UNIVERSITI TEKNOLOGI MALAYSIA

Lecture 4:

INTERPRETATION OF INSTRUMENTATION AND MONITORING WORKS

PROF. Ir. Ts. DR. AZMAN BIN KASSIM
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Kursus Instrumentasi dan Pengawasan Cerun serta Sistem Amaran Awal

18-19 Mac 2021

UNIVERSITI TEKNOLOGI MALAYSIA

IMPLEMENTATION OF SLOPE MONITORING PROGRAM AND INSTALLATION OF REAL TIME VIBRATION MONITORING SYSTEM AT GUNUNG PULAI WATER TREATMENT PLANT

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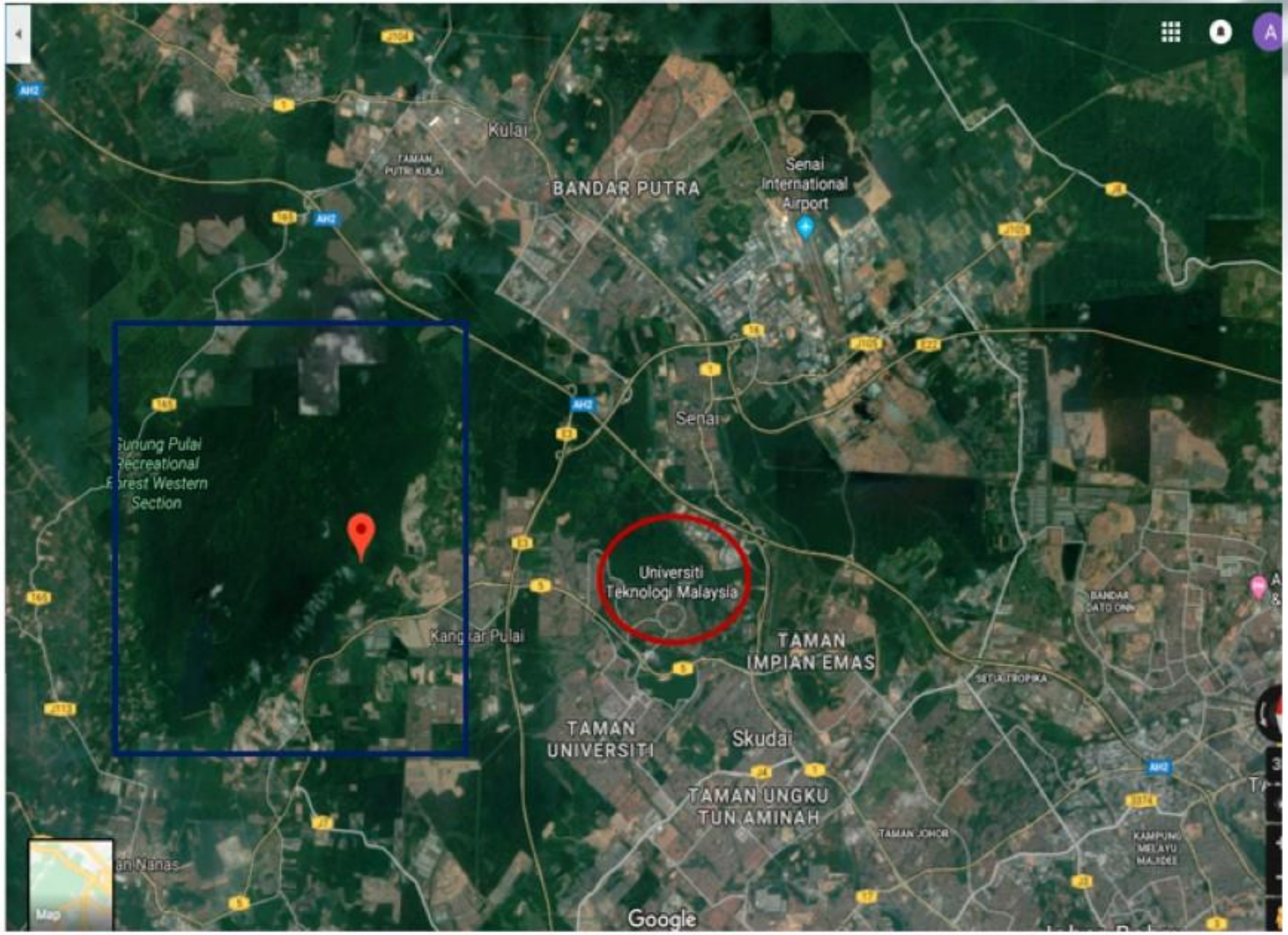
INTRODUCTION

Sultan Ibrahim Reservoir



SULTAN IBRAHIM RESERVOIR

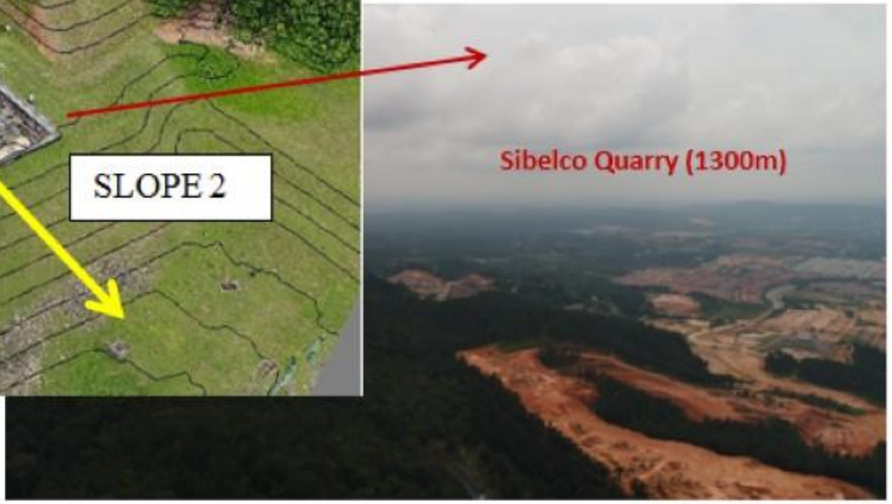
- Sultan Ibrahim Reservoir located at Gunung Pulai catchment area was built within 1924 to 1929
- The reservoir has 130 acres of lake with a maximum capacity of 1220 million gallons of water
- A dam was built to retain the water where the geometry of the dam is 36.6 m height and 182.3 m length
- It was built and previously managed by the Singapore's Public Utilities Board (PUB) for more than 50 years and it was handed over to the Johor State Government under new management of the Syarikat Air Johor (SAJ)

GUNUNG PULAI TREATMENT PLANT (GPWTP)

- The Gunung Pulai Water Treatment Plant is situated near the Sultan Ibrahim Reservoir to treat raw water from the reservoir before supplying to the consumers
- The integrity of the water treatment structure (Water Infiltration Plant – Office Building and Water Sedimentation Plant) should be checked due to the structure was built over more than 90 years, and moreover after a several cracks was recently observed

QUARRY ACTIVITIES AND SLOPE MOVEMENT

- There are six (6) nearby active quarries have been identified in the area, the two nearest quarries are Malaysian Rock Products Sdn. Bhd. (MRP), is about 500m to the South-west and Sibelco Quarry is located about 1300m North-east from the GPWTP



THE MULTIPLE MONITORING SYSTEM

The implementation of slope monitoring program and installation of vibration monitoring devices that include designing, setting-up and installing multiple monitoring systems with the aim of identifying contributed factors to the problem of crack on water treatment structures

The three (3) main objectives of the monitoring are:

1. Settlement and Crack Monitoring at the Water Treatment Plant
   Surface settlement monitoring
   Structural crack measurement

2. Slope Stability Monitoring and Analysis
   Subsurface profile investigation
   Slope inclinometer
   Pneumatic piezometer

3. Vibration Monitoring at the Water Treatment Plant

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Settlement Monitoring at the Water Treatment Plant

Crack Monitoring at the Water Treatment Plant

Crack Monitoring at the Water Treatment Plant

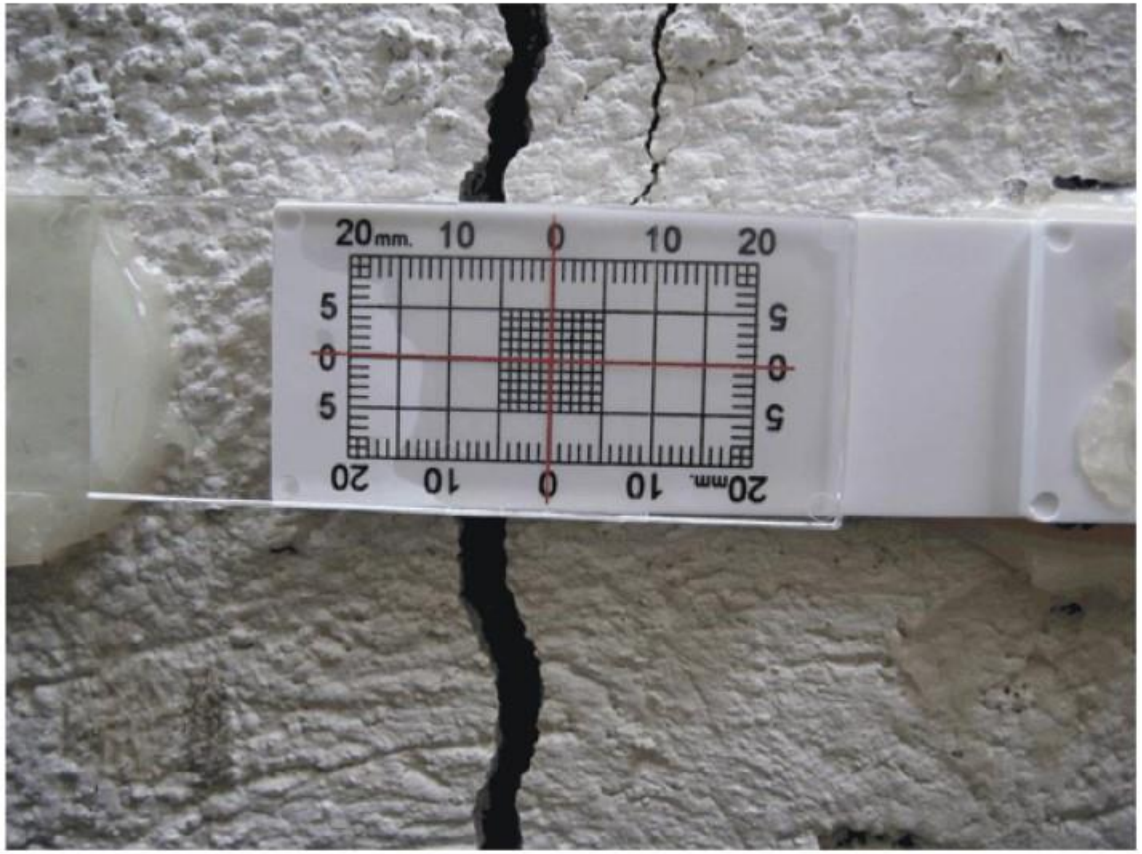
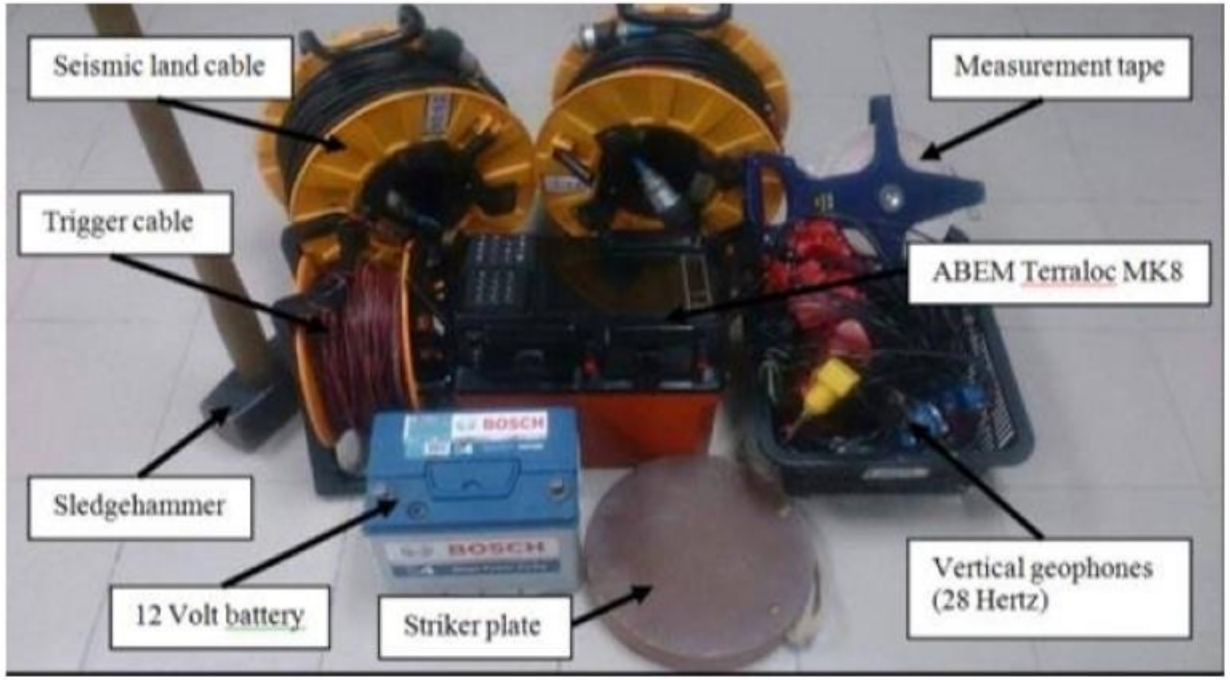


Figure 11

Slope Stability Monitoring and Analysis

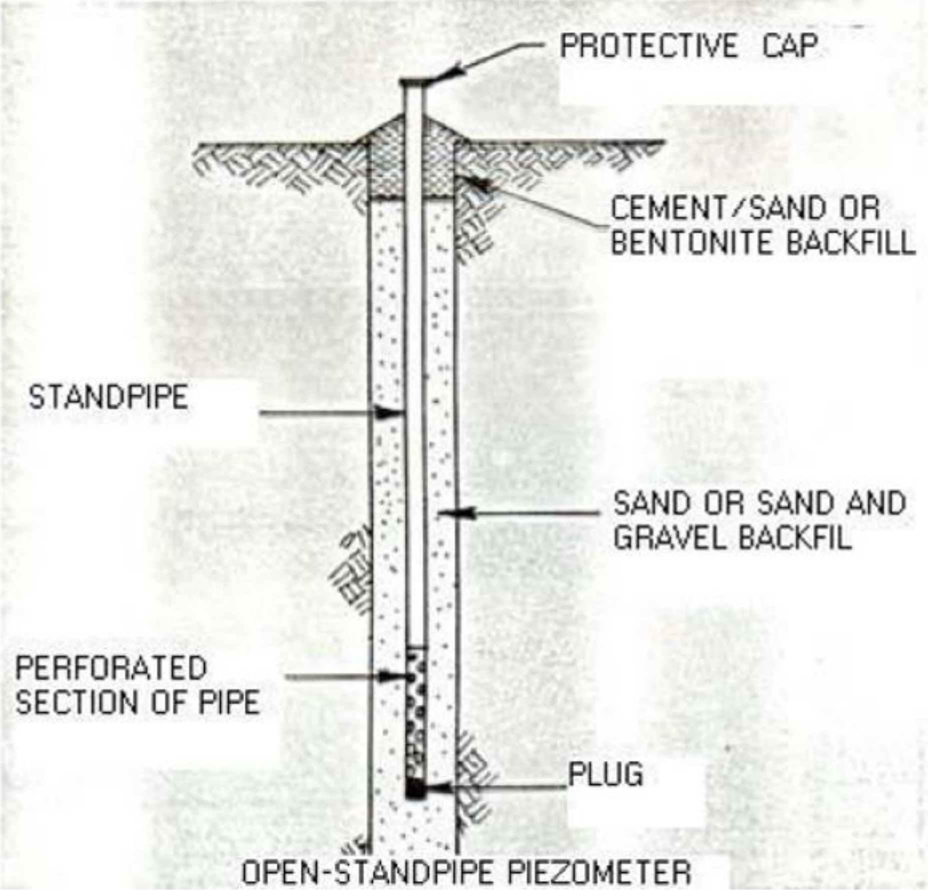
Subsurface profile investigation

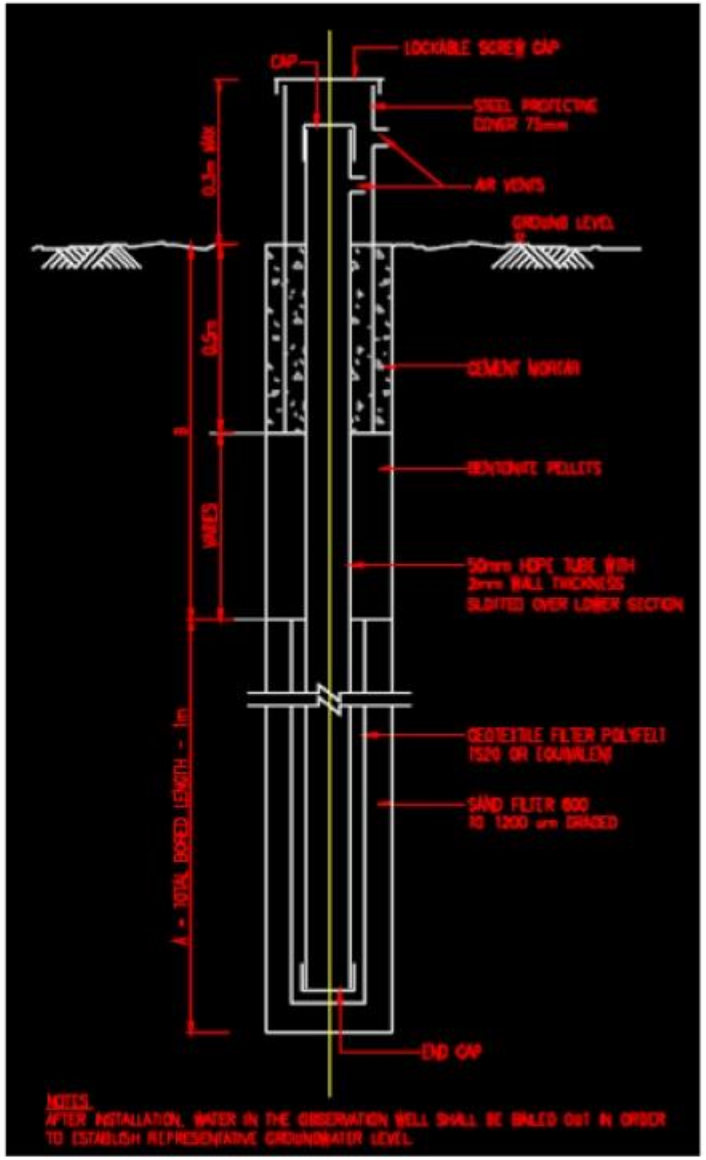
Slope Stability Monitoring and Analysis
Subsurface profile investigation



Slope Stability Monitoring and Analysis

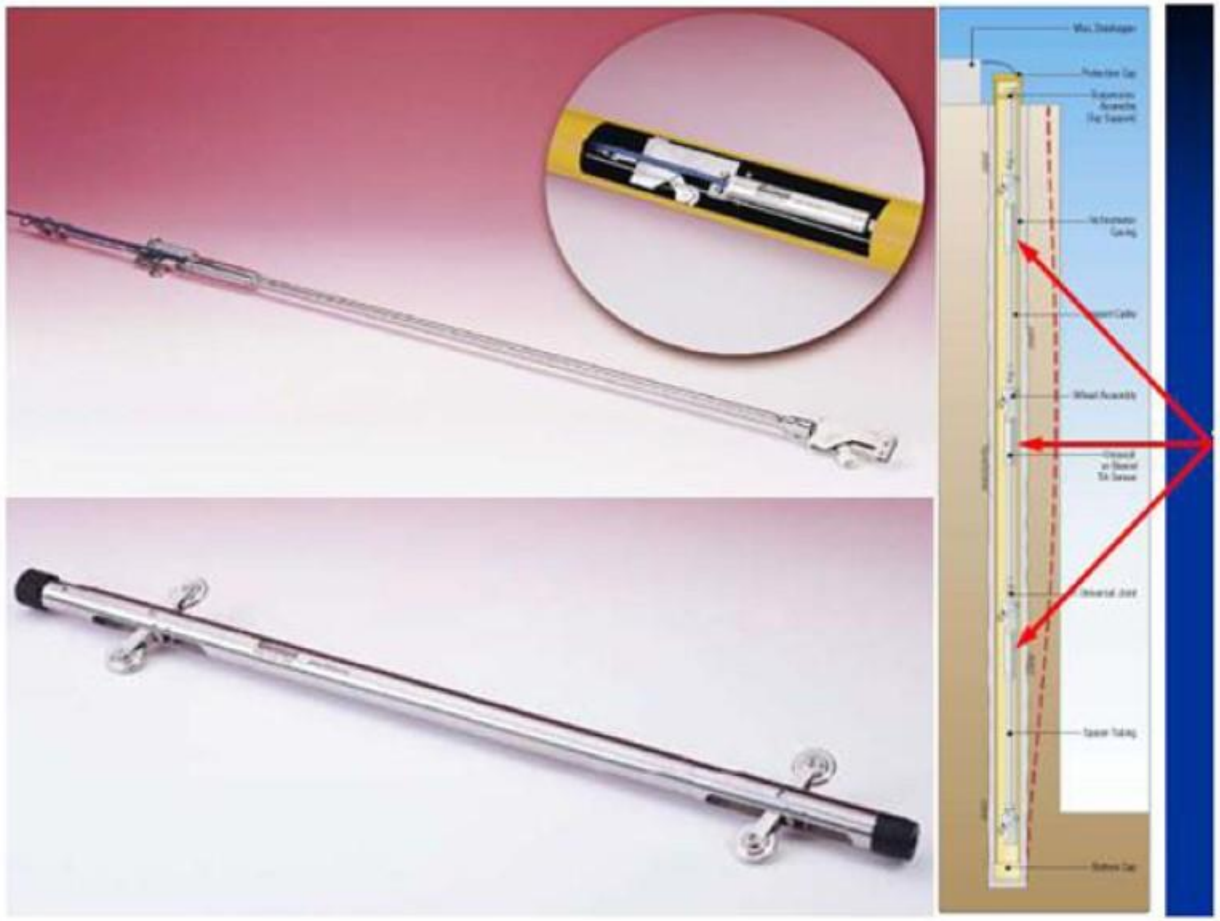
Groundwater level investigation



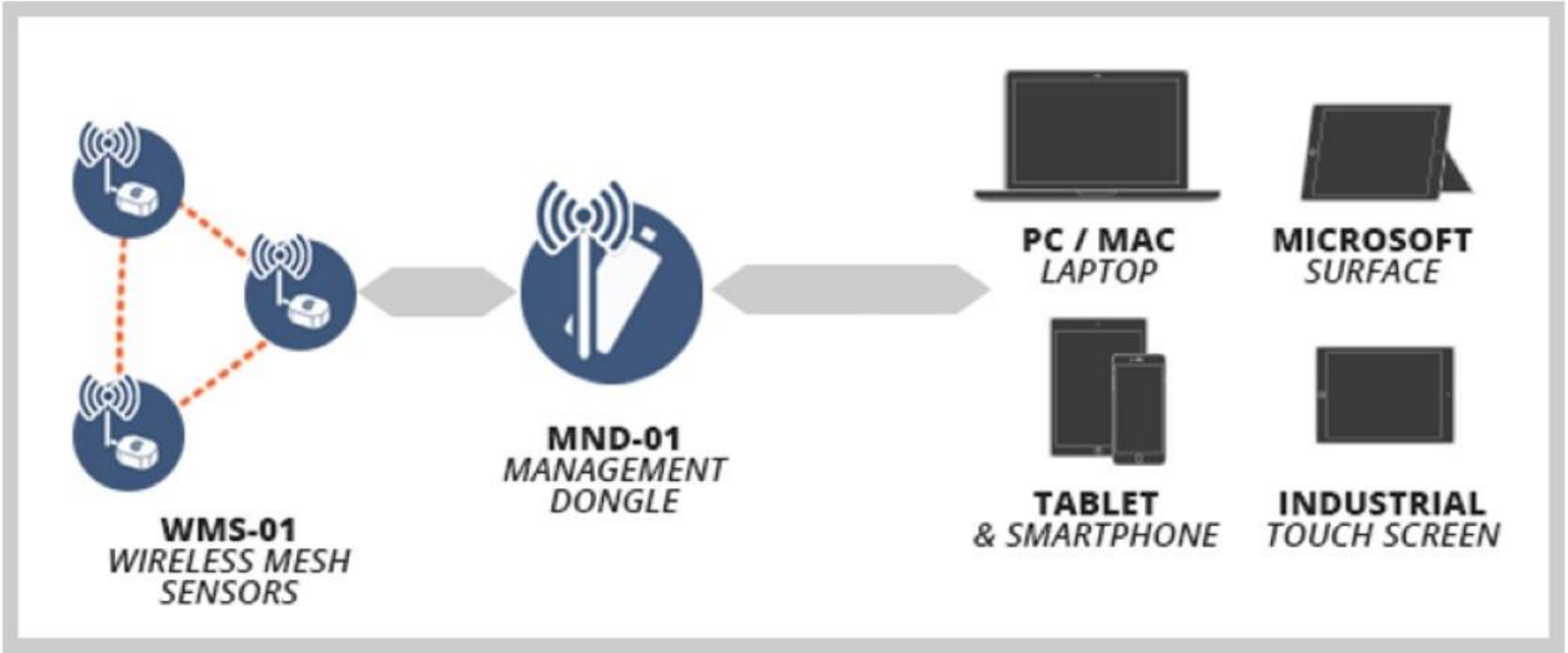


Slope Stability Monitoring and Analysis

Groundwater level investigation



Vibration Monitoring at the Water Treatment Plant



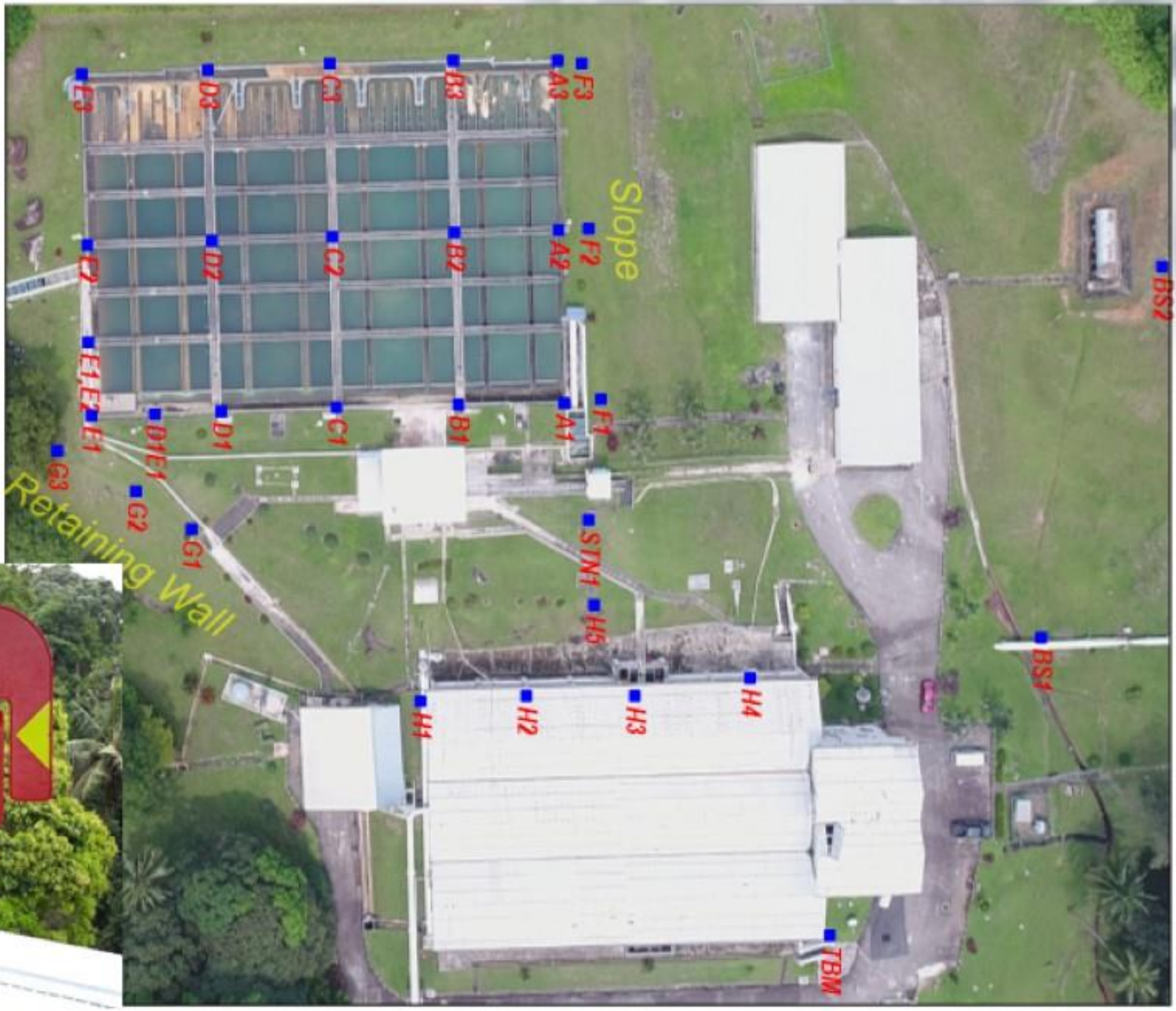
SURFACE SETTLEMENT MONITORING

- Settlement monitoring is based on a three-dimensional displacement approach that utilizes precise total stations and levels

Type A, B, C, D & E

Type F & G

Type H



RESULTS OF SETTLEMENT MONITORING

- A 95% confidence level was chosen (confidence interval of ± 1.96σ and standard error, σ of ± 0.3 mm)
- Any differences greater or smaller than ±1.96 × 0.3 mm (approx. ±0.6 mm) will be considered as the effects of random errors and not settlements

Type A, B, C, D & E

Point	7/11/2017 Base (m)	7/1/2018 Epoch 1 (m)	9/3/2018 Epoch 2 (m)	26/5/2018 Epoch 3 (m)	15/7/2018 Epoch 4 (m)	Epoch 1 - Base Diff. (mm)	Epoch 2 – Base Diff. (mm)	Epoch 3 – Base Diff. (mm)	Epoch 4 - Base Diff. (mm)	Remark
A1	40.4331	40.43322	40.43312	40.43293	40.43308	0.12	0.02	-0.17	-0.02	Stable
A2	40.4173	40.41685	40.41727	40.41705	40.41741	-0.45	-0.03	-0.25	0.11	Stable
A3	40.40758	40.40744	40.40778	40.40729	40.40758	-0.14	0.20	-0.29	0.00	Stable
B1	40.43954	40.43911	40.43968	40.43918	40.4397	-0.43	0.14	-0.36	0.16	Stable
B2	39.67953	39.67926	39.6794	39.67942	39.67949	-0.27	-0.13	-0.11	-0.04	Stable
B3	40.43406	40.43357	40.43378	40.43373	40.43406	-0.49	-0.28	-0.33	0.00	Stable
C1	40.44129	40.44095	40.44136	40.44077	40.4415	-0.34	0.07	-0.52	0.21	Stable
C2	39.68093	39.68069	39.68114	39.68086	39.68097	-0.24	0.21	-0.07	0.04	Stable
C3	40.43463	40.43443	40.43463	40.43463	40.43472	-0.2	0.00	0	0.09	Stable
D1	40.42953	40.42938	40.42984	40.42922	40.42992	-0.15	0.31	-0.31	0.39	Stable
D1,E1	40.40542	40.40535	40.4057	40.40491	40.40563	-0.07	0.28	-0.51	0.21	Stable
D2	39.67945	39.67926	39.67961	39.67964	39.67969	-0.19	0.16	0.19	0.24	Stable
D3	40.42953	40.42953	40.42988	40.43002	40.42996	0	0.35	0.49	0.43	Stable
E1	40.31851	40.31838	40.31809	40.31731	40.31747	-0.13	-0.42	-1.2	-1.04	Settlement
E1,E2	40.425	40.42503	40.42526	40.42473	40.42486	0.03	0.26	-0.27	-0.14	Stable
E2	40.43953	40.43968	40.43988	40.43951	40.43962	0.15	0.35	-0.02	0.09	Stable
E3	40.43241	40.43193	40.43281	40.43257	40.43252	-0.48	0.40	0.16	0.11	Stable

RESULTS OF SETTLEMENT MONITORING

- A 95% confidence level was chosen (confidence interval of ± 1.96σ and standard error, σ of ± 0.3 mm)
- Any differences greater or smaller than ±1.96 × 0.3 mm (approx. ±0.6 mm) will be considered as the effects of random errors and not settlements

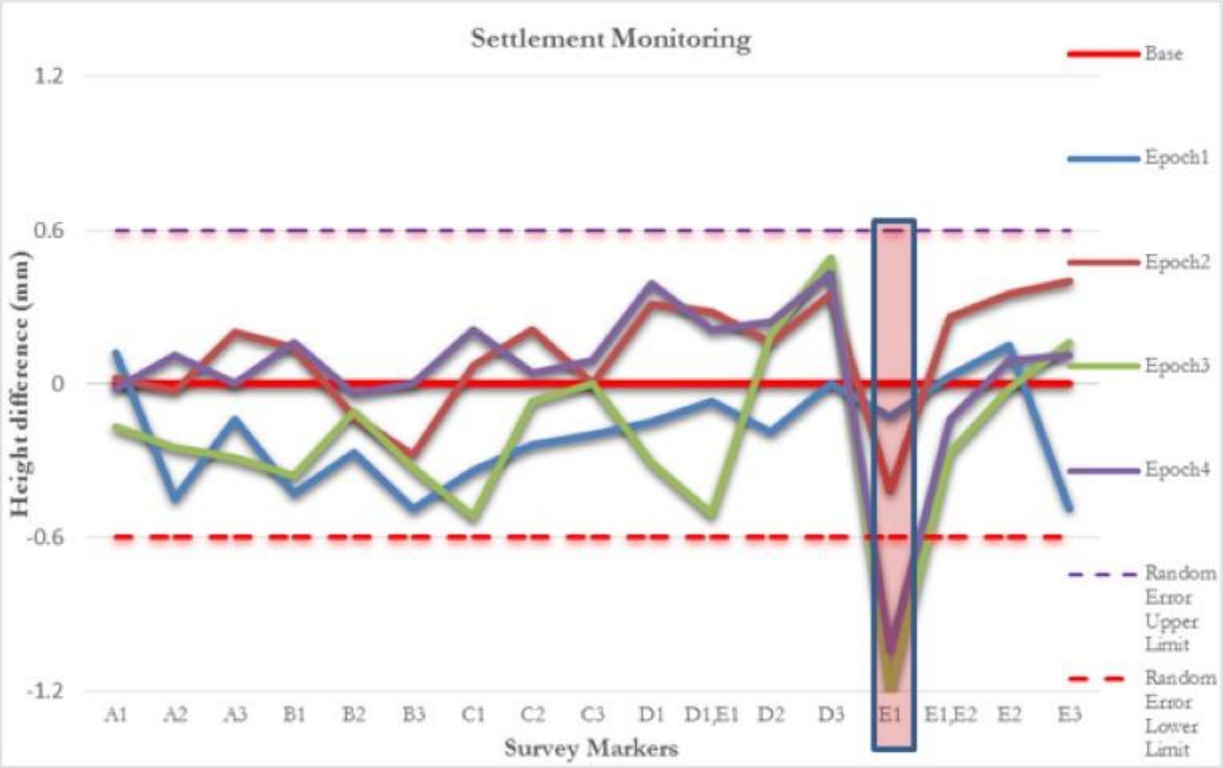
Type H

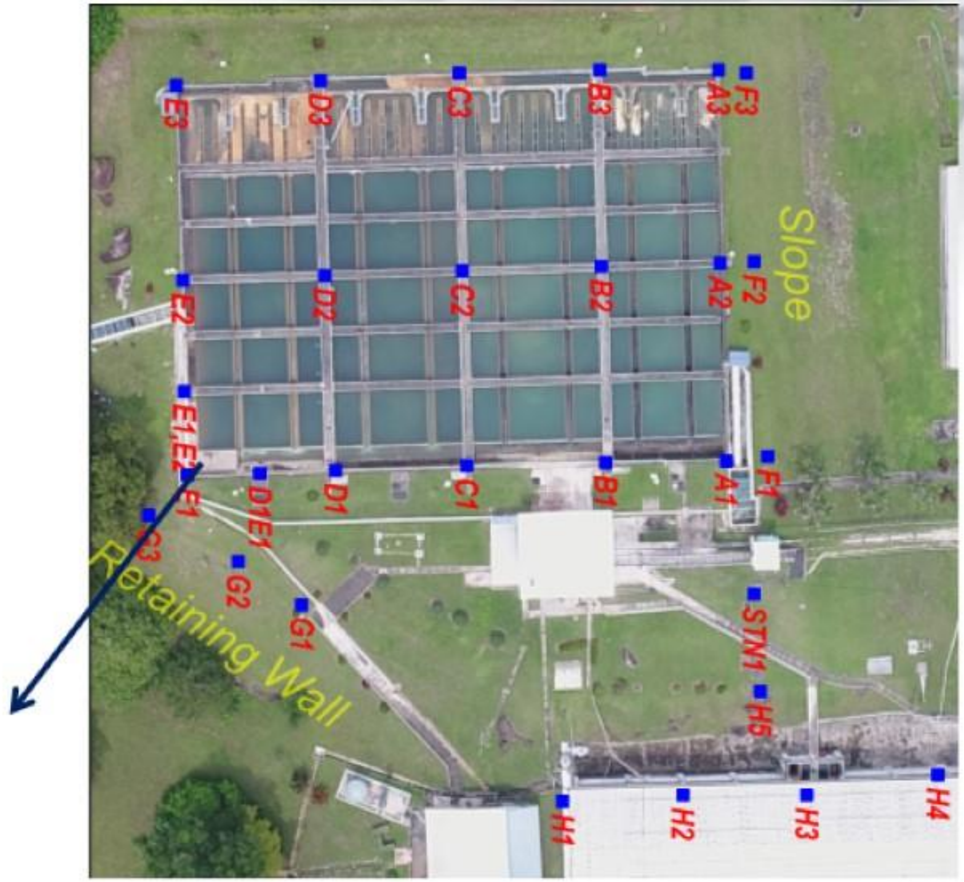
Date	Base (20/1/2018)			Epoch 3 (16/7/2018)			Epoch3 – Base			Remark
Pt	Northing (m)	Easting (m)	Height (m)	Northing (m)	Easting (m)	Height (m)	dN (mm)	dE (mm)	dZ (mm)	
H1	1027.71473	989.75815	28.03693	1027.71550	989.75796	28.03836	0.78	-0.19	1.43	Point Stable
H2	1017.23011	983.94439	28.14698	1017.22962	983.94511	28.14764	-0.49	0.72	0.67	Point Stable
H3	1002.01773	976.06748	28.09930	1002.01774	976.06792	28.10013	0.02	0.45	0.83	Point Stable
H4	991.20248	971.80508	26.64762	991.20198	971.80608	26.64812	-0.50	1.00	0.50	Point Stable
H5	1005.95420	989.21521	28.42334	1005.95384	989.21616	28.42392	-0.36	0.95	0.58	Point Stable

Type F & G

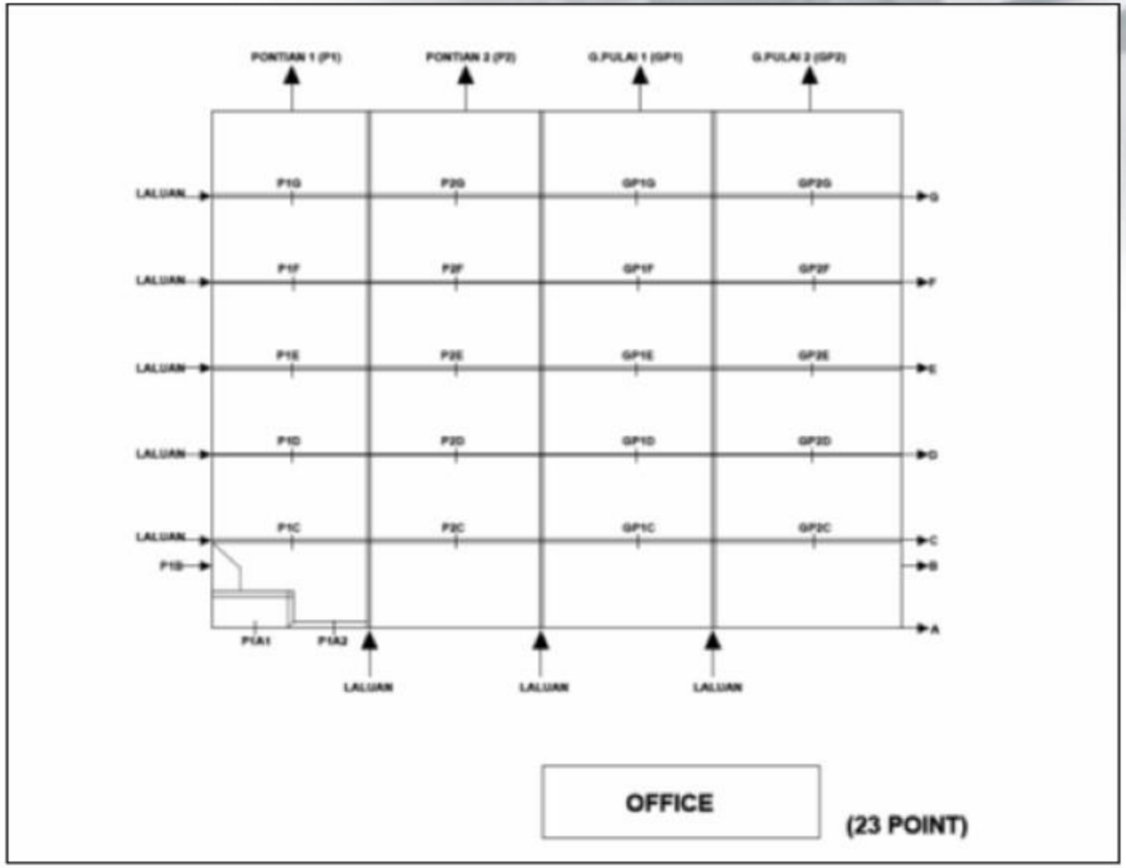
Point	9/3/18 Base (m)	26/5/18 Epoch 1 (m)	15/7/18 Epoch 2 (m)	Epoch 1 – Base Difference (mm)	Epoch 2 – Base Difference (mm)	Remark
F1	39.25592	39.25614	39.25584	0.22	-0.08	Stable
F2	38.69308	38.6936	38.69314	0.52	0.06	Stable
F3	38.5134	38.51395	38.51343	0.55	0.03	Stable
G1	37.52109	37.52055	37.52086	-0.54	-0.23	Stable
G2	38.5703	38.56971	38.56991	-0.59	-0.39	Stable
G3	39.29574	39.2948	39.29518	-0.94	-0.56	Settlement

INTERPRETATION OF SETTLEMENT MONITORING





STRUCTURAL CRACK MONITORING



STRUCTURAL CRACK MONITORING

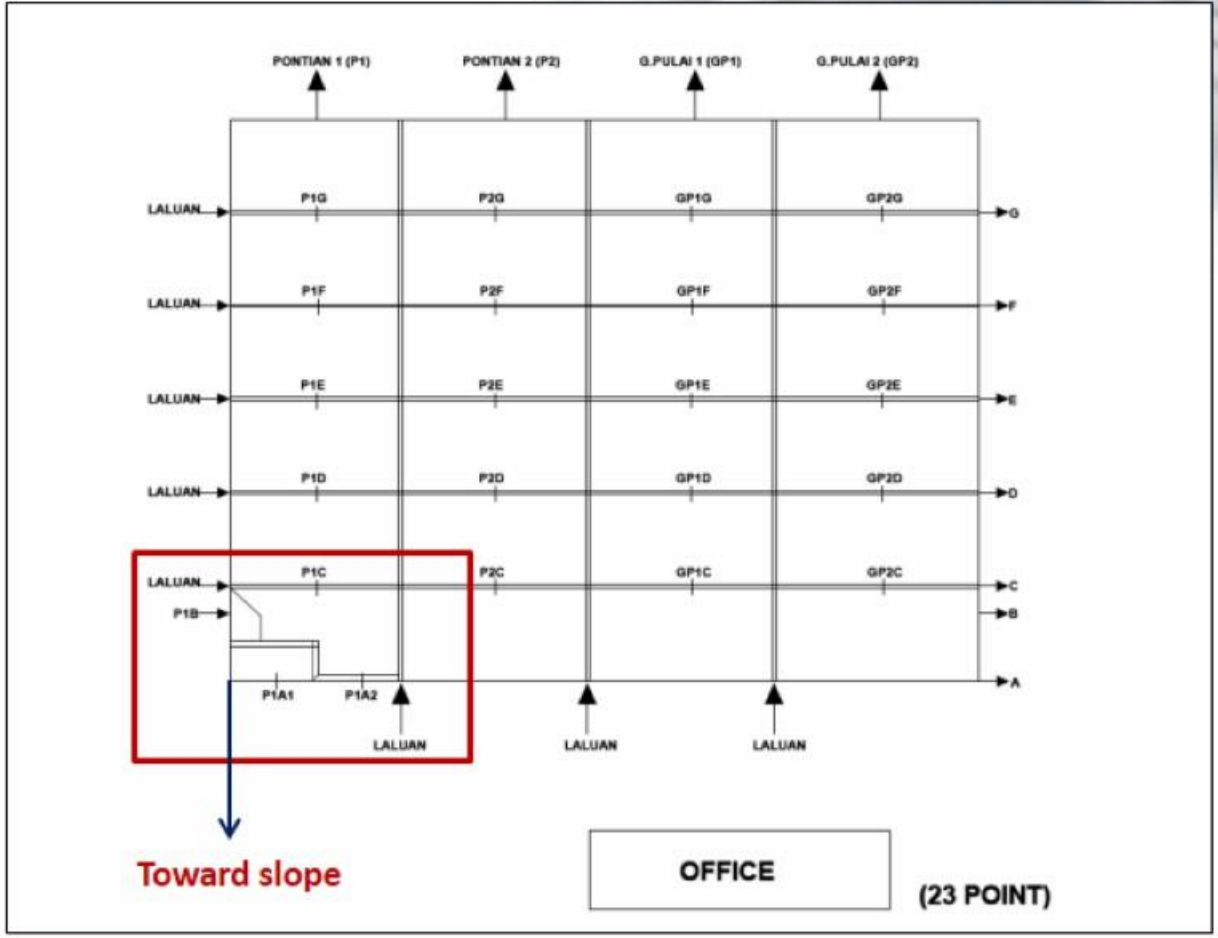
Crack Measurement

Crack Propagation

RESULTS OF CRACK MEASUREMENT

- The size of all cracks is in the range of between 0.5mm to 1.0mm width (more than 0.5mm [0.2mm – water tight) and passing through the concrete thickness can be classified as structural crack)

No	Point	Crack Size (mm)
1	P1A1	3.5
2	P1B	6.0
3	P1C	0.6
4	P1F	0.6
5	P1G	0.75
6	P2G	0.75
7	P2F	0.5
8	P2C	0.5
9	P2D	0.75
10	P1A2	3.5
11	P1E	0.75
12	P1D	0.75
13	P2E	1.0
14	GP1C	0.8
15	GP2C	0.5
16	GP2D	0.5
17	GP1D	1.0
18	GP1E	0.5
19	GP2E	1.0
20	GP1G	0.6
21	GP1F	0.6
22	GP2G	0.7
23	GP2F	0.7

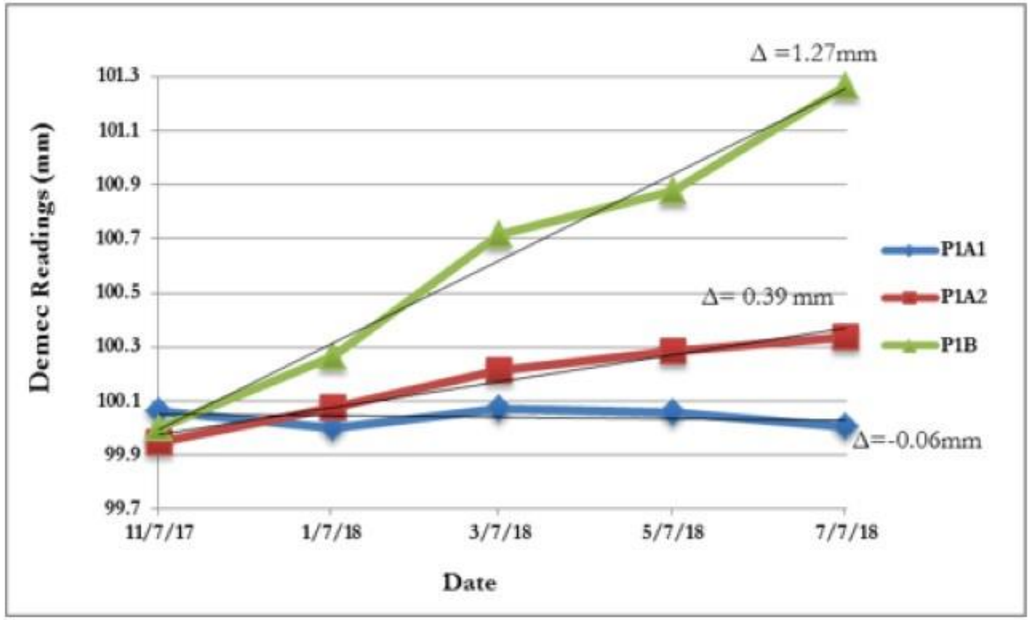


CRACK PROPAGATION

Point	7/11/17	7/01/18	7/03/18	7/05/18	7/07/18
P1A1	100.064	100.001	100.072	100.058	100.005
P1A2	99.950	100.078	100.213	100.283	100.336
P1B	100.002	100.265	100.717	100.879	101.267
P1C	99.601	99.497	100.067	99.747	100.062
P1D	100.000	100.119	100.013	99.970	99.920
P1E	99.815	99.845	99.975	99.899	99.930
P1F	99.897	99.829	100.001	99.910	100.015
P1G	99.997	100.087	100.054	100.029	99.979
P2C	99.841	99.821	100.034	99.929	99.998
P2D	99.755	99.848	99.979	99.873	99.870
P2E	99.832	99.554	99.959	99.752	99.854
P2F	99.883	99.788	99.902	99.853	99.894
P2G	99.528	99.498	99.767	99.662	99.757
GP1C	99.810	99.782	100.054	99.958	100.046
GP1D	99.323	99.581	99.786	99.701	99.760
GP1E	99.149	99.093	99.256	99.215	99.286
GP1F	99.813	99.592	99.872	99.801	99.826
GP1G	99.923	99.945	99.904	99.932	99.915
GP2C	99.771	99.674	100.074	99.986	100.068
GP2D	99.879	99.615	100.055	99.871	99.998
GP2E	99.081	99.010	99.292	99.222	99.314
GP2F	99.854	99.449	99.834	99.725	99.849
GP2G	99.688	99.390	99.606	99.589	99.665

CRITICAL CRACK INCREMENT

- Crack propagation monitoring critical value of crack increment is 1.27mm which pointed at the slope area (P1B)

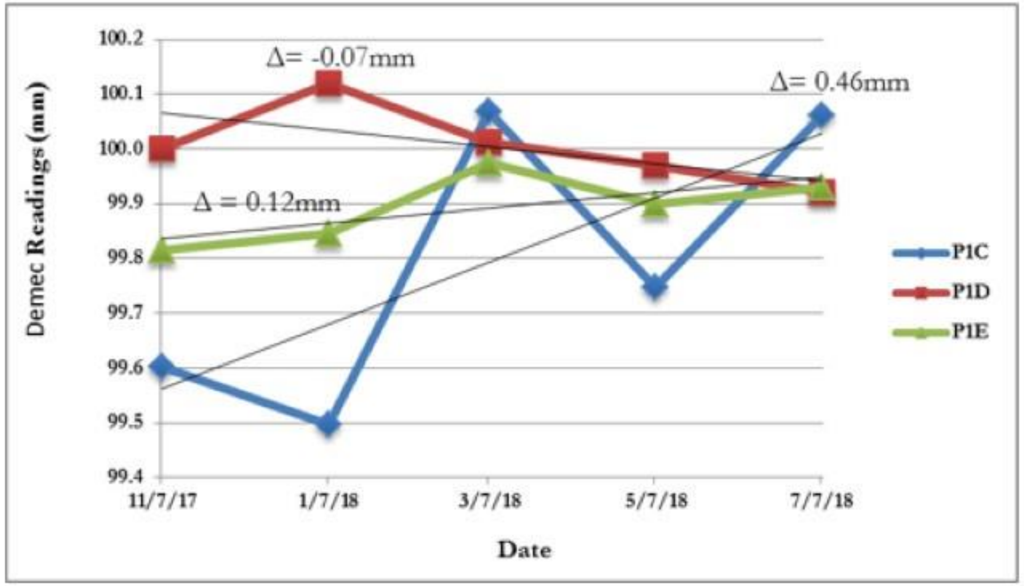


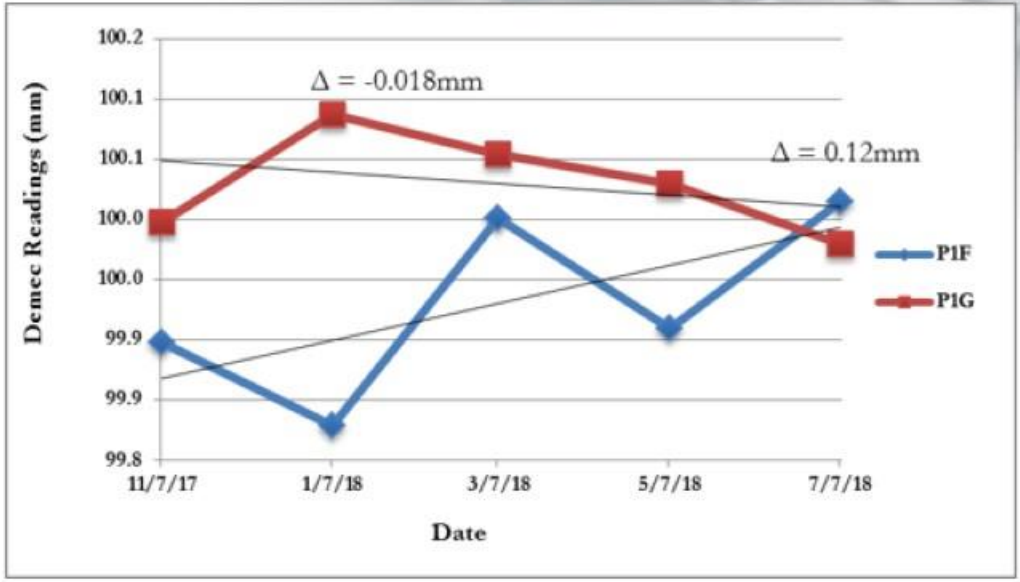
a) P1A1

b) P1A2

c) P1B

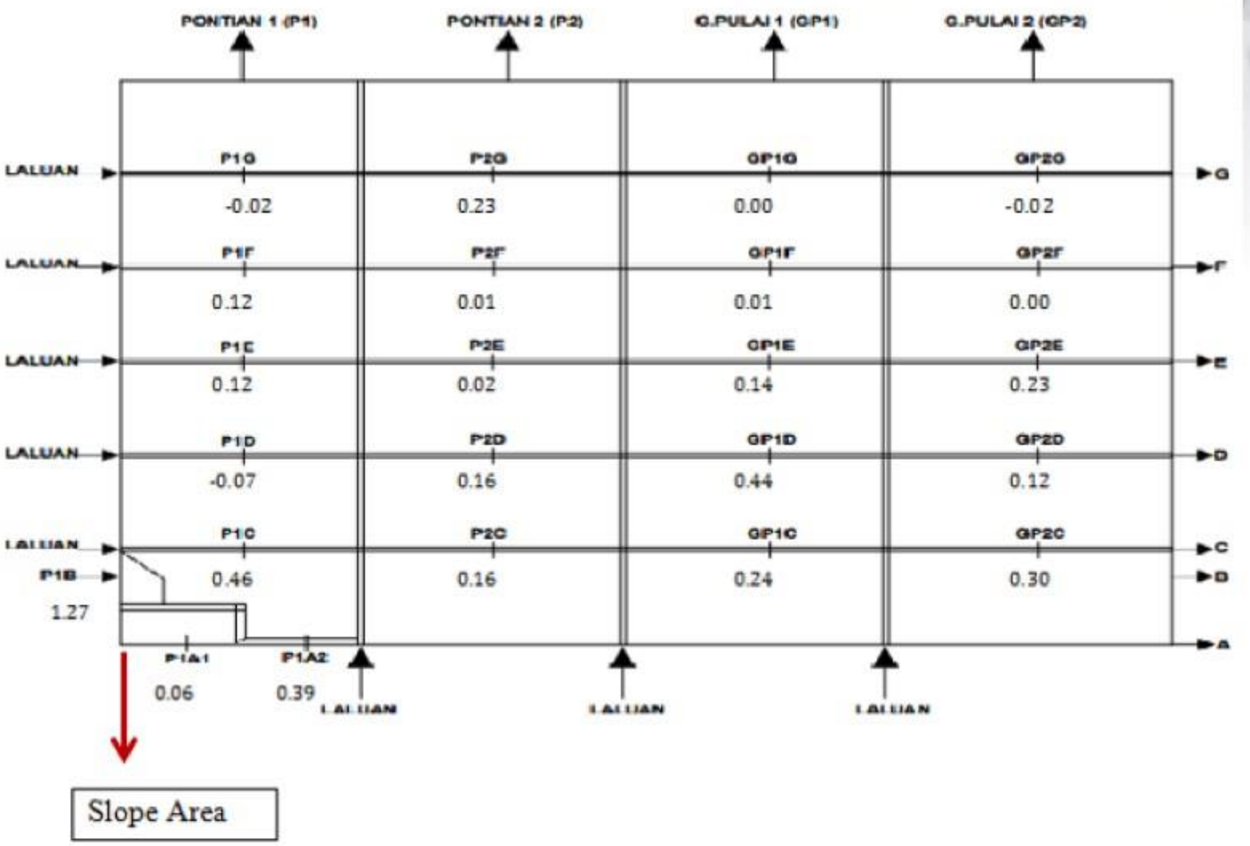
FLUCTUATION OF CRACK MEASUREMENT





INTERPRETATION OF CRACK MONITORING

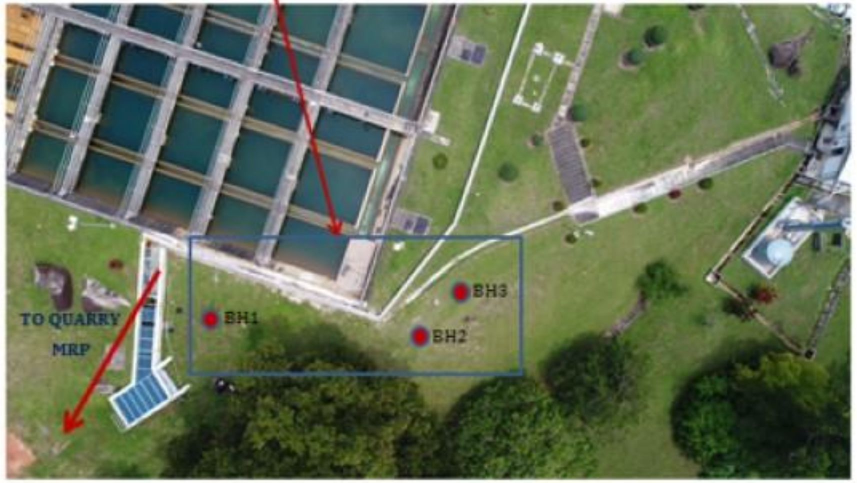
- Based on the deviation of points from the trend lines, the uncertainty of the estimation is in the average of ± 0.1 mm (except points near the slope)
- Assuming linear increment of crack, it can be projected that in the next 5 years, the crack size will increase about 0.5mm, e.g. the existing crack size is in the average of about 0.75mm, thus will be estimated to become 1.25mm in the next five years
- However, this size of crack is still within the allowable limit, based on the fact that the concrete slab walkways are not carrying gravity load, functioning as tie member only, and penetration of water between ponds is not an issue



SLOPE STABILITY MONITORING AND ANALYSIS

Subsurface Profile Investigation
<u>Rotary Drilling</u>:

- ❑ Explored the subsoil condition at the proposed site by four (4) exploratory borehole
- ❑ Carried out Standard Penetration Test.
- ❑ Installed and monitored two (2) numbers of Pneumatic Piezometer
- ❑ Installed and monitored one (1) number of Inclinometer
- ❑ Obtained undisturbed and disturbed samples
- ❑ Performed laboratory test on selected samples



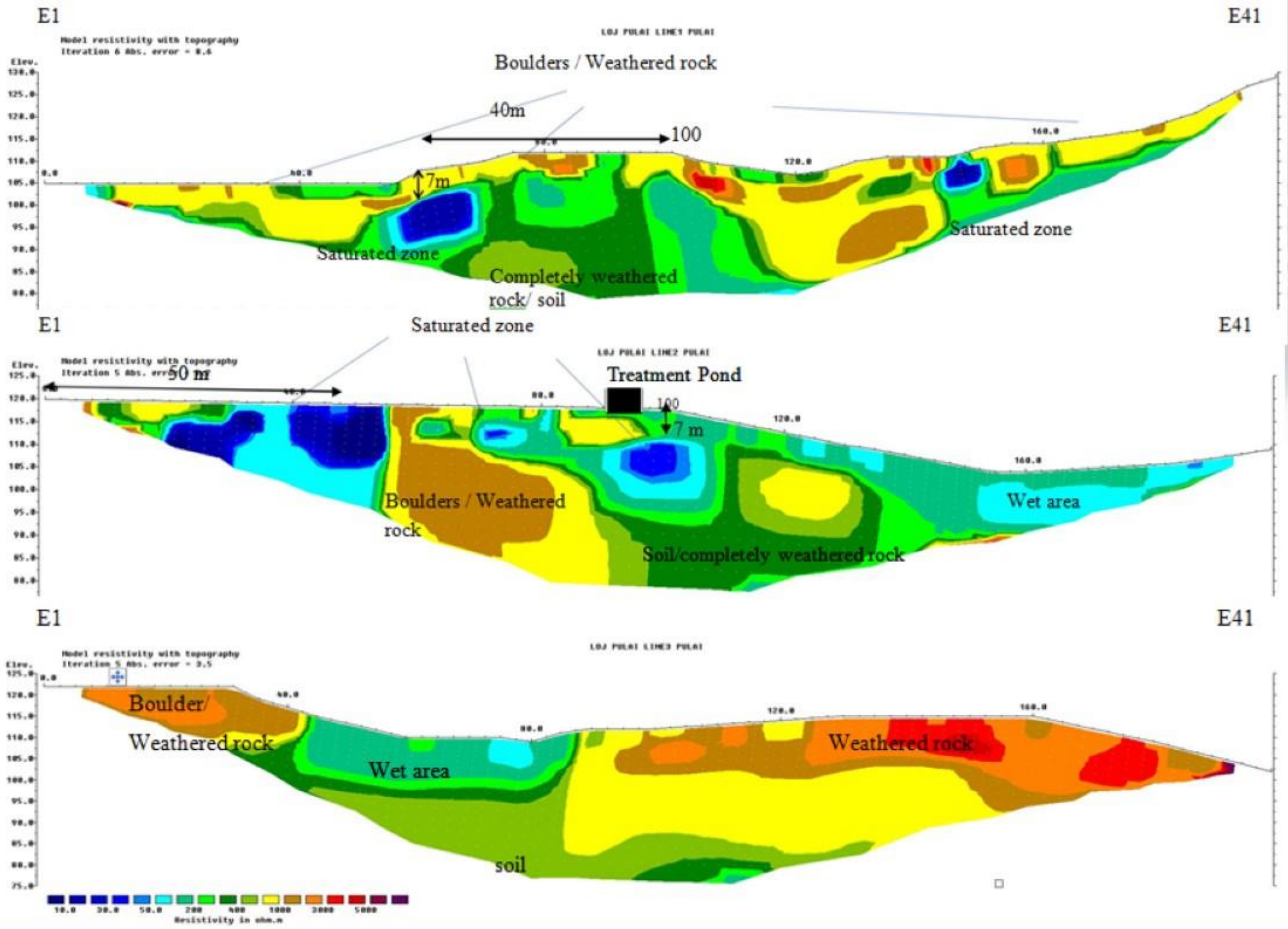
GEOPHYSICAL SURVEY

Resistivity Imaging

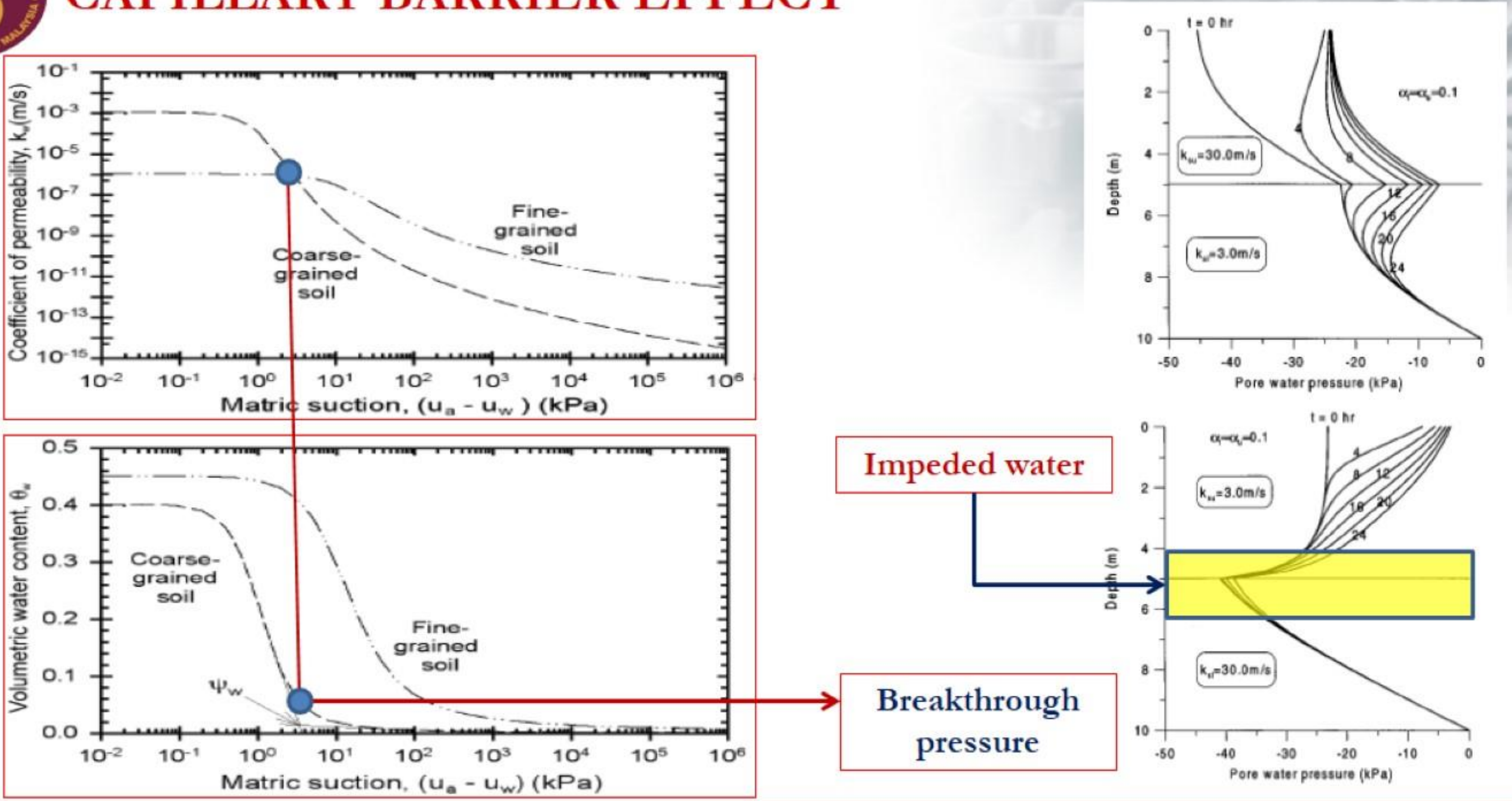
Seismic Imaging

Lost of water during drilling?

Capillary Barrier Effect or Leakage?



CAPILLARY BARRIER EFFECT



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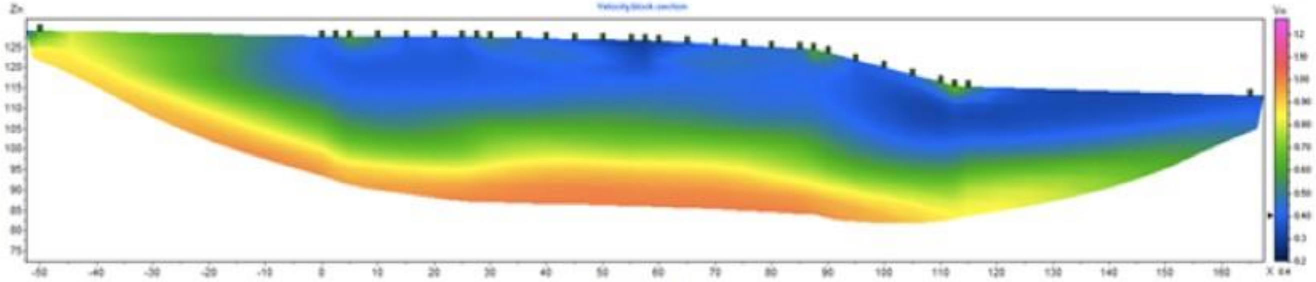
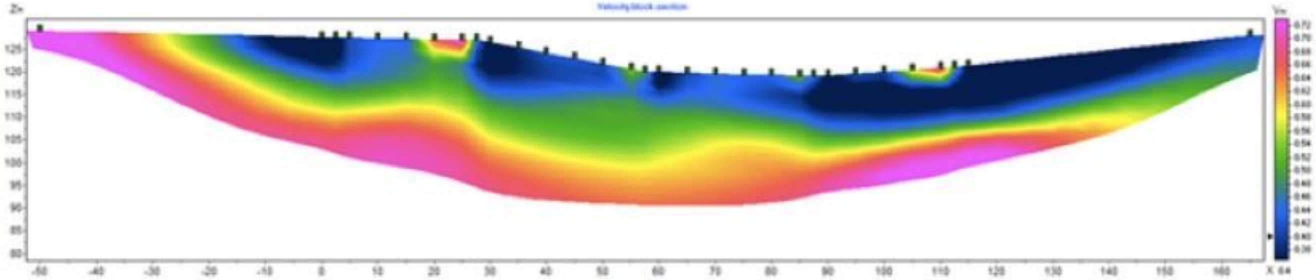
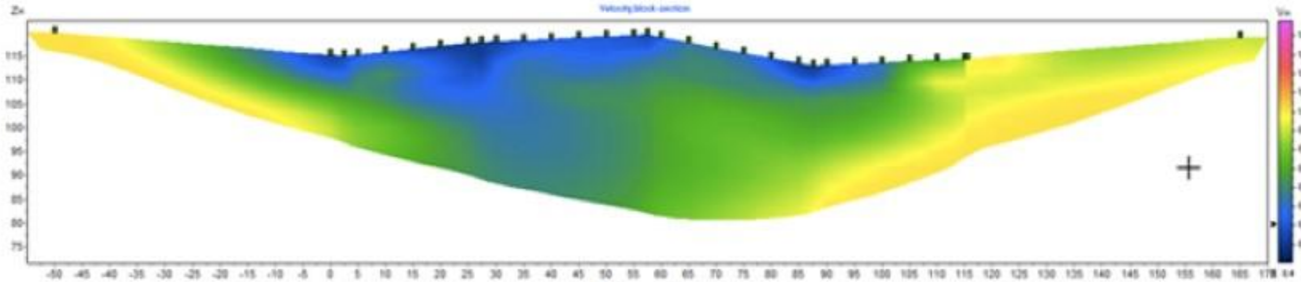


Line 1



Line 2



Line 3

Continuous wet surfaces

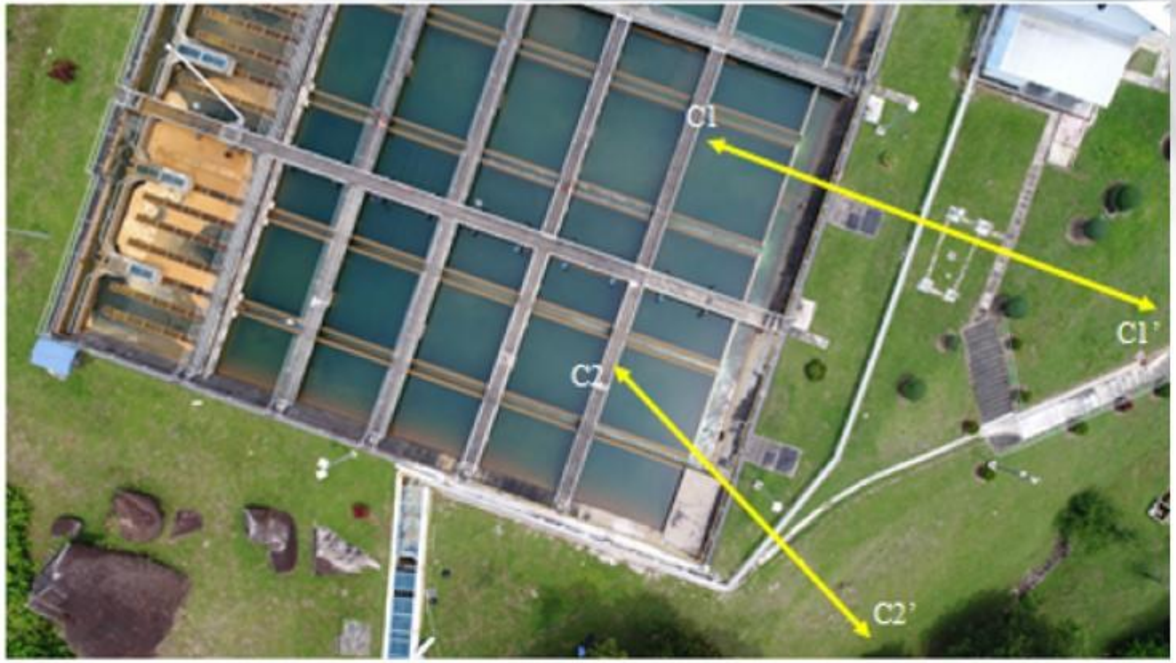
Part of the quarry faces at MRP Quarry

SLOPE STABILITY ANALYSIS

The geometry and soil profile – **CROSS SECTION C1 & C2** consist of two main layers of soil:

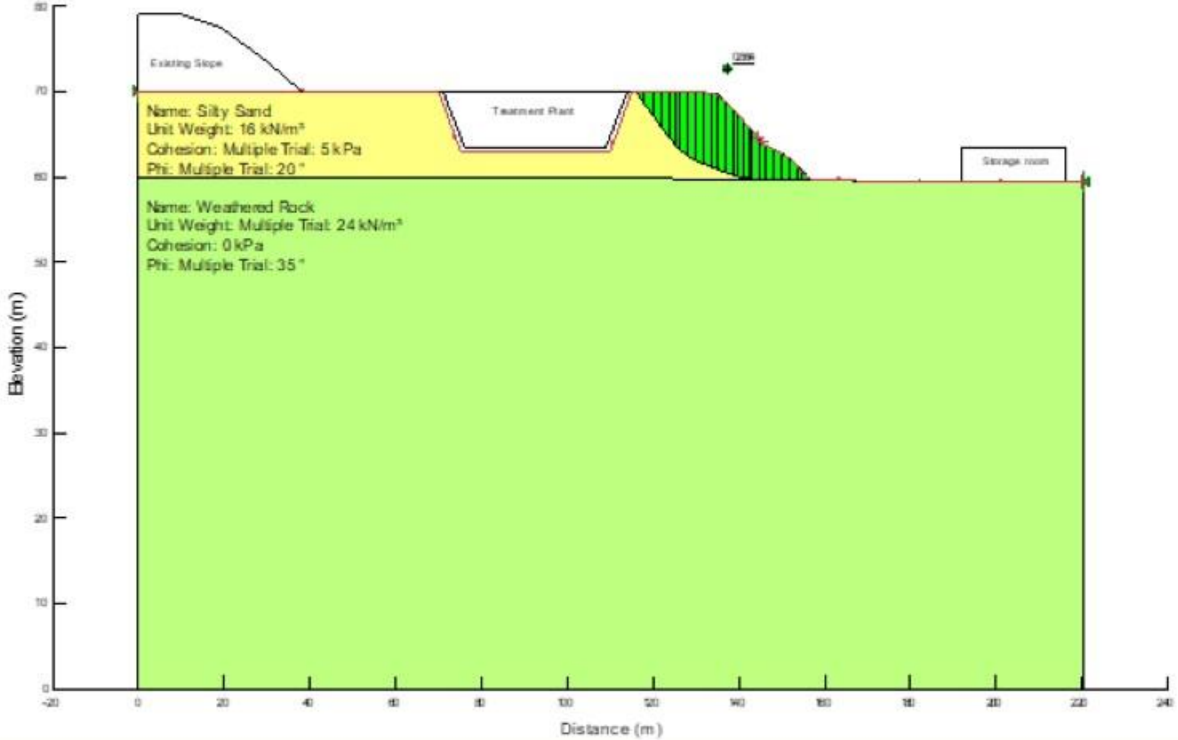
- **Top Soil: Firm to stiff Silty SAND: Unit weight, γ = 16kN/m^3, effective friction angle, ϕ' = 20, effective cohesion, c' = 5kPa, Young Modulus, E = 3000kPa and Poisson's ratio, υ = 0.4**

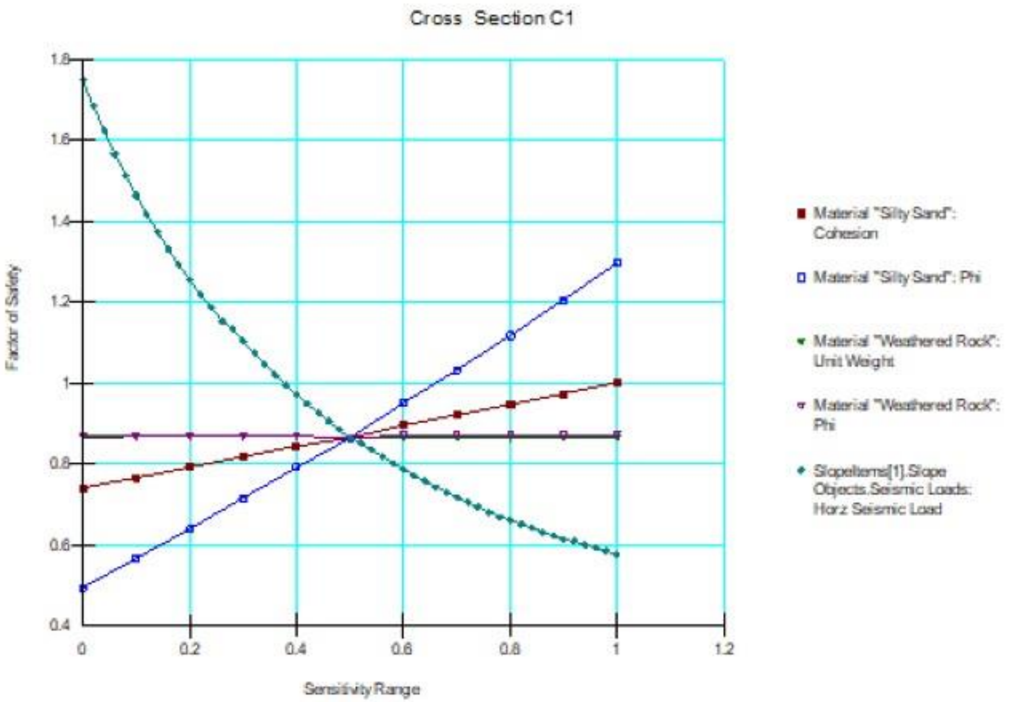
- **Bottom Soil: Stiff to very stiff Weathered Rock: γ = 24kN/m^3, ϕ' = 35, c' = 0kPa, E = 30000kPa and υ = 0.3**



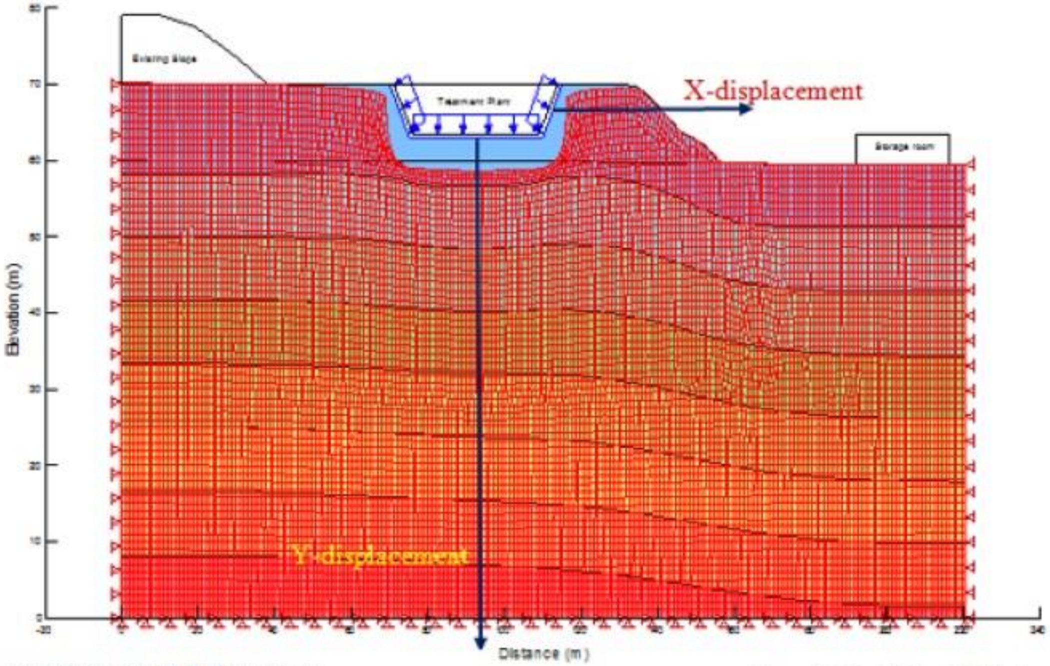
STABILITY OF CROSS SECTION C1

- The failure feature is likely global and deep seated with the **FOS = 0.864** via sensitivity analysis.
- The FOS = 1 (stable condition) with sensitivity of k_h, ϕ' and c' at 0.21g, 24° and 10kN/m^3 (in-situ ϕ' = 20° and c' = 5kN/m^3) respectively on top soil (Silty SAND) but FOS is not sensitive to bottom soil (Weathered Rock)
- The results indicate any decrease in ϕ' and c' (wetting/saturated condition) or increase in k_h cause instability on slope

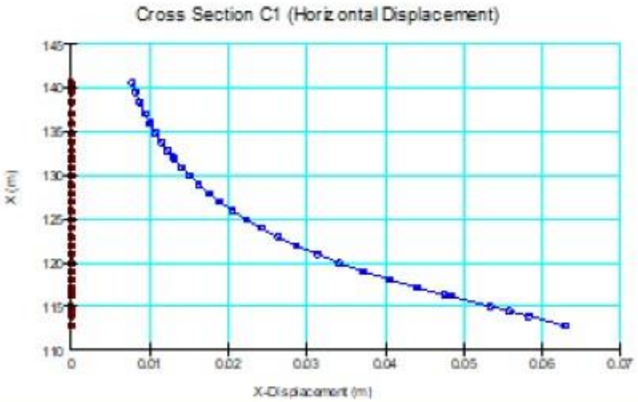


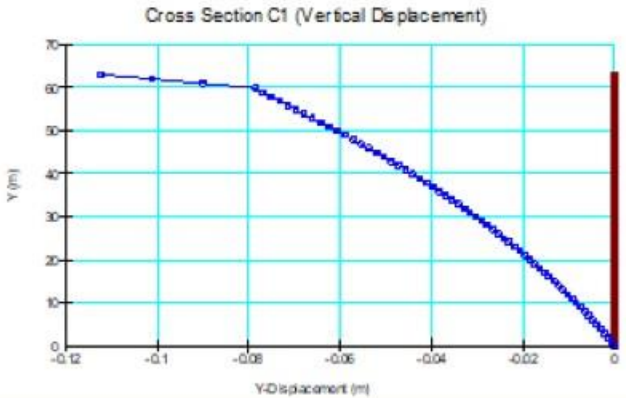


LOAD AND DEFORMATION ANALYSIS OF C1



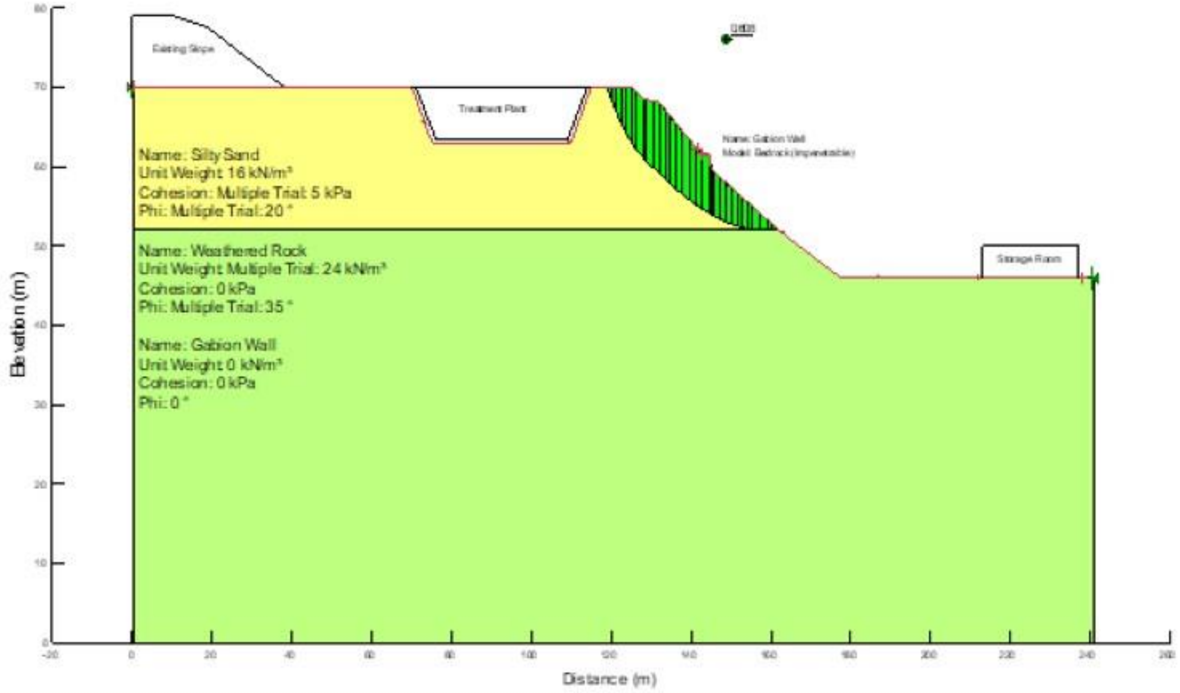
- The vertical displacement is maximum on the bottom of treatment plant (Y-displacement = 110mm)
- The horizontal displacement, X-displacement = 10mm to 60mm
- The results indicate applied load significantly affect deformation at both vertical and horizontal directions which could have contributed to FOS < 1 in slope stability analysis

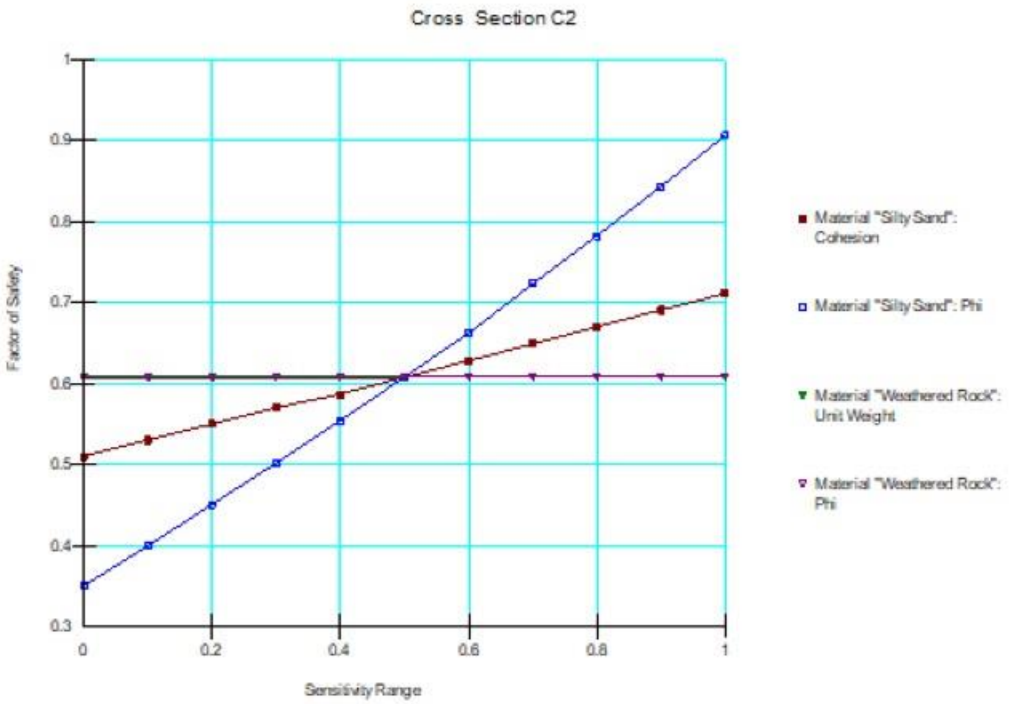




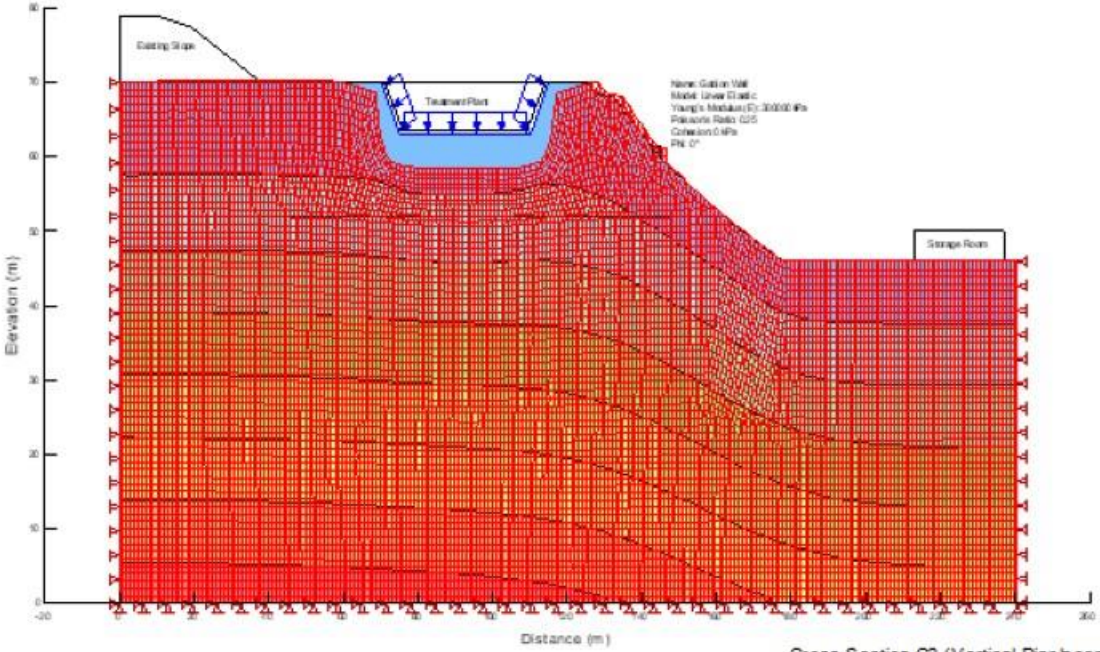
STABILITY OF CROSS SECTION C2

- The failure feature is likely global and deep seated with the **FOS = 0.608** via sensitivity analysis.
- The FOS < 1 for all k_h, ϕ' and c' values to show original slope at cross section C2 is unstable. However, the sensitivity trends are similar to cross section C1 where it is sensitive to top soil but FOS is not sensitive to bottom soil
- The results indicate the slope at C2 is likely to fail (to compare to **FOS for C1 = 0.864**)

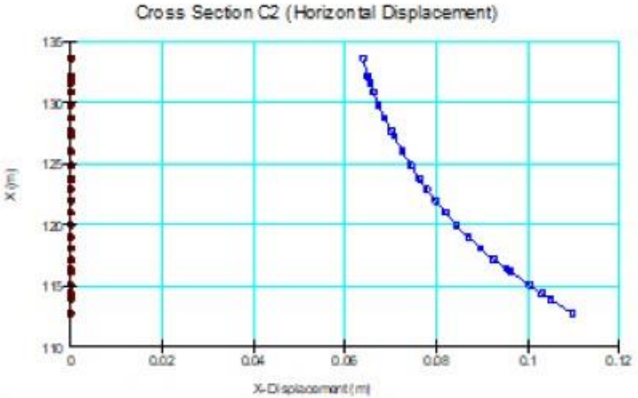


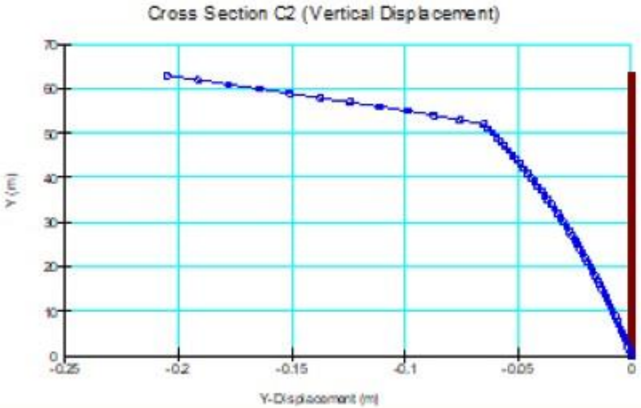


LOAD AND DEFORMATION ANALYSIS OF C2



- The maximum vertical displacement, Y-displacement = 200mm is larger than found in C1 (Y-displacement = 110mm)
- The horizontal displacement, X-displacement = 60mm to 150mm
- The results indicate deformation due to applied load is more critical at cross section C2 to compare to cross section C1





VIBRATION MONITORING

- There are six (6) nearby active quarries have been identified in the area, the two nearest quarries are Malaysian Rock Products Sdn. Bhd. (MRP), which is about 500m to the South-west and Sibelco Quarry which is located about 1300m North-east from the GPWTP
- Based on the safe buffer zone of 500m (as imposed by Department of Environment (DOE)) being the closest quarry, operation at MRP Quarry has been selected for the monitoring purpose

REGULATORY LIMITS

Table 1: Regulatory limits set by DMG

Impacts of blasting operation	Limits
Ground Vibration (PPV)	5 mm/sec
Noise	124 dBL

Table 2: Recommended limits for damage risk in buildings from steady state vibration set by DOE

Damage Description	Vertical Vibration Peak Velocity V_{max} [mm/s]
Safe	Less Than 3
Caution Level (Damage Not Necessary Inevitable)	3 to 5
Minor Damage	5 to 30
Major Damage	More Than 30

Table 3: Peak particle velocity threshold damage level (Willie and Mah, 2004)

Velocity (mm/s)	Effect/damage
3–5	Vibrations perceptible to humans.
10	Approximate limit for poorly constructed and historic buildings.
33–50	Vibrations objectionable to humans.
50	Limit below which risk of damage to structures is very slight (less than 5%).
125	Minor damage, cracking of plaster, serious complaints.
230	Cracks in concrete blocks.

Table 4: Peak particle velocity and structure damage (USBM 1971)

Peak Particle Velocity (mm/s)	Level of damage
< 50	No physical damage
50 - 100	Plaster cracking
100 - 175	Minor damage
>175	Major damage

Table 5: Vibration noise and impacts on human and buildings (USBM 1971)

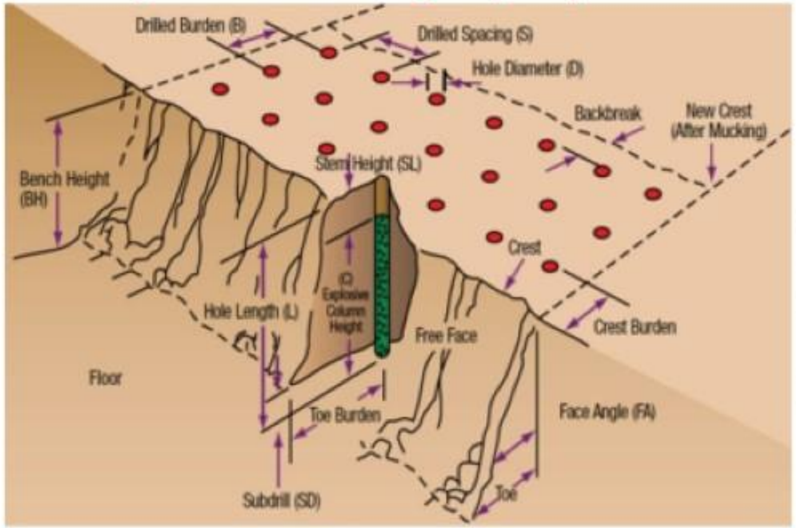
Vibration noise (dBL)	Response and level of damage
100 - 115	Generally no complaint
115 - 120	People may be irritated
120 - 125	**Limit sets by authority**
125 - 130	People start to complaint
130 - 140	Unlikely to cause damage
140 - 150	Some window panes break
150 - 160	Many window panes break

Table 6: Safe level blasting criteria: threshold PPV values at different frequencies (USBM and DIN 4150)

USBM			German Standard (DIN 4150-3)			
Structure	PPV (mm/s)		Structure	PPV (mm/s)		
	< 40Hz	≥ 40Hz		10Hz	10 – 50Hz	50 – 100Hz
Modern home dry	18,75	50	Industrial buildings	50	20-40	40-50
Wall interior			Residential buildings	5	5-15	15-20
Older homes	12,50	50	More sensitive buildings than above	3	3-8	8-10

BLASTING OPERATION – PPV AND FREQUENCIES

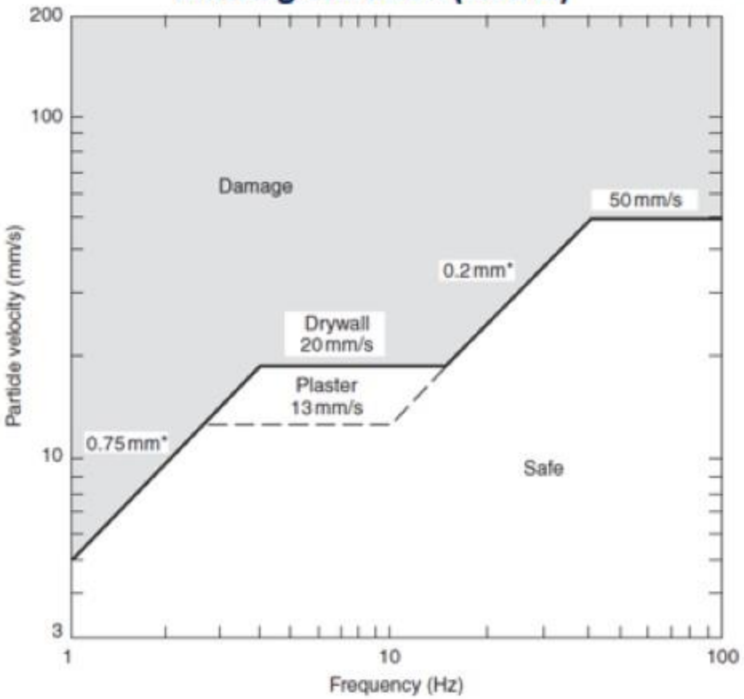
Typical blast design parameters for production blasting in quarry



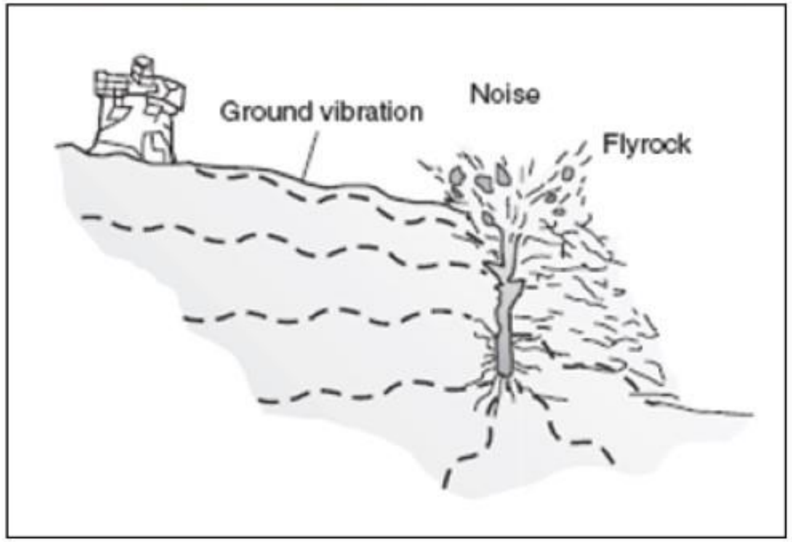
The 'Rule of Thumb':

Hole Diameter = D (mm)
Burden, B (mm) = (25 to 40) X D
Spacing, S (mm) = (1.0 to 1.5) X B
Subdrill, SD (mm) = B / 3 or (3 to 15) X D
Hole Length, HL (mm) ≥ B X 3
Burden Stiffness Ratio = HL / B

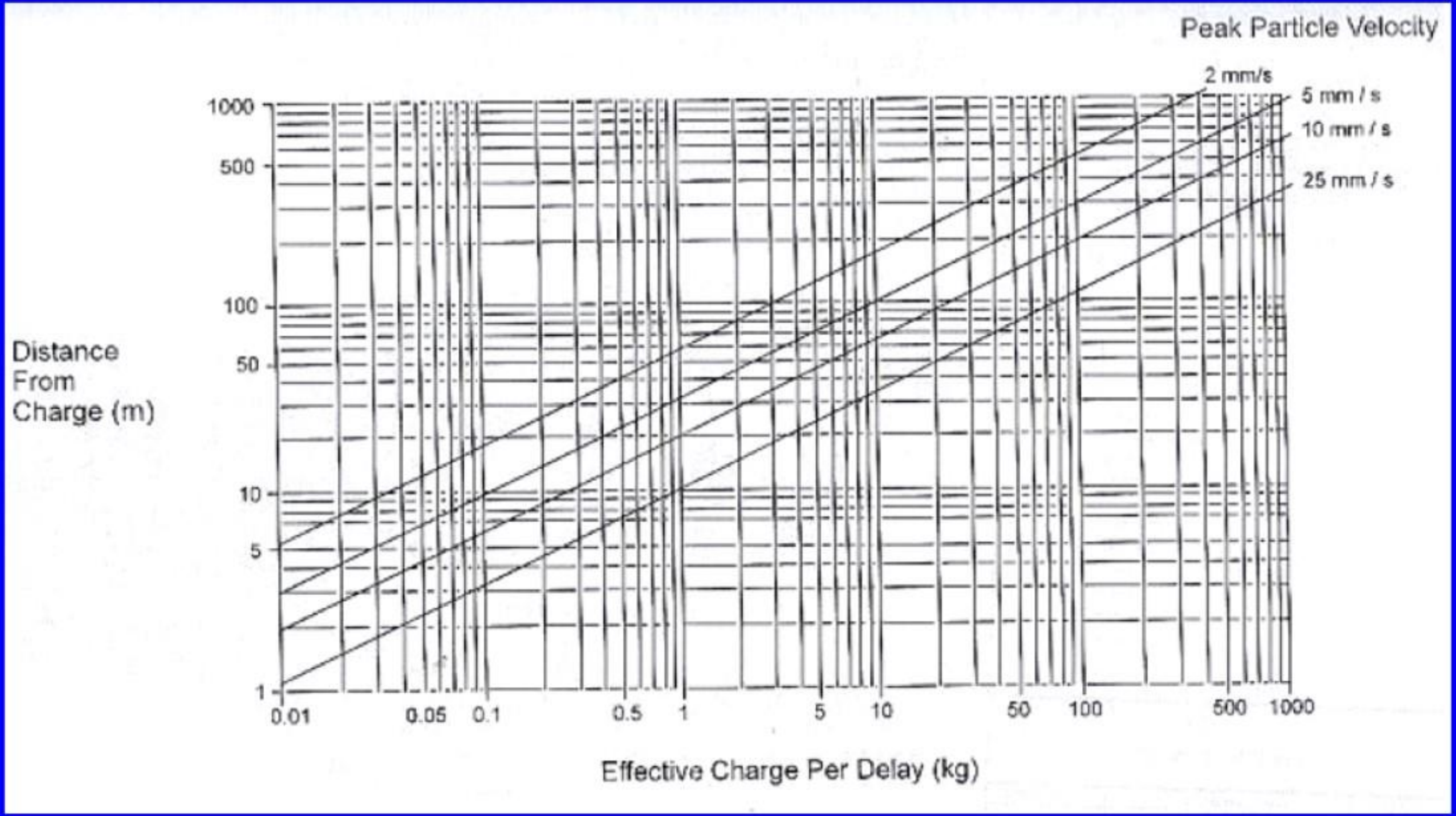
Recommended safe levels for blasting vibration (USBM)



Effect of blasting operation



**Graphical method is also available:
Scale distance chart for estimating Ground Vibration (Australian Standard) for free face average rock blasting (JMG limit 5mm/s)**



Vibration standard and its effect on structure close to blast point (USBM 1971)

PARTICLE VELOCITY	DAMAGE
< 50 mm/s	No damage
50 – 100 mm/s	Plaster cracking
100 – 175 mm/s	Minor damage
> 175 mm/s	Major damage to structure

PROPOSED VERTICAL HOLE BLAST DESIGN (Production stage)

(NON-ELECTRIC INITIATION)

PARAMETERS	SPECIFICATIONS
PRODUCTION :	
Rock type	Granite
Tonnage per Month	50,000 tonne maximum
BLASTHOLES :	
Initiation Method	Non Electric (NONEL)
Blasting Days	Everyday except Sunday & Public Holidays
Blasting Time	12.00 pm - 5.00 pm
Bench Height	12.2 m
Depth of Holes	12.9 m
No. of Holes	Varies (Optimum = 50)
Diameter of Holes	90 mm
Inclination of Holes	90°
No. of Rows	Varies (Optimum = 3)
Spacing	3.6 m
Burden	3 m
Sub-drill	0.7 m
Column Charge	10.4 m (11.1 m?)
Stemming	1.8 m
EXPLOSIVES :	
BULK	11.1 x 7.44 kg @ 50 = 4,129.2 kg
High Explosive	1 x 0.4 kg / hole @ 50 = 20 kg
Delay	1 Hole / Delay
Total of Explosive	4,149.2 kg
Average Load per Hole	82.584 kg
Average Load per Delay	82.584 kg
Powder Factor	0.59 kg / m3

Blast design for primary or production blasting

Powder factor & blasthole diameters are important parameters for calculating flyrocks

PROPOSED VERTICAL HOLE BLAST DESIGN (Development Stage)

(ELECTRIC INITIATION)

PARAMETERS	SPECIFICATIONS
BLASTHOLES	
Initiation Method	Electric
Blasting Days	Everyday except Sunday & Public Holidays
Blasting Time	12.00 pm - 5.00 pm
Depth of Holes	3m
No. of Holes	Varies (Optimum = 21)
Diameter of Holes	76 mm
Inclination of Holes	90°
No. of Rows	Varies (Optimum = 3)
Spacing	1.8 m
Burden	1.5 m
Column Charge	0.59 m
Stemming	2.41 m (3 m - 0.59 m)
EXPLOSIVES	
ANFO	0.59 x 3.86 kg @ 21 = 47.8254 kg
High Explosive	1 x 0.183 kg / hole @ 21 = 3.843 kg
Delay	1 Hole / Delay
Total of Explosive	51.6684 kg (ANFO + High Explosive)
Average Load per Hole	2.278 kg
Average Load per Delay	2.278 kg
Powder Factor	0.282 kg / m3

Blast design for development and secondary blasting

Note: Average load per delay is important parameter for estimating ground vibration & noise

GROUND VIBRATION AND NOISE PREDICTION

Estimation of Ground Vibration Level

$$V = K\,[D/Q^{0.5}]^{-B}$$

V: ground vibration as ppv, (mm/s)
D: distance between charge & point of measurement, (m)
Q: Effective charge mass per delay or maximum instantaneous charge (MIC) (kg)
K & B: constants related to site conditions of site (site specific)

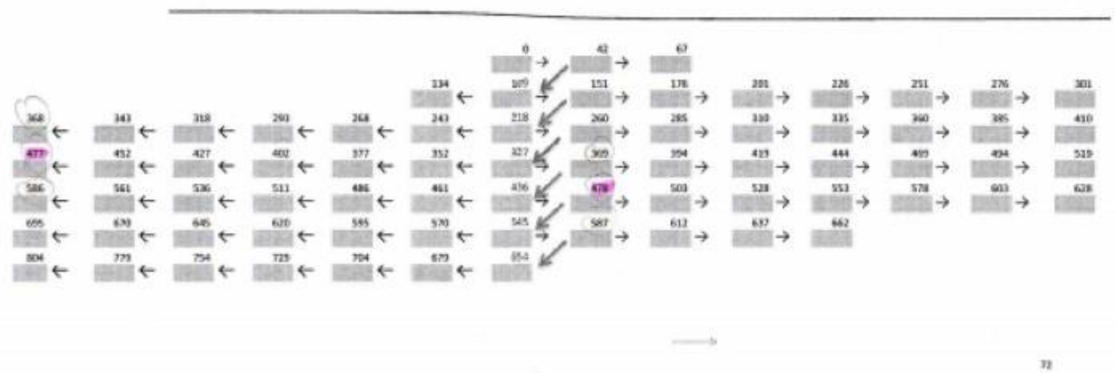
Note: Q is Charge per delay = load per delay = maximum instantaneous charge (MIC), unit is in kg.

Typical Blast Design Parameters for Production Blasting in Quarry

Parameter	Specification/Design
Production:	
Rock type	Granite
Volume per Blast	2,268 m^3
Volume per Month	11,340 m^3 (@ 5 blast per month)
Tonnage per Blast	6,124 tonnes (taking sp. gr. of granite = 2.7; 2,268 × 2.7) tonnage blasting per month
Tonnage per Month	30,618 tonnes
Blast Frequency	5 blast per month, on weekdays except Sunday and Public Holidays (can be 4 to 8 times monthly)
Blastholes:	
Initiation Method	NONEL (Non electric) or Electric (NONEL usually for production blasting & Electric for some development & secondary blasting)
Bench Height	15.0 m
Depth of Holes	15.5 m
Diameter of Holes (D)	76 mm (50, 76 and 100 mm diameter)
Number of Holes	30 number (total number of holes per blast)
Inclination of Holes	85^0 (near vertical, usually at 10^0 to 15^0 from vertical)
Number of Rows	3 rows @ 10/10/10 (i.e. holes per row)
Spacing	2.4 m (spacing between hole along a row (approximately 50 × D but usually 3 – 5 m)
Burden (B)	2.1 m (approximately [30 – 40] × D)
Sub-drill	0.7 m (extra drill below working level, approximately B/3)
Stemming	2.1 m (depth of stemming = B, helps to reduce flyrocks)
Explosives:	
ANFO/Bulk	47 kg/hole = 1,410 kg Total (47 kg × 30 holes)
High Explosive	1.0 kg/hole @ primer = 30 kg Total (1 kg × 30 holes)
Delay	NONEL: 30 @ 25 ms, TLD 2 @ 42 ms; Electric: EDD No. 1-20 @ up to 2 holes per/delay Electric: EDD No. 1-18 @ up to 3 holes/delay
Total Explosives	1,440 kg (ANFO + High Explosive, 1,410 + 30 kg)
Average Load per Hole	48 kg (Total Explosive / Total number of holes)
Average Load per Delay	NONEL: 48 kg; Electric: 96 kg
Powder Factor	0.63 kg/m^3 ([Total Explosive] / [Volume per Blast] = 1,440 kg / 2,268 m^3)

Dumont Construction Sdn Bhd	Blast Design No:	6/6/2017

Free Face



HOLES DESCRIPTION

Total Holes:	72			
Burden:	11	3.35m		
Spacing:	11	3.35m		
Depth:	50	15.85m		
Subdrill:	0	0.92 m		
Stemming:	7	2.13 m		
Drilling Pattern:		Square		
No. of Rows:	8			
Holes Diameter:	89	mm		
Stemming Material:		Chipping		
Cubic Meter:			12,344.30	m3
Total Tonnage:			32,095.17	mT

EXPLOSIVES USAGE

EZ-Det 25ms,24m:		72
EZ-Det 25ms,12m:		0 nos
Emulex 25 mm:		0.00 kgs
Emulex 50 mm:		0.00 kgs
Booster 250gm:		0.00 kgs
Booster 400gm:		35.3
IED (Initiation):		2 nos
TLD 17ms:		0 nos
TLD 42ms:		6
TLD 67ms:		6
ANFO:		0 Kgs
Bulk Emulsion:		6432
Powder Factor:	0.52	kg/m3

REMARK

MRP QUARRY ACTIVITY

Calculated PPV and Air Blast Noise Value for MRP Quarry

MRP QUARRY BLAST DESIGN

QUARRY: MRP QUARRY

LOCATION: LGPWTP

$$PPV = K(D/Q^{0.5})^B$$

$PPV = K(D/Q^{-1/2})^B$

	Malaysia	Australia	Tunisia
K =	37	1140	1508
B =	-0.63	1.6	-1.73

ρ_{BE} = 1.2 kg/m³

Hole diameter = 0.089 m

Charge per unit weight = 7.47 kg/m (from chart) of densty 1.20g/cm3 Anfo

Area = 0.01 m²

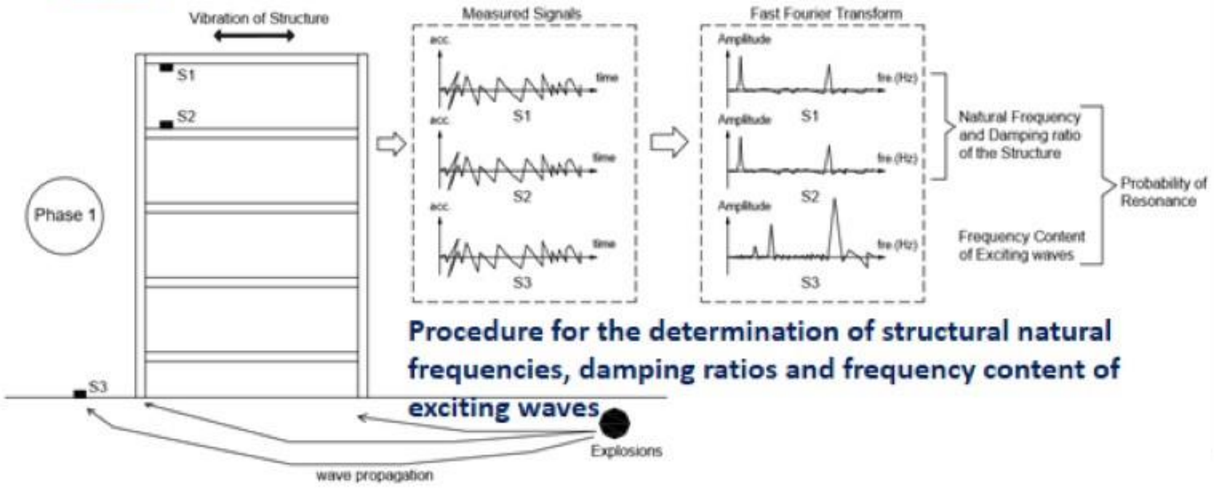
D = 628.9 m

DOE (ISO DP 4688: 1975)	
Damage Details	PPV (10-100Hz)
Safe	<3
Caution	3 to 5
Minor	5 to 30
Major	>30

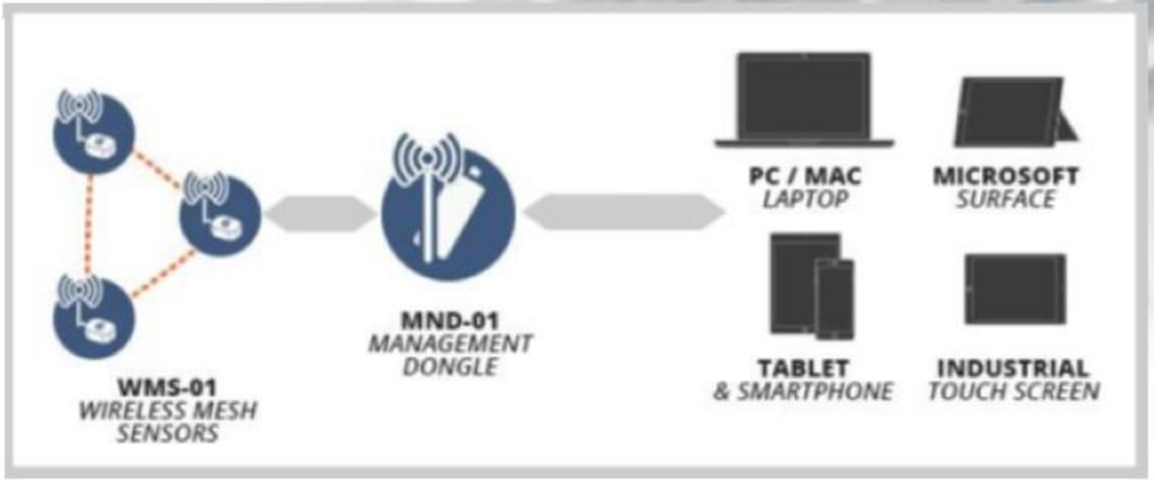
A = 165 - [24log(D/Q

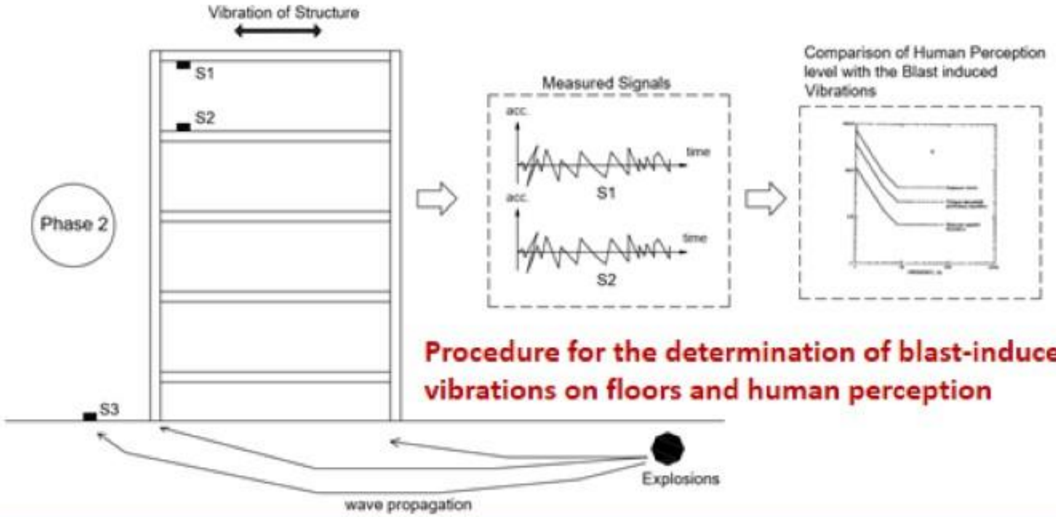
YEAR	DATE	Vol. of rock (m³)	Number of hole	Bulk Emulsion	Estimated charge per	PF (kg/m³)	Hole depth (m)	Stemming	Subdrill (m)	Explosive column (m)	ANFO used (kg)	Booster used (kg)	Charge per column	Q	PPV (mm/s)	JMG Limit (<5mm/s)	DOE Limit (1975)	Air Blast Noise Level, A (dBL)	JMG Limit (<125dbL)
2017	01/11/17	7667.18	43	4200	97.67	0.55	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	219.52	3.489	Safe	Caution	116.547	Safe
	01/11/17	10184.04	54	5900	109.26	0.58	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	219.52	3.489	Safe	Caution	116.547	Safe
	11/11/17	11315.61	60	5500	91.67	0.49	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	219.52	3.489	Safe	Caution	116.547	Safe
	11/11/17	12258.57	65	5500	84.62	0.45	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	219.52	3.489	Safe	Caution	116.547	Safe
	21/11/17	8905.04	49	4500	91.84	0.51	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	219.52	3.489	Safe	Caution	116.547	Safe
	21/11/17	11315.61	60	6000	100.00	0.53	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	219.52	3.489	Safe	Caution	116.547	Safe
	02/12/17	18173.55	100	9230	92.30	0.51	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	109.76	2.804	Safe	Safe	114.141	Safe
	16/12/17	11881.39	63	6300	100.00	0.53	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	109.76	2.804	Safe	Safe	114.141	Safe
	20/12/17	9618.26	51	5300	103.92	0.55	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	109.76	2.804	Safe	Safe	114.141	Safe
	20/12/17	10938.42	58	6000	103.45	0.55	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	109.76	2.804	Safe	Safe	114.141	Safe
	30/12/17	6000.70	35	3000	85.71	0.5	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	219.52	3.489	Safe	Caution	116.547	Safe
	30/12/17	6034.99	32	3000	93.75	0.5	15.85	2.13	0.92	14.64	109.3608	0.4	109.7608	109.76	2.804	Safe	Safe	114.141	Safe
2018	Jan-18	11783.63	60	6588.12	109.80	0.56	17.5	2.1	0.91	16.31	121.8357	0.4	122.2357	122.24	2.901	Safe	Safe	114.515	Safe
	12/02/18	13918.59	74	7719.08	104.31	0.56	16.76	2.13	0.91	15.54	116.0838	0.4	116.4838	116.48	2.857	Safe	Safe	114.348	Safe
	26/02/18	19561.27	104	10848.44	104.31	0.56	16.76	2.13	1	15.63	116.7561	0.4	117.1561	234.31	3.561	Safe	Caution	116.773	Safe
	10/03/18	11599.58	64	6397.61	99.96	0.55	16.76	2.13	0.91	15.54	116.0838	0.4	116.4838	116.48	2.857	Safe	Safe	114.348	Safe
	17/03/18	11055.85	61	6097.719	99.96	0.55	16.76	2.13	0.91	15.54	116.0838	0.4	116.4838	116.48	2.857	Safe	Safe	114.348	Safe
	17/03/18	4617.83	27	2523.806	93.47	0.55	16.76	2.13	0.91	15.54	116.0838	0.4	116.4838	116.48	2.857	Safe	Safe	114.348	Safe
	12/04/18	6975.01	68	3544.18	52.12	0.51	16.76	2.13	0.91	15.54	116.0838	0.4	116.4838	232.97	3.555	Safe	Caution	116.753	Safe
	12/04/18	13354.33	71	7406.145	104.31	0.56	16.76	2.13	0.91	15.54	116.0838	0.4	116.4838	232.97	3.555	Safe	Caution	116.753	Safe
	07/05/18	5799.79	32	3267.251	102.10	0.57	16.76	2.13	0.91	15.54	116.0838	0.4	116.4838	116.48	2.857	Safe	Safe	114.348	Safe
	07/05/18	12656.29	74	7075.384	95.61	0.56	15.24	1.83	0.91	14.32	106.9704	0.4	107.3704	214.74	3.465	Safe	Caution	116.471	Safe
	15/05/18	12225.79	65	6919.309	106.45	0.57	16.76	1.83	0.91	15.84	118.3248	0.4	118.7248	237.45	3.576	Safe	Caution	116.820	Safe
	22/05/18	1627.37	17	812.107	47.77	0.5	8.53	1.83	0.91	7.61	56.8467	0.4	57.2467	57.25	2.284	Safe	Safe	111.882	Safe
	05/06/18	13340.41	78	7457.837	95.61	0.56	15.24	1.83	0.91	14.32	106.9704	0.4	107.3704	214.74	3.465	Safe	Caution	116.471	Safe
	12/06/18	9961.09	56	5597.906	99.96	0.56	15.85	1.83	0.91	14.93	111.5271	0.4	111.9271	111.93	2.822	Safe	Safe	114.209	Safe
	12/06/18	8360.2	47	4698.242	99.96	0.56	15.85	1.83	0.91	14.93	111.5271	0.4	111.9271	111.93	2.822	Safe	Safe	114.209	Safe
	30/06/18	2256.52	22	1146.647	52.12	0.51	9.14	1.83	0.91	8.22	61.4034	0.4	61.8034	61.80	2.340	Safe	Safe	112.148	Safe
	30/06/18	11206.23	63	6297.644	99.96	0.56	15.85	1.83	0.91	14.93	111.5271	0.4	111.9271	223.85	3.510	Safe	Caution	116.615	Safe

VIBRATION MONITORING SYSTEM

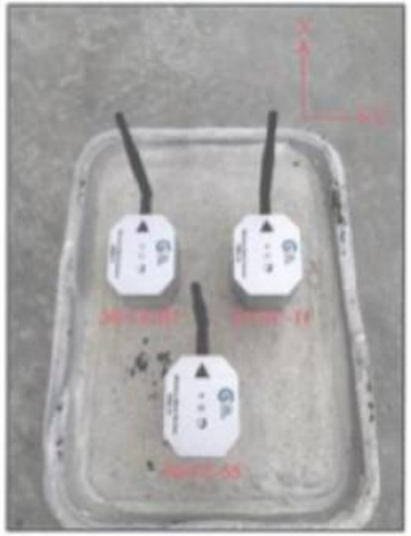


Procedure for the determination of structural natural frequencies, damping ratios and frequency content of exciting waves





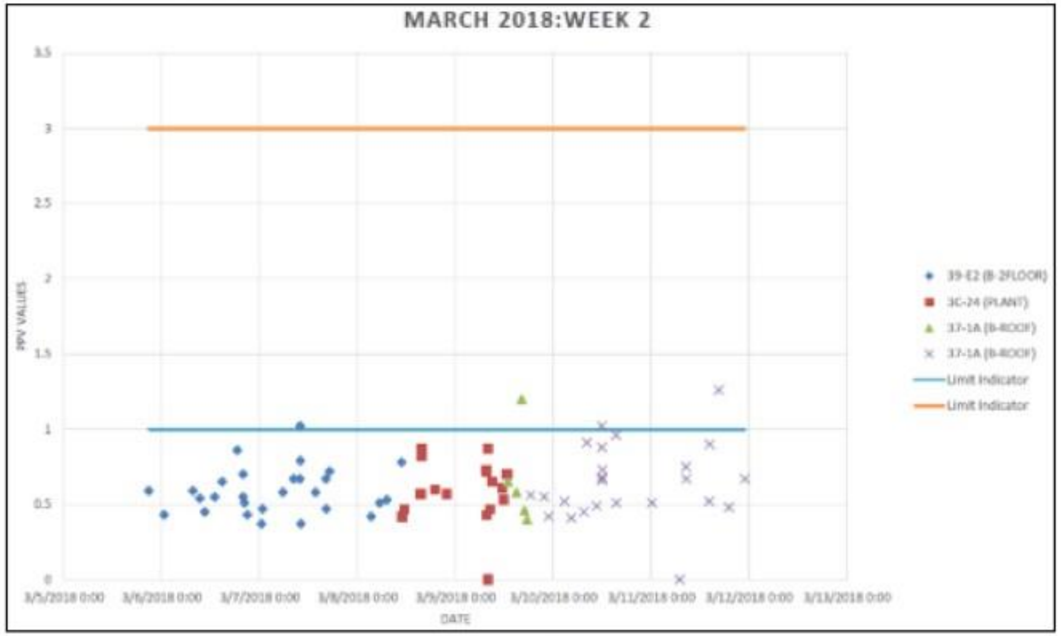
Procedure for the determination of blast-induced vibrations on floors and human perception

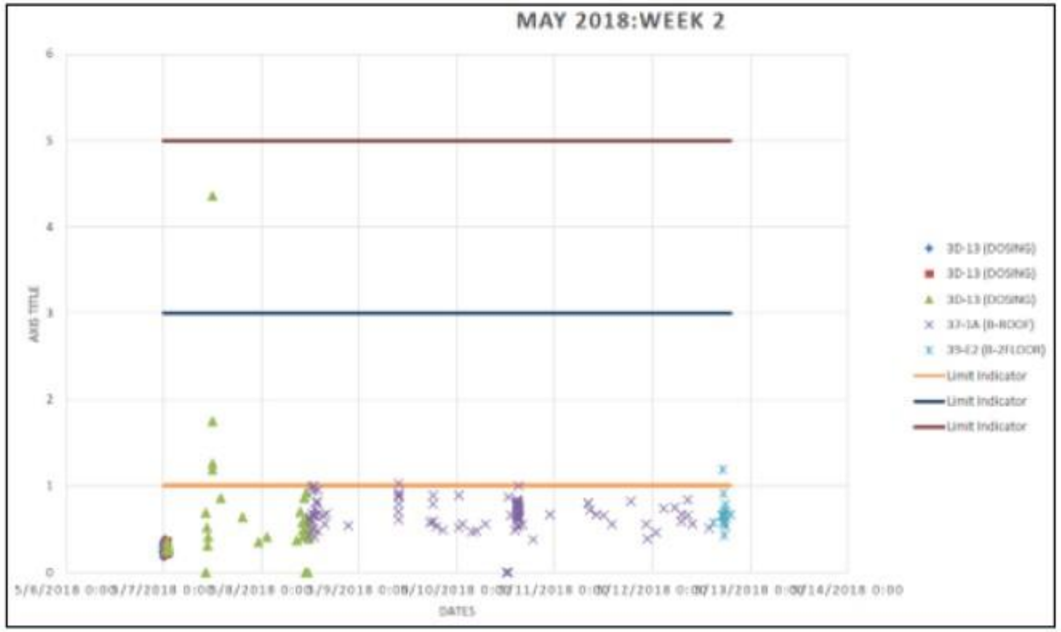


INSTALLATION OF VIBRATION MONITORING DEVICES

- Ground vibration at GPWTP has been continuously monitored using five (5) vibration sensors installed at strategic locations since 22nd February 2018
- The triggering value for the sensor is set at 0.5mm/s so as to allow the sensors to monitor a much lower vibration level

Legend:
1. DA-B5 (Ground Level)
2. 39-E2 (2nd Floor Level)
3. 37-1A (Roof Level)
4. 3D-13 (Dosing)
5. 3C-24 (Plant)





- The calculated values of PPV and air blast noise for MRP quarry is the range of 2.640 to 4.115mm/s and 114.273 to 119.164dBL, respectively. Sibelco quarry which is located further away from the plant, exhibit a much lower PPV and air blast noise

- Both parameters are much lower than the stated regulatory limit as imposed by authorities (5 mm/s and 124dBL). The further the distance from blasting point, the lower is the impacts from blasting operation. In other words, the levels of PPV and air blast noise decreases with distance

- With regards to the recorded PPV data at GPWTP, in general, the PPV value recorded are consistently lower than the limit set by DMG and DOE, i.e. 5mm/s, with few cases exceeded 3mm/s

- It was found that two factors have triggered the sensor more than 1mm/s which are, (1) work carried out at the plant itself and also (2) blasting work from the MRP

- The work on filtration tank, tank cleaning and work at the chlorine room have triggered the sensor at average of 2mm/s to the maximum of 8.08mm/s (15th April 2018).

- Whereas, it is easily can be identified if the sensor triggered by the blasting activity at the quarry, where more than one sensor will be triggered at the same time, and it is normally occurred during midday

BLAST INDUCED LATERAL FORCES AND DISPLACEMENTS

Natural Frequency:

- Water Filtration Tank (Office Building) – 1.4Hz (X-direction) and 1.5Hz (Y-direction)
- Water Sedimentation Tank – 16.6 Hz (X-direction) and 20.8Hz (Y-direction)

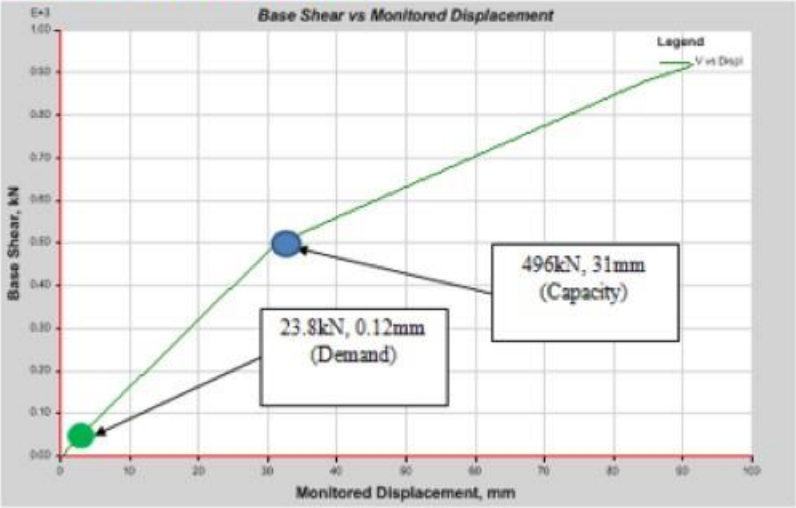
The Maximum Base Shear Force and its corresponding displacement:

- Water Filtration Tank (Office Building) – 23.8kN and 0.12mm (X-direction), 41.8kN and 0.12mm (Y-direction)
- Water Sedimentation Tank – 279kN and 0.021mm (X-direction) and 421kN and 0.046mm (Y-direction)
- Comparison between the obtained maximum base shear force of office building and sedimentation tanks indicate that the blast induced force to the sedimentation tanks is significantly larger than the building office (almost 10 times)

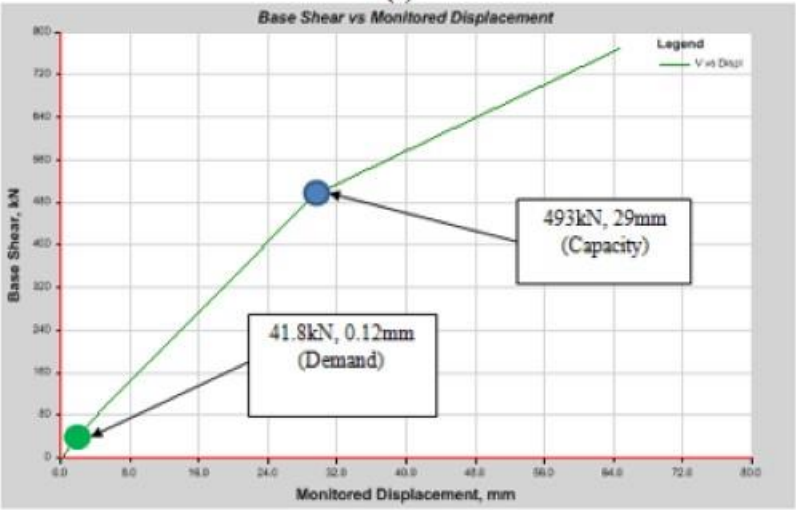
Dominant frequencies of the recorded ground motions

Record no	Peak ground acceleration (g)	Dominant frequency (Hz)
1837(X)	0.052	212
1837(Y)	0.039	206
1846 (X)	0.066	118
1846 (Y)	0.046	167
1852 (X)	0.009	15
1852(Y)	0.051	46
1858 (X)	0.022	198
1858 (Y)	0.043	198
1874 (X)	0.064	67
1874 (Y)	0.014	27.7
1877 (X)	0.044	12.3
1877 (Y)	0.012	297
1975 (X)	0.049	152
1975 (Y)	0.032	144

Capacity curve of the water filtration tank (office building)
(a) X-direction (b) Y-direction

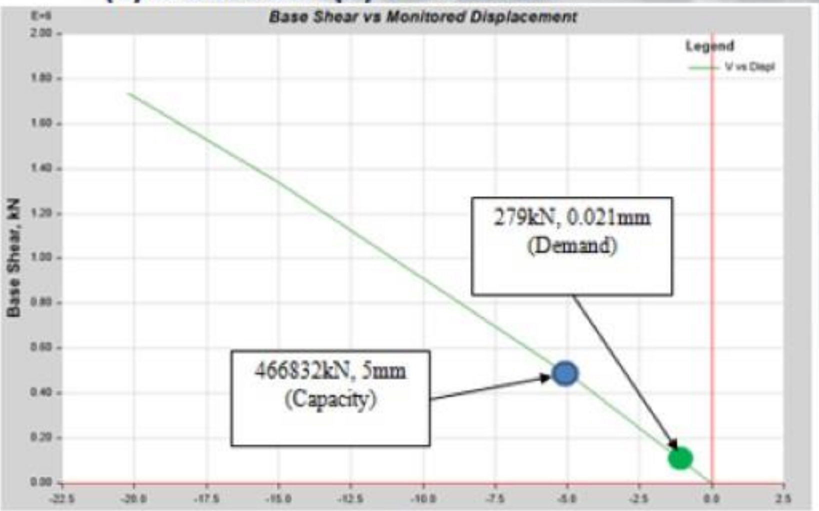


(a)

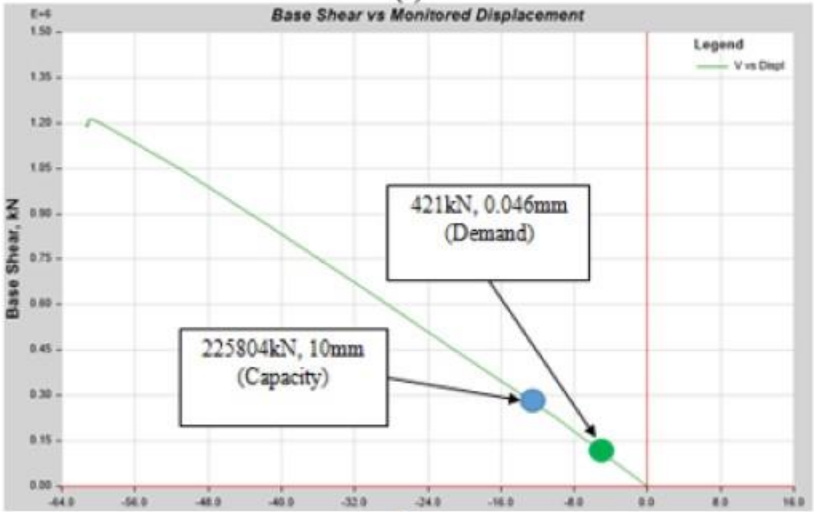


(b)

Capacity curve of the sedimentation tanks
(a) X-direction (b) Y-direction

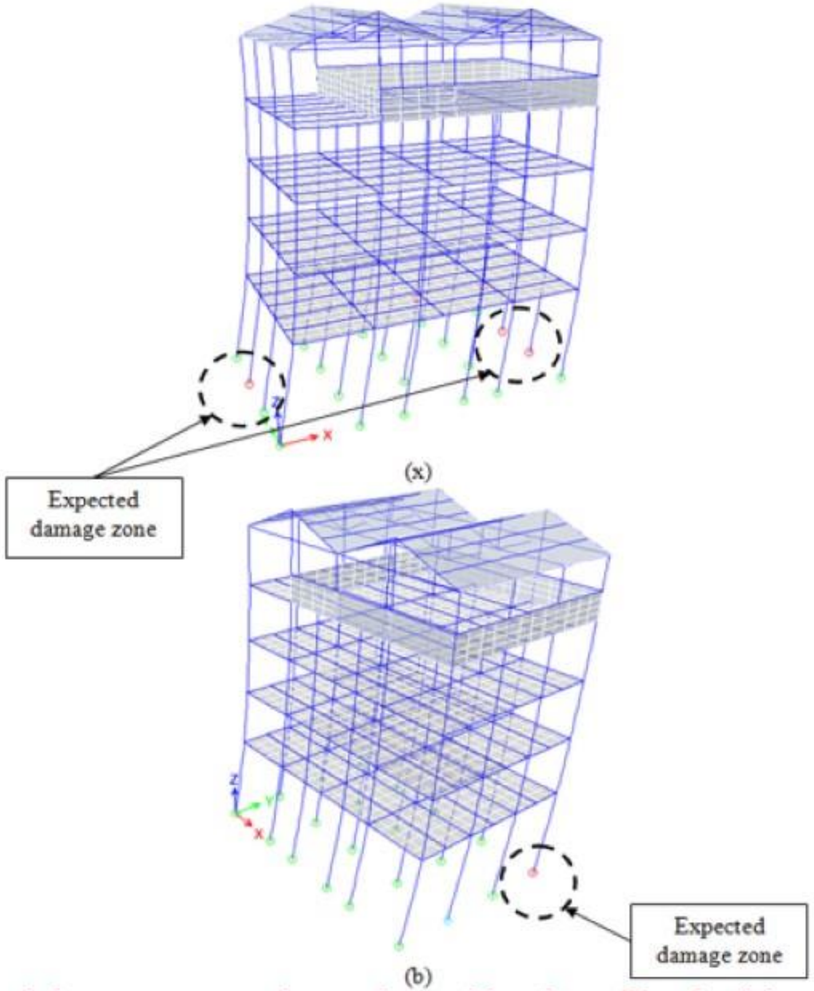


(a)

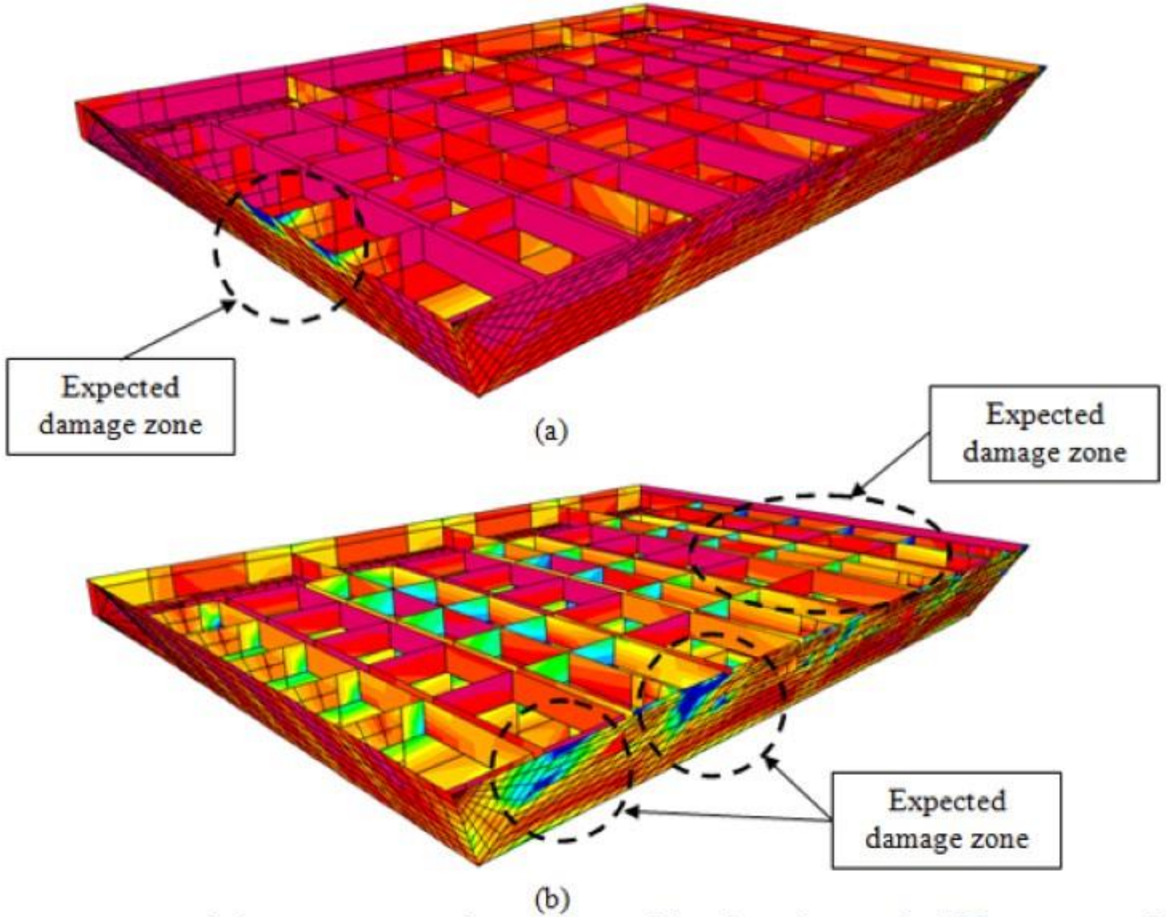


(b)

EXPECTED DAMAGE ZONE OF STRUCTURES DUE TO LATERAL LOADS

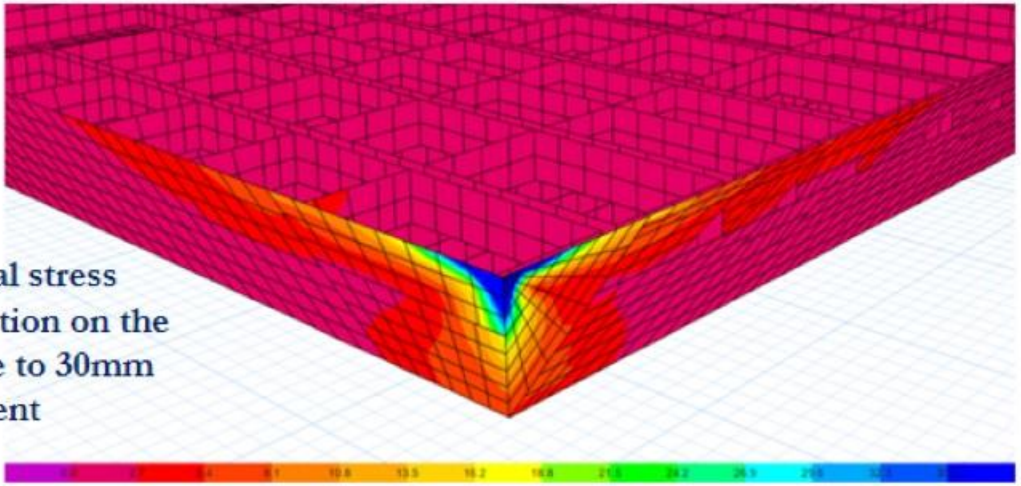


Expected damage zones due to lateral load in office building
(a) X-direction (b) Y-direction

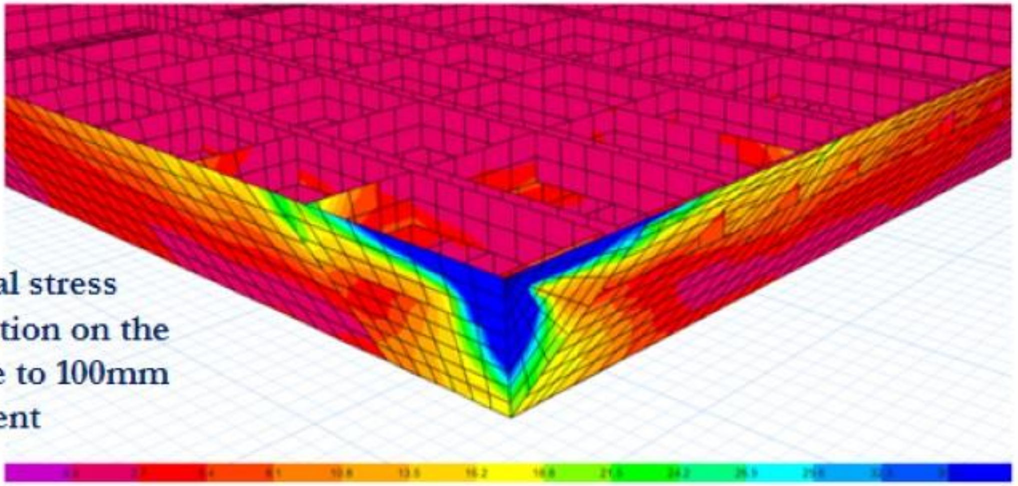


Expected damage zones due to lateral load in the roof of filtration tank
(a) X-direction (b) Y-direction

EXPECTED DAMAGE ZONE OF THE SEDIMENTATION TANK DUE TO SETTLEMENT

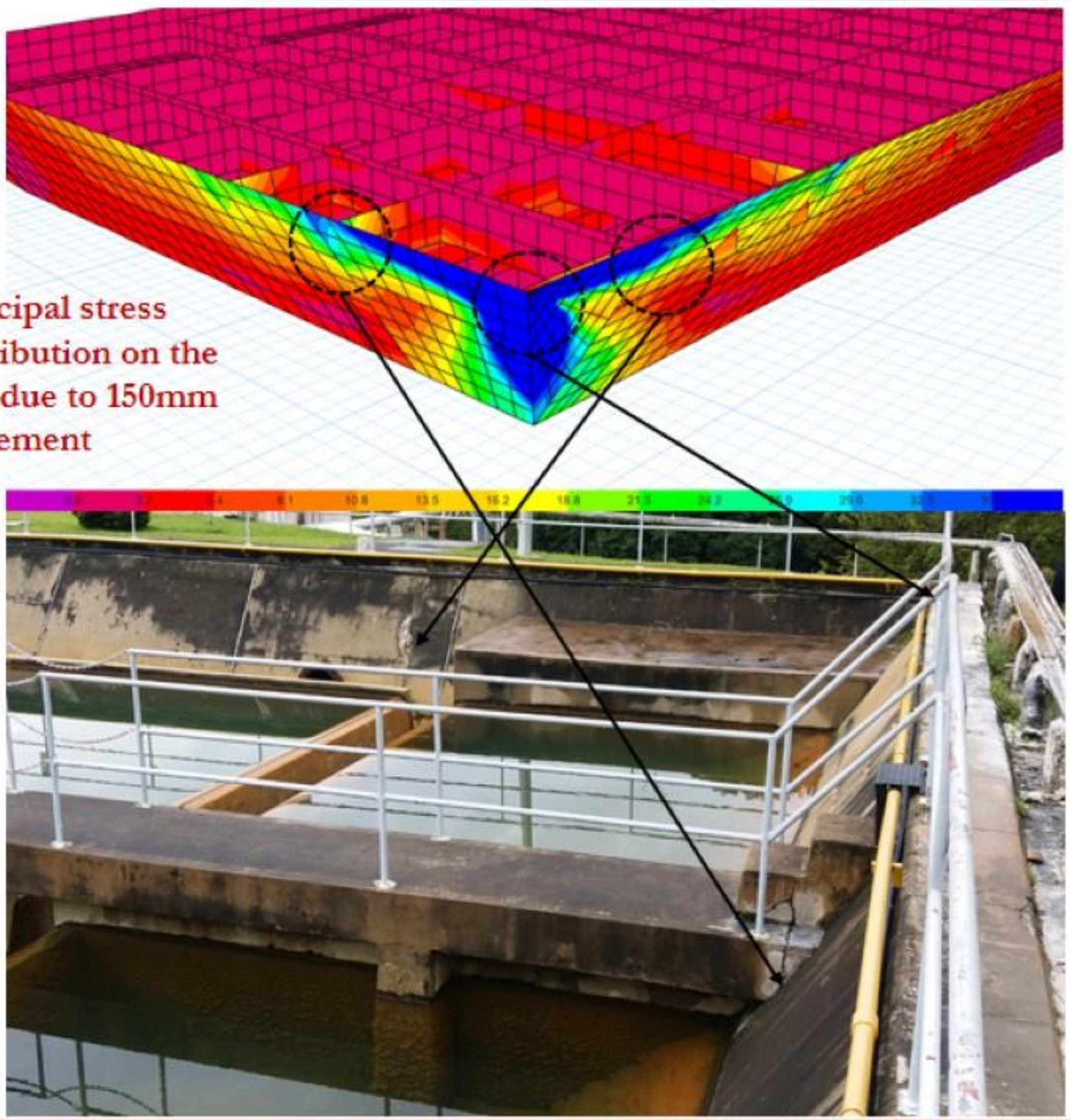


Principal stress distribution on the wall due to 30mm settlement



Principal stress distribution on the wall due to 100mm settlement

Principal stress distribution on the wall due to 150mm settlement



CONCLUSIONS

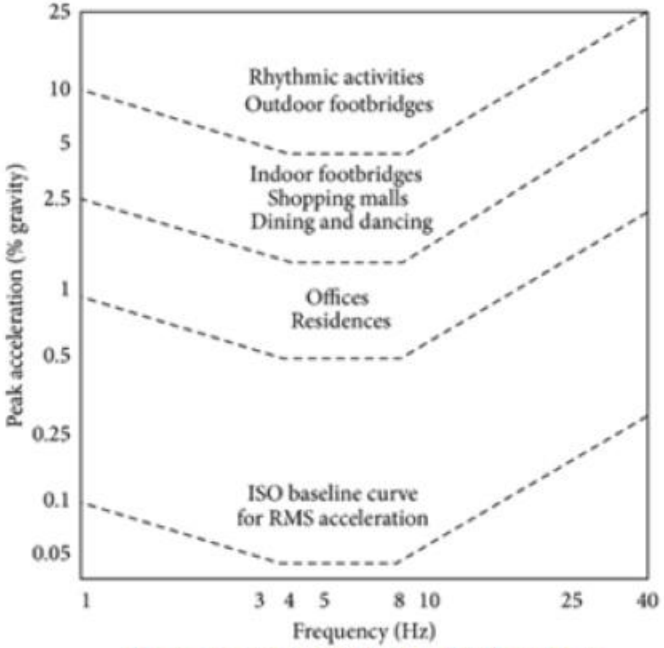
(1) The crack monitoring results indicate the size of cracks are within allowable limit and, the increments of crack are not significant for the most of locations, except on three locations at near slope area (at point P1A1, P1A2 and P1B). The settlement monitoring works also concluded that all monitoring point are not exceed ±0.6mm and can be considered stable, except for points E1 and G3 at near slope area. To conclude, both settlement and crack monitoring results give clear indication that the soil under the corner area is not stable

(2) The results of Load-Deformation analysis on cross sections of original slope also show maximum vertical displacement on the bottom of treatment plant, and horizontal displacement is also decreasing from 150mm to 10mm toward the slope. The results indicate applied structural and water loads significantly affect deformation at both vertical and horizontal directions which could have contributed to FOS < 1 in slope stability analysis.

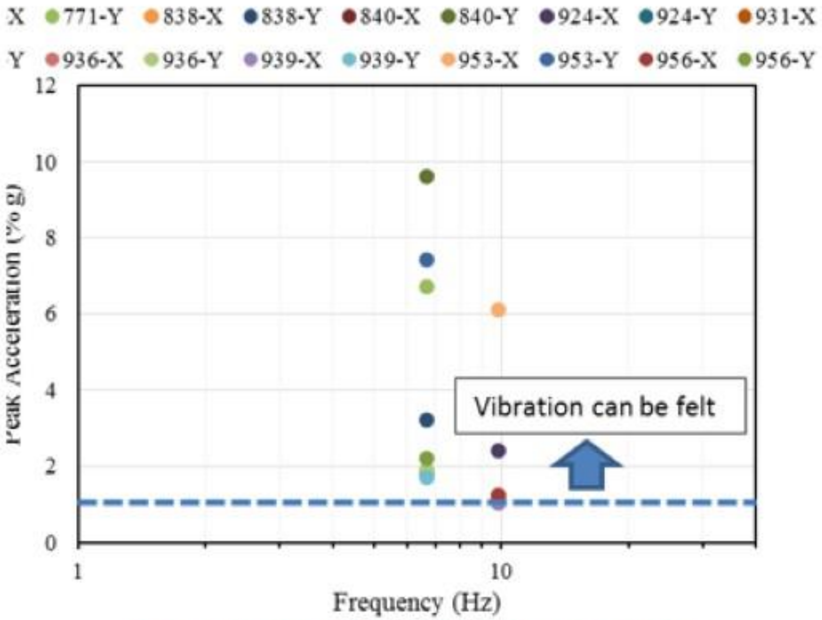
(3) The calculated values of PPV and air blast noise for the nearest active quarry to the GPWTP are much lower than the stated regulatory limit as imposed by DMG and DOE. With regards to the recorded PPV data at GPWTP, in general, the PPV value recorded are consistently lower than the limit set by authorities, i.e. 5mm/s, with few cases exceeded 3mm/s

CONCLUSIONS

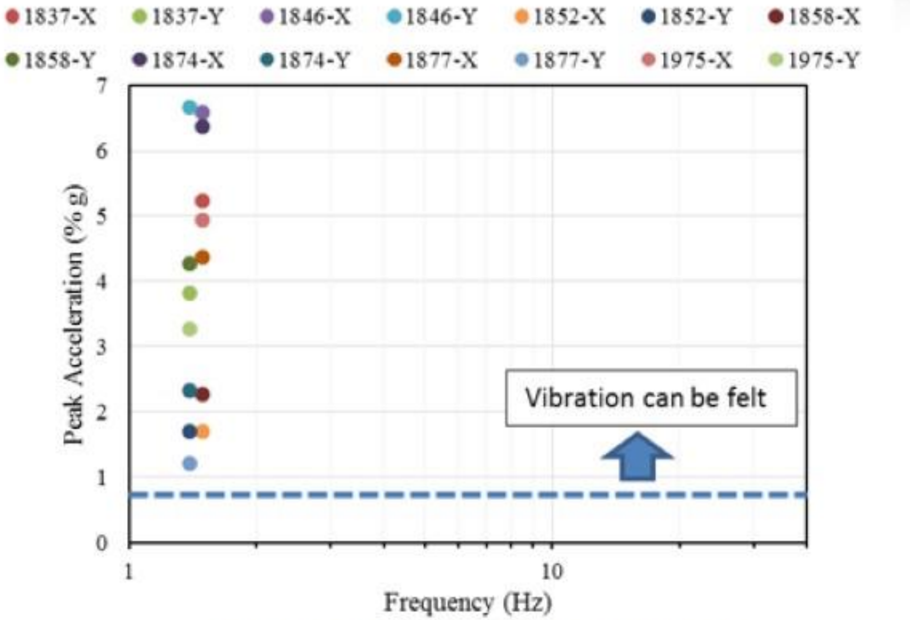
(4) The blast induced forces and displacements are smaller than the capacity of the structures, however, they are large enough to be felt by people who occupy the buildings. During the events of blast induced peak acceleration are larger than the limit of 0.01g (1% of g), the people who work inside these buildings will feel the vibrations. However, these vibrations result in structural responses that are smaller than structural capacities



Human perception of vibration



Measured peak accelerations for the filtration tank



Calculated peak accelerations for the office building

CONCLUSIONS

(5) The obtained maximum base shear force of office building and sedimentation tanks indicate that the blast induced force to the sedimentation tanks is significantly larger than the building office (almost 10 times). However, the maximum blast induced forces in X and Y directions are significantly smaller than the lateral capacities of the office building and sedimentation tanks to indicate that the structures can safely resist against vibrations imposed by blast forces.

(6) A small amount settlement at the corner of surrounding walls of the sedimentation tank causes the principal stress to exceed the considered ultimate capacity of concrete (i.e. 20MPa). This implies settlement can result in a significant damage to the surrounding concrete walls as the settlement reaches 150mm the damage zones become similar to the observed cracks on the wall of sedimentation tank. It can be concluded that it is likely that the observed damage to the sedimentation tank is due to excessive settlement of the structure rather than the blast induced forces.