increased by as much as a factor of two, provided no hazards arise as a result of mechanical processes in the ground.

5.2 Effects on floors

Where short-term vibration causes floors to vibrate, if v_z is no greater than 20 mm/s when measured at the point of maximum velocity (which is usually at the centre of the floor), a reduction in the serviceability of the floor is not to be expected. In the case of buildings as in line 3 of table 1, it may be necessary to lower this value to prevent minor damage.

5.3 Effects on buried pipework

Table 2 gives guideline values for evaluating the effects of vibration on buried pipework. It is assumed that the pipes have been manufactured and laid using current technology; if this is not the case, special considerations will have to be made. Additional considerations need also be made where mechanical processes in the ground could have deleterious effects on pipes, or where there are different stress conditions at junctions (e.g. junctions with the structure).

The values given in table 1 for foundations also apply to the first two metres (nearest the building) of gas and water service pipes. For information regarding gas supply pipelines, see DIN EN 1594.

Drain pipes shall be evaluated using the values given in line 3 of table 2.

Table 2: Guideline values for vibration velocity to be used when evaluating the effects of short-term vibration on buried pipework

Line	Pipe material	Guideline values for velocity measured on the pipe, v_i, in mm/s
1	Steel (including welded pipes)	100
2	Clay, concrete, reinforced concrete, prestressed concrete, metal (with or without flange)	80
3	Masonry, plastic	50

5.4 Measurement

Instruments used to perform measurements as in this standard shall meet the requirements specified in DIN 45669-1, and the procedure shall be as in DIN 45669-2. To measure vibration in foundations, the pick-ups for the three directions of measurement shall be placed close together on the ground floor of the building to be investigated, either at the foundation of the outer wall, on the outer wall itself, or in a recess in that wall. In buildings without a basement, the point of measurement shall be no more than 0,5 m above the ground. Measurement points shall preferably be on the side of the structure that faces the source of excitation. The time history of the vertical vibration (z-axis) and horizontal vibration (x- and y-axes, at right angles to each other) shall be recorded, with one of the directions of measurement running parallel to a side wall of the building. For structures with a large ground floor area, simultaneous measurements shall be made at several locations.

In addition to the measurements made on the foundation and the highest floor, a measurement in the vertical direction may also have to be made on the floors on which the strongest vibration is expected; in this case, the point of measurement should be in the centre of the floor (cf. subclause 5.2).

Pick-ups for measurements in the highest floor shall be placed on or immediately next to structural masonry so that the two horizontal directions of measurement, x and y, are at right angles to each other, with one direction running parallel to a side wall.

When carrying out measurements on pipework, pick-ups shall be placed directly on the pipes whenever possible. As an alternative, the pick-up may be placed on the ground surface directly above the pipe, although in this case, it is only possible to make estimates (see Appendix D.1).

A test report as in Appendix A shall be drawn up for each measurement.

6 Evaluating effects of long-term vibration

6.1 Effects on the structure as a whole

Table 3 gives guideline values for the highest value of the two horizontal components measured in the top floor, for different types of building. Experience has shown that if these values are complied with, damage will not occur. Exceeding the values in table 3 slightly does not necessarily lead to damage. Should they be considerably exceeded, the stresses may be determined as described in subclauses 4.2 and 4.3 and evaluated as in subclause 4.4. In the case of multi-storey frame structures, the dynamic stress component can also be determined from the relative displacement of the ends of the vertical members.

If a building is subjected to harmonic vibration, then the maximum values can also occur in floors other than the top floor, or in the foundation. The values given in table 3 also apply in these cases.

When other points of reference are used, separate analysis is required.

Table 3: Guideline values for vibration velocity to be used when evaluating the effects of long-term vibration on structures

Line	Type of structure	Guideline values for velocity, v_i, in mm/s, of vibration in horizontal plane of highest floor, at all frequencies
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	10
2	Dwellings and buildings of similar design and/or occupancy	5
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings under preservation order)	2,5

6.2 Effects on floors

To evaluate vibration in components such as floors and walls, the dynamic loading may be determined as in subclauses 4.2 and 4.3.

In the case of flexural vibration close to resonance, which often occurs when floors vibrate at high magnitudes, the additional dynamic stress can be approximated using the method mentioned in subclause 4.2 as described below.

For beams and one-way spanning solid slabs of rectangular cross section (i.e. $y_{max}/i = 1{,}73$, where y_{max} is the outer fibre distance and i is the radius of inertia) with a constant stiffness and weight loading, and for vibration with a natural mode, the maximum bending stress, $\dot{\sigma}_{max}$, is defined by equation (1), regardless of the dimensions of the vibrating system:

$$\dot{\sigma}_{max} = 1{,}73\,(E_{dyn}\,\varrho\,G_{tot}/G_{beam})^{0,5}\,k_n\,\dot{v}_{max} \qquad (1)$$

where

$\dot{v}_{max}$ is the peak velocity along the beam length;

E_{dyn} is the dynamic modulus of elasticity of the material;

ϱ is the material density;

G_{tot}/G_{beam} is the coefficient of loading, where the beam is to accommodate evenly distributed loads in addition to its self-weight;

G_{tot} is the self-weight of the beam, plus other loads;

k_n is the eigenmode coefficient.

The eigenmode coefficient is dependent on the boundary conditions and the degree of the mode. Both of these have only a slight influence; however, in practice, the value for k_n lies between 1 and 1,3. For two-way spanning slabs, the bending stress so calculated is also to be considered a maximum.

Experience has shown that vertical vibration velocities up to 10 mm/s do not cause damage in floors of structures as in lines 1 and 2 of table 3, even if the maximum design stresses are fully utilized. Such vibration is very clearly perceptible. For structures as in line 3 of table 3, no guideline value can be given for vertical vibration.

Minor damage (cf. subclause 4.5) should not be automatically attributed to dynamic loading and further investigations are necessary.

6.3 Effects on buried pipework

The guideline values given in table 2 may be reduced by 50 % without further analysis when evaluating the effects of long-term vibration on buried pipework.

The restrictions given in subclause 5.3 apply here by analogy.

6.4 Measurement

If a building is subjected to harmonic vibration, measurements shall be taken on several floors simultaneously in order to correctly determine the vibrational mode. For vibration having the lowest natural mode, it is normally sufficient to take measurements on the top floor. The lowest natural frequency of horizontal vibration in buildings with about five or more storeys, f_i, in Hz, may be taken to be approximately $10/n$ (where n is the number of storeys).

When evaluating horizontal vibration in the structure as a whole, it may be necessary in special cases to take into account possible rotational movements in the floor plane and any rigid rotation.

The natural frequency of floors is normally greater than 10 Hz, and in most cases, only vertical movements are significant. The vertical vibration shall thus be measured at the point of maximum velocity, which is usually at the centre of the floor.

A test report as in Appendix A shall be drawn up for each measurement.

Appendix A

Sample test report form

The test report shall include the information listed below.

Table A.1: Test report form

Line	Type of information	Details
1	General: a) Testing agency b) Client c) Contract identification d) Person carrying out measurement e) Time and date of measurement	
2	Type of vibration: a) Source b) Operating conditions	Blasting (charge, ignition stages, number of drill holes, series, etc.) Pile driving (equipment used, type of pile used) Machinery (speed, load, etc.) Traffic (rail traffic, trucks, etc.) Frequency of occurrence
3	Structure: a) Designation b) Classification c) Description	Address Type of building according to the tables in this standard Type of structure, size, foundation, structural condition
4	Site and location a) of source of vibration b) of the measurement points and their distance from the source, and measurement direction	Sketches giving heights
5	Environmental conditions	Details of rock and soil, ground water, structural condition of building, weather conditions (frost, storm, etc.), extraneous sources of vibration (e.g. traffic)
6	Subjective observations	Perceptible secondary effects (e.g. rattling of objects)
7	Measuring chain: a) Pick-ups, natural frequency of equipment, damping coefficient, frequency response, operating frequency range b) Signal conditioning equipment c) Recording devices d) Tools for analysis	Accelerators, velocity or displacement pick-ups Filters, amplifiers Magnetic tape recorder, plotters, PCs Frequency analyzers, software
8	Results of measurement: a) Measured quantities and frequencies b) Derived quantities c) Duration and occurrence of effects	
9	Signatures	

Appendix B

Measures for limiting the effects of vibration

Normally, vibration is transmitted through the ground and decays with increasing distance from its source. For this reason, the effects of vibration can be reduced by increasing the distance between the vibration source and receiver. (Airborne vibration plays a role only under special circumstances.)

The following measures may be used to limit the effects of vibration.

B.1 Measures taken at the vibration source

B.1.1 Measures against stationary vibration with harmonics, generated by machinery (e.g. oscillating screens, motors, compressors, sawmills)

a) Balance machines.

b) Provide or improve balancing systems.

c) Change the speed, where resonance occurs.

d) Isolate against vibration by placing the installation on an elastic element (for excitation at frequencies over 3 Hz).

B.1.2 Measures against shocks generated by machinery (e.g. forge hammers, presses, mills)

Isolate the installation against vibration.

B.1.3 Measures against vibration generated by traffic

a) Build and maintain smooth road surfaces.

b) Regularly maintain tracks of railways.

c) Regularly maintain running gear of rail vehicles.

d) Isolate railways against vibration.

e) Reduce speed.

B.1.4 Measures against vibration generated by blasting

Modify the blasting technique (e.g. a different charge for each ignition stage, different firing orders or hole depths).

B.1.5 Measures against vibration generated by construction work

a) Switch to low-vibration techniques.

b) Use vibration hammers having higher vibration frequencies.

c) Avoid resonance.

B.2 Measures taken at the vibration receiver (structure)

a) Fit the structure with dynamic vibration absorbers (especially effective against resonance and where there is minimal damping in the structure).

b) Isolate the structure against vibration (for excitation frequencies above 5 Hz).

c) Adapt the structure to avoid resonance.

B.3 Measures taken along the transmission path

a) Increase the distance between the source and the receiver (structure).

b) In special cases, dig trenches or fit elements in the ground near the vibration source or the structure.

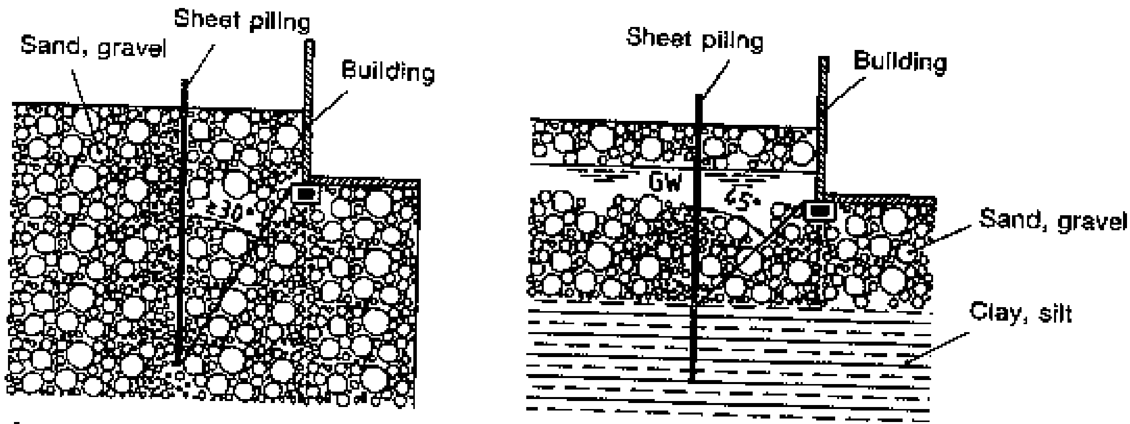
Where the foundation may be susceptible to differential settlement, adequate measures should be taken to strengthen the foundation accordingly (e.g. by sinking a deep foundation).

Appendix C

Effects of vibration on soil

Non-cohesive soil tends to settle, for instance when vibrating rams are used nearby to drive sheet piling. For this reason, the distance between the vibration source and the building foundation should be such that an angle of at least 30° to the vertical is formed as shown in figure C.1. For piling extending below the groundwater table, an angle of 45° is more suitable, as shown in the figure.

This tendency is considerably lower in the case of percussive driving methods (e.g. when using diesel or pneumatic rams).



GW – Groundwater table

Figure C.1: Distance between sheet piling and building (schematic)

Even at great distances from the vibration source, vibration-induced foundation settlement can still occur at vibration severities which are normally not expected to cause structural damage. For this to occur, the soil has to be very sensitive to vibration (as is non-cohesive, uniformly graded sand or silt, for instance), and the vibration has to be continuous or frequent.

Since few investigations have been made regarding dynamically-induced settlement, it is recommended that expert advice be sought.

Another effect vibration has on soil is liquefaction, when sand or silt at the groundwater level suddenly loses its bearing capacity as a result of dynamic effects. During earthquakes, this process can lead to damage as serious as the collapse of buildings. Since the vibration covered by this standard normally lies well under the vibration magnitudes which occur during strong earthquakes, these effects should only be expected under the most unfavourable circumstances.

Appendix D

Additional information on measurements on pipework and evaluation of frequencies

D.1 Vibration measurements on pipework

Measurements carried out to evaluate the effects of vibration on pipework should preferably be performed directly on the pipes. Wherever possible, buried pipes should be exposed only at the point of measurement. The pick-up should be mounted as described in subclause 5.3 of DIN 45669-2. The time history of the vibration should be measured in the z, x and y directions, one of which should run along the pipe axis.

Any insulation at the point of measurement should be removed, although thin coatings have little effect on results. To provide the pick-up with a flat support surface, a concrete or plaster base may be mounted on the pipe.

Often, mounting pick-ups directly on the pipe can be quite involved. Where the vibration source is not immediately next to the pipework, or is nearby but much deeper than the pipes, measurements can be made on the ground surface. Previous investigations have shown that vibration measured on the surface is usually greater than that measured directly on pipes.

D.2 Role of frequency in evaluations

Table 1 gives guideline values for vibration at foundations as a function of frequency. It is assumed the following procedures will be carried out:

1) Finding the maximum velocity values over the time, $v_i(t)$.
2) Determining the significant frequencies, f_i, over $v_i(t)$.
3) Comparing the maximum velocities, v_i, with the values given in table 1 for this significant frequency.

NOTE: Narrow-band spectra are particularly suited for determining frequencies f_i. To reduce distortions of the spectra caused by the duration and form of the data window, the location and length of the latter have to be fitted to the time history, $v_i(t)$. Frequency weighting is not necessary.

EXAMPLE: When a construction machine is started up, short-term vibration occurs. The vibration components, $v_x(t)$, $v_y(t)$, and $v_z(t)$, measured in the foundation of a nearby building have qualitatively similar time histories, as have the spectra. The maximum value of the vertical component, v_z, is considerably greater than those for v_x and v_y; the horizontal components are therefore disregarded. Figure D.1 shows the time history of the vertical component $v_z(t)$ with a maximum value of 5,1 mm/s.

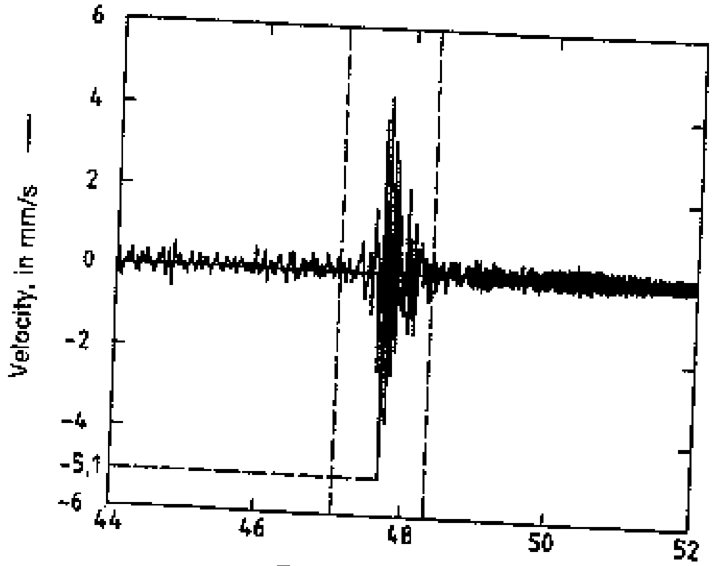


Figure D.1: Time history of the vertical vibration component, with a maximum of 5,1 mm/s

The main section of the vibration signal is enclosed by dashed lines and is enlarged in figure D.2.

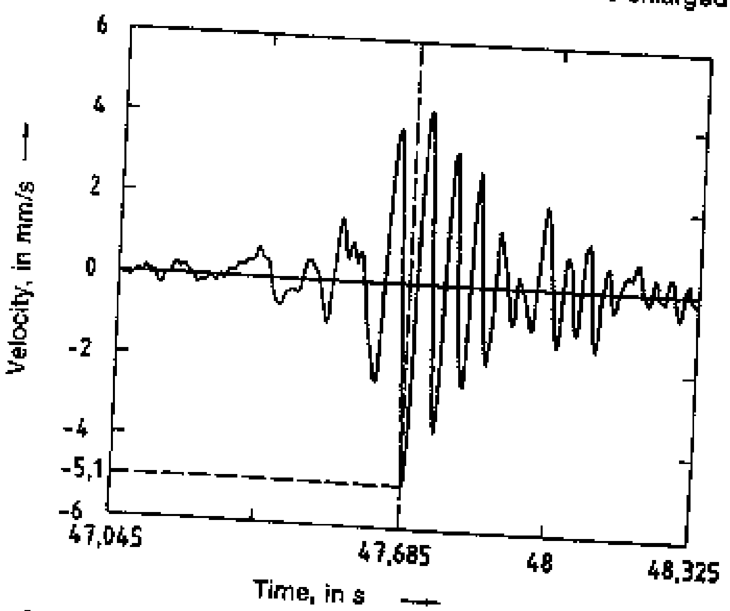


Figure D.2: Enlargement of 1,28 s section of time history shown in figure D.1

Before being transformed into a frequency range, the time history illustrated in figure D.2 is multiplied by the shifted Hanning window shown in figure D.3, given by

$$h_w(t) = \begin{cases} (1 - \cos(2\pi(t - t_0)/T_0))/2 & \text{for } t_0 \le t \le T_0 + t_0 \\ 0 & \text{otherwise} \end{cases}$$

The peak of the Hanning window corresponds to the maximum of v_z; the length of the window has been adjusted to the length of the enlargement in figure D.2 (1,28 s).

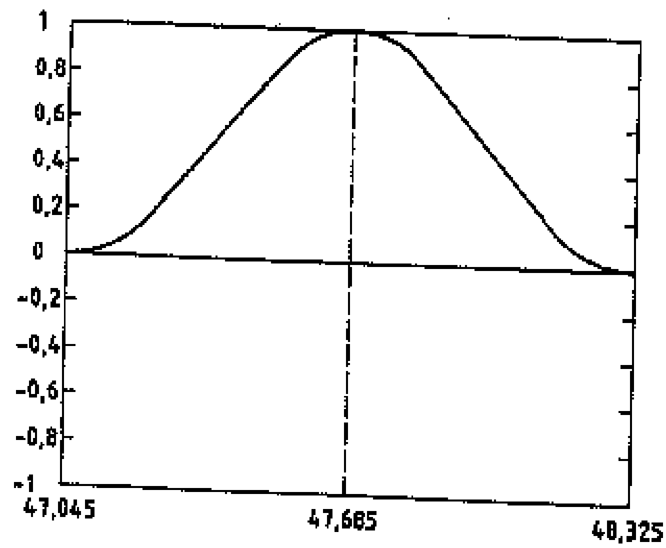


Figure D.3: Hanning window, ($h_w(t)$), fitted to $v_z(t)$ (with t_0 = 47,045 s and T_0 = 1,28 s)

The product of $h_w(t)$ and $v_z(t)$ is transformed into a frequency spectrum using a discrete Fourier transformation. The spectrum is shown in figure D.4 as a normalized spectrum where the maximum of f_z is 16,5 Hz.

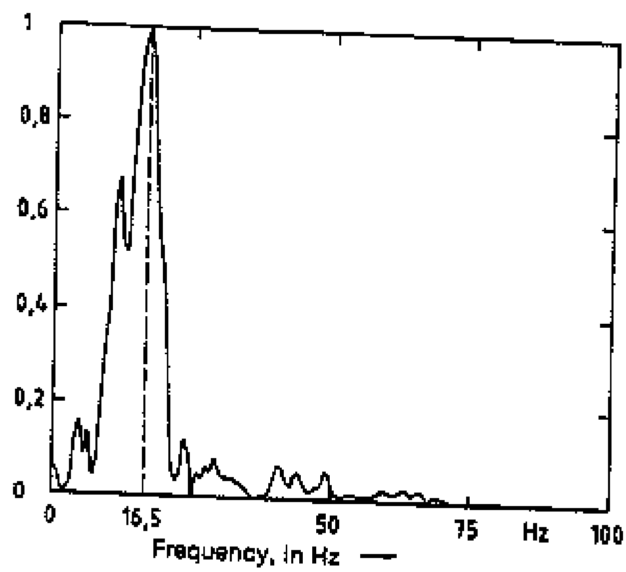


Figure D.4: Normalized spectrum

The value given in line 2 of table 1 for a dwelling and a frequency of 16,5 Hz is 6,5 mm/s. The measured maximum of 5,1 mm/s lies beneath this value.

CONTINUOUS MONITORING OF CONSTRUCTION INDUCED VIBRATION

METHODOLOGY

This methodology presents the procedure for the monitoring of piling induced vibration on building structures adjacent to the piling site.

MONITORING EQUIPMENT

The monitoring equipments shall consist of a triaxial velocity transducers connected to Instantel MiniMate Plus seismographs.

Depending on the structure being monitored, the vibration transducer shall be bolted or glued to the structure using high strength glue. Where necessary, a mounting bracket may be used to aid the installation of the transducer. The transducer shall be connected to the seismograph located at a secure location.

SOURCE OF VIBRATION

The vibration to be monitored comes from installation of 250 mm x 250 mm steel "H" pile using a hydraulic operated drop hammer. The hammer has a 3-tones ram and ram stroke of up to 1.0 m shall be used for driving the piles. The piles shall be driven to set of 25 mm per 10 hammer blows.

ALLOWABLE LIMITS FOR VIBRATION

The allowable vibration limits that may be applicable to the buildings being monitored are recommended by DIN 4150 Part 3 "Structural Vibrations in Buildings" for the appropriate type of structure. The buildings being monitored may be considered at Line 2 (Residential) structures.

FIELD MONITORING

Continuous monitoring of the affected structures shall be conducted during installation of the initials piles. The seismograph shall be set to record the maximum vibration measured within each 15 minutes interval. In addition, the time domain records for vibration events with vibration velocity greater than 5.0 mm/s shall be recorded.

The results of monitoring shall be assessed with referenced to the vibration limit recommended by DIN 4150 Part 3 "Structural Vibrations in Buildings" for Line 2 (residential) structure. The monitoring work shall be documented and the findings submitted in formal report.