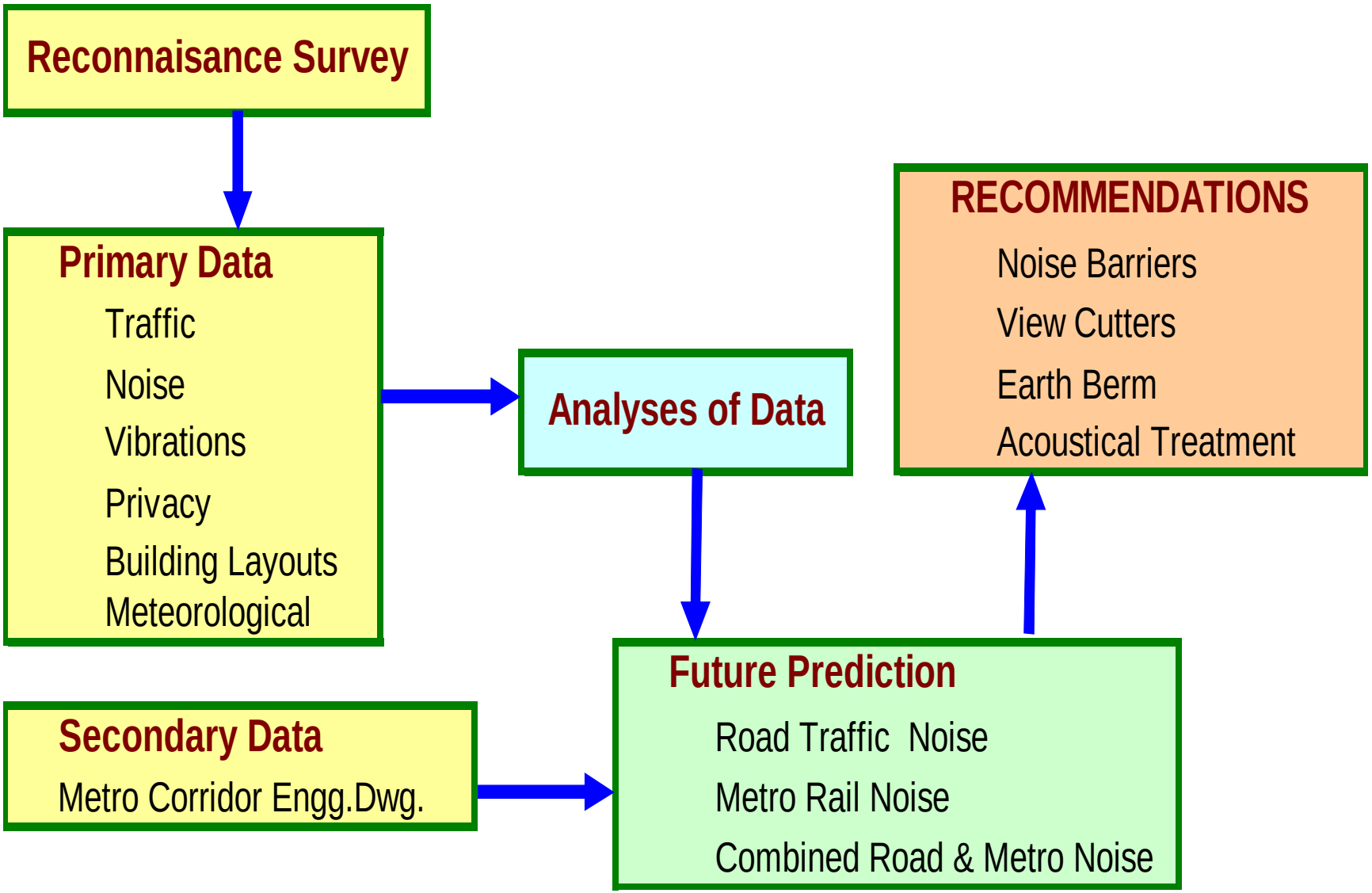
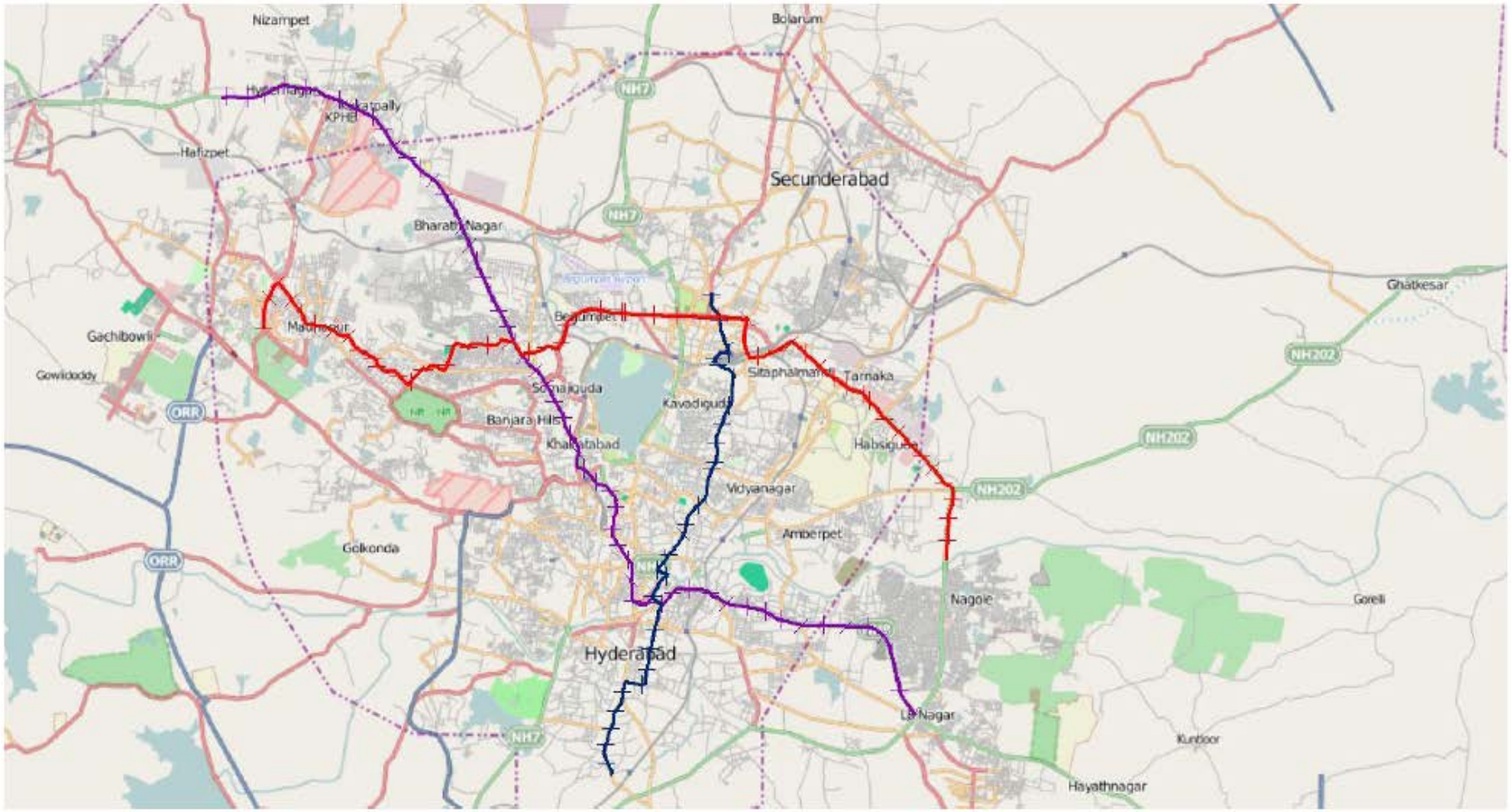
Noise & Vibration Study of L&T Hyderabad Metro Rail Project

Dr. Akhtar Nasim (Acoustic Expert & Project Leader) &
Dr Kayitha Ravinder (Traffic Expert)
(Senior Scientist))
CSIR-Central Road Research Institute
New Delhi-25

August 30th, 2013


Reconnaisance Survey
Primary Data
Traffic
Noise
Vibrations
Privacy
Building Layouts
Meteorological
Analyses of Data
RECOMMENDATIONS
Noise Barriers
View Cutters
Earth Berm
Acoustical Treatment
Secondary Data
Metro Corridor Engg.Dwg.
Future Prediction
Road Traffic Noise
Metro Rail Noise
Combined Road & Metro Noise


GOVERNMENT OF INDIA
AUTOMATED ROAD SURVEY SYSTEM
FORCE
DL 3C BV 0720



- Corridor I : Miyapur to LB Nagar
- Corridor II : JBS to Falaknuma
- Corridor III : Nagole to Shilparamam

	A	B	C	D	E	F	G	H	I	J	K	L
1	Chainage (km) From	To	Grade (%)	RF (m/km)	NUM_RFS (1/km)	CURVATURE deg/km	Cross Slope HDM 4 (%)	Speed (km/h)	Latitude (deg)	Longitude (deg)	Altitude (m)	Survey Day
2	0	1	-0.2	6.6	11	53.9	1.7	44.8	17.35	78.546	505.4	04-07-2013
3	1	2	-1.7	17.1	5	10.3	3.5	52.6	17.36	78.544	487.7	04-07-2013
4	2	3	-0.5	8.9	9	79.1	2	37.9	17.37	78.537	482.9	04-07-2013
5	3	4	-0.5	9.6	6	84.8	1.7	28.5	17.37	78.527	475.3	04-07-2013
6	4	5	1.8	20.0	2	63.6	1.7	34.4	17.37	78.518	494.7	04-07-2013
7	5	6	0.2	9.5	6	62.5	1.8	43.2	17.37	78.509	496.4	04-07-2013
8	6	7	-0.4	12.8	8	57.9	1.9	44.2	17.37	78.5	490.7	04-07-2013
9	7	8	-0.4	10.3	6	152.4	3.7	36.8	17.38	78.492	486.1	04-07-2013
10	8	9	0.2	4.4	13	365.6	3.3	16.1	17.37	78.484	487.6	04-07-2013
11	9	10	0.4	8.0	11	392.5	1.2	10.7	17.37	78.477	490.5	04-07-2013
12	10	11	0.0	5.2	9	191.9	2.4	31.2	17.38	78.475	490.2	04-07-2013
13	11	12	0.7	7.3	5	75.6	2.3	31.7	17.39	78.47	497.3	04-07-2013
14	12	13	0.9	11.5	5	130.6	2.4	26.9	17.4	78.471	506.5	04-07-2013
15	13	14	0.9	14.1	7	238.9	1.7	31.3	17.4	78.465	514.2	04-07-2013
16	14	15	0.2	20.4	4	239.5	1.9	24.7	17.41	78.461	518.3	04-07-2013
17	15	16	0.6	10.2	6	148.4	2.3	40.5	17.42	78.457	520.6	04-07-2013
18	16	17	0.3	9.8	7	37.8	3.2	42.4	17.43	78.452	523.3	04-07-2013
19	17	18	1.0	11.6	5	49.3	2.1	37.1	17.43	78.446	532.8	04-07-2013
20	18	19	0.4	14.9	9	95.7	2.6	36.3	17.44	78.442	536.7	04-07-2013
21	19	20	0.4	14.3	7	61.3	1.8	31.9	17.45	78.437	540	04-07-2013
22	20	21	0.4	19.6	2	38.4	2.1	30.2	17.46	78.433	543.9	04-07-2013
23	21	22	-0.2	17.1	3	20.6	1.2	45	17.47	78.43	541.2	04-07-2013
24	22	23	-0.1	6.8	12	26.4	3.3	44.6	17.47	78.425	539	04-07-2013
25	23	24	0.9	9.3	1	49.9	3.4	32.2	17.48	78.418	547.7	04-07-2013
26	24	25	1.5	15.1	5	72.2	4.2	27.6	17.49	78.411	562.6	04-07-2013
27	25	26	1.4	13.8	3	48.7	5.7	38.9	17.49	78.405	577	04-07-2013
28	26	27	1.2	12.1	5	39	3.3	37.6	17.5	78.397	588.6	04-07-2013
	27	28	0.4	10.3	8	72.8	3.1	28.9	17.5	78.388	591.5	04-07-2013
	28	29	1.1	11.1	2	49.9	3.5	40.2	17.5	78.379	602.7	04-07-2013
	29	30	-0.8	8.8	6	56.7	2.6	44.7	17.5	78.37	594.3	04-07-2013

GEOMETRY_C1-final (Miyapur to LB Nagar 29.87 km) UP

602.7

475.3

127.4

GEOMETRY-C2-final (JBS to Falaknuma 14.78 km) UP

	A	B	C	D	E	F	G	H	I	J	K	L
1	Chainage (km)		Grade (%)	RF (m/k	NUM_	CURVATURE	Cross Slope	Speed (km/h)	Latitude (deg)	Longitude (deg)	Altitude (m)	Survey Day
2	0	1	0.6	18.7	3	153.0	1.7	18.8	17.44079	78.498845	531.6	04-07-2013
3	1	2	-0.1	10.2	7	256.7	1.4	19.1	17.43441	78.498645	528.3	04-07-2013
4	2	3	-0.9	13.6	4	109.4	3.0	24.2	17.41997	78.500276	515.7	04-07-2013
5	3	4	-0.8	12.7	6	87.7	1.6	24.3	17.41146	78.497898	504.5	04-07-2013
6	4	5	-1.4	13.8	5	84.8	1.3	21.9	17.40286	78.495216	489.3	04-07-2013
7	5	6	0.9	13.5	6	107.1	2.0	23.0	17.39557	78.490556	498.2	04-07-2013
8	6	7	0.2	6.6	9	104.3	1.7	17.4	17.38753	78.486665	499.7	04-07-2013
9	7	8	-1.1	13.7	3	205.7	1.0	10.7	17.38123	78.483665	483.8	04-07-2013
10	8	9	0.5	5.4	12	303.7	2.6	11.6	17.37498	78.480987	487.2	04-07-2013
11	9	10	1.0	9.7	6	194.2	2.0	19.1	17.3673	78.48127	494.4	04-07-2013
12	10	11	1.0	11.1	2	81.4	1.4	18.2	17.35844	78.479277	503.2	04-07-2013
13	11	12	0.5	9.1	11	153.6	0.8	16.5	17.35487	78.473744	508.2	04-07-2013
14	12	13	1.7	17.2	8	193.7	0.9	22.2	17.34691	78.470377	520.2	04-07-2013
15	13	14	0.4	7.4	13	130.6	1.1	27.9	17.33834	78.467829	522.5	04-07-2013
16	14	15	0.7	15.8	3	128.3	1.1	32.2	17.33212	78.469933	526	04-07-2013

Table : GEOMETRY-C3-final (Shilparamam to Nagole 26.51 km) DN

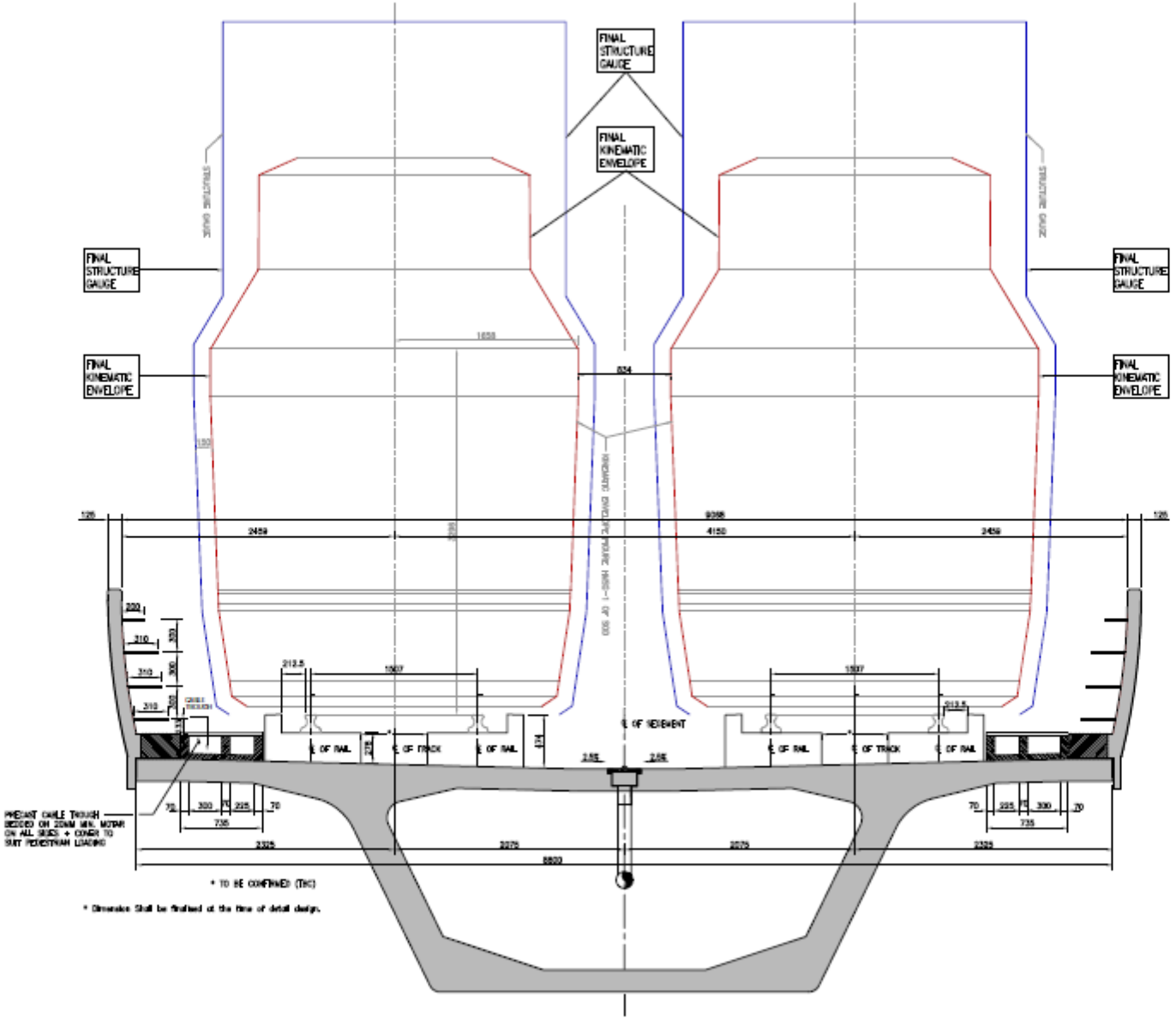
	A	B	C	D	E	F	G	H	I	J	K	L
1	Chainage (km)		Grade (%)	RF (m/km)	NUM_RFS	CURVATUR	Cross Slope	Speed (km/h)	Latitude (deg)	Longitude (deg)	Altitude (m)	Survey Day
2	27	26	-0.7	21.8	6	69.3	1.5	49.5	17.449	78.379	586.4	04-07-2013
3	26	25	-1.2	12.5	6	177.0	1.9	36.9	17.447	78.3844	572.4	04-07-2013
4	25	24	-1.1	14.2	7	140.4	2.0	40.2	17.441	78.3905	560.1	04-07-2013
5	24	23	1.0	15.0	9	189.7	1.7	38.7	17.439	78.3991	569.7	04-07-2013
6	23	22	1.7	22.0	3	198.2	1.3	41.1	17.433	78.4061	585.6	04-07-2013
7	22	21	1.5	23.7	5	269.9	2.2	39.7	17.429	78.4131	599.6	04-07-2013
8	21	20	-3.0	29.8	5	159.3	1.5	35.1	17.431	78.4196	566.6	04-07-2013
9	20	19	-2.0	26.9	11	553.5	1.5	16.3	17.433	78.4263	550.8	04-07-2013
10	19	18	-0.1	10.3	5	257.8	1.9	22.0	17.437	78.4325	543.9	04-07-2013
11	18	17	-1.0	10.6	5	210.9	1.6	18.2	17.438	78.441	535.2	04-07-2013
12	17	16	-0.4	14.3	6	590.2	4.9	24.9	17.435	78.4495	524.9	04-07-2013
13	16	15	0.2	10.4	5	240.1	1.9	34.8	17.438	78.4569	526.8	04-07-2013
14	15	14	-0.9	15.3	4	84.8	1.4	41.1	17.445	78.4621	515.3	04-07-2013
15	14	13	1.1	18.1	5	83.7	1.3	40.1	17.444	78.4714	526.3	04-07-2013
16	13	12	-1.1	13.6	6	53.9	2.1	39.4	17.444	78.4807	514	04-07-2013
17	12	11	0.9	20.8	3	31.5	1.5	40.6	17.443	78.4901	522.5	04-07-2013
18	11	10	1.8	20.5	2	14.3	1.2	43.8	17.443	78.4995	540.8	04-07-2013
19	10	9	0.0	15.4	7	297.4	3.4	20.0	17.44	78.5053	539.7	04-07-2013
20	9	8	-1.4	15.2	5	157.6	1.5	13.3	17.433	78.5085	526.6	04-07-2013
21	8	7	0.2	5.4	8	175.9	2.5	14.6	17.437	78.5169	524.6	04-07-2013
22	7	6	1.4	16.3	6	92.8	1.6	25.4	17.432	78.5242	539.6	04-07-2013
23	6	5	-0.6	17.3	5	60.2	2.0	44.0	17.426	78.5317	531.4	04-07-2013
24	5	4	-1.2	14.8	5	84.8	1.7	41.3	17.422	78.5394	517	04-07-2013
25	4	3	-1.0	11.0	7	55.0	2.6	13.9	17.415	78.546	506.7	04-07-2013
26	3	2	-0.7	12.5	4	39.5	4.2	48.2	17.409	78.5529	496.8	04-07-2013
27	2	1	-0.8	15.3	6	53.3	3.4	39.7	17.402	78.5594	485.6	04-07-2013
28	1	0	-0.6	9.6	7	100.3	2.4	21.5	17.394	78.5591	479.5	04-07-2013

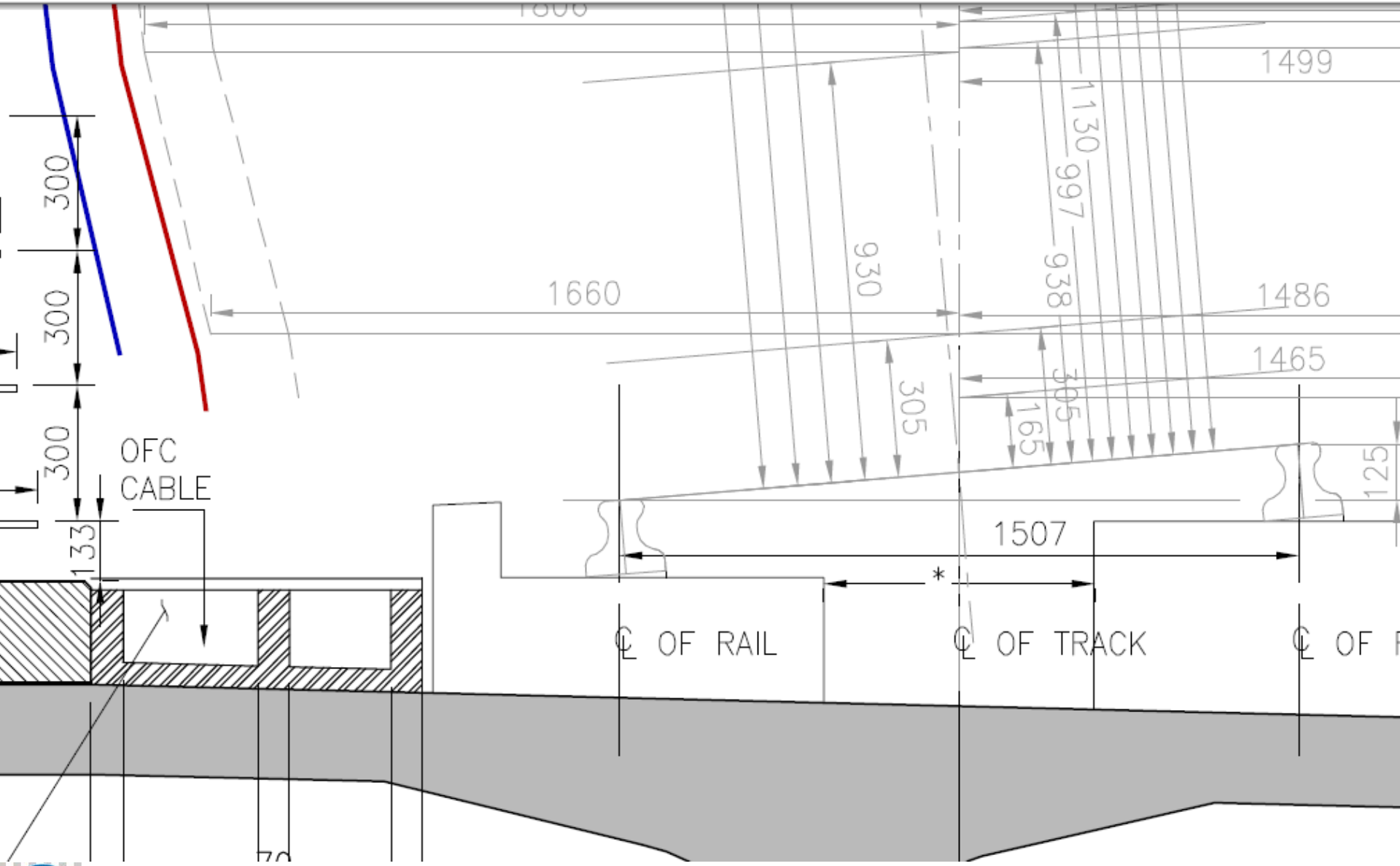
1	23425	23750	325	LHS	2110
	25350	25525	175	LHS	
	25245	25770	525	LHS	
	27240	27800	560	RHS	
	32325	32850	525	RHS	
2	9578	9701	123	LHS	12695
	9640	9730	90	RHS	
	10126	10769	643	RHS	
	10523	10631	108	LHS	
	10920	11530	610	LHS	
	11243	11593	350	RHS	
	15632	15802	170	LHS	
	16467	16673	206	LHS	
	16467	16742	275	RHS	
	18150	23370	5220	LHS	
	18280	23180	4900	RHS	
3	15520	15775	255	RHS	3925
	17100	17350	250	RHS	
	18100	18675	575	RHS	
	24350	26100	1750	LHS	
	26300	26875	575	LHS	
	26320	26840	520	RHS	
				Total	18730

Total Length= 72km approx.

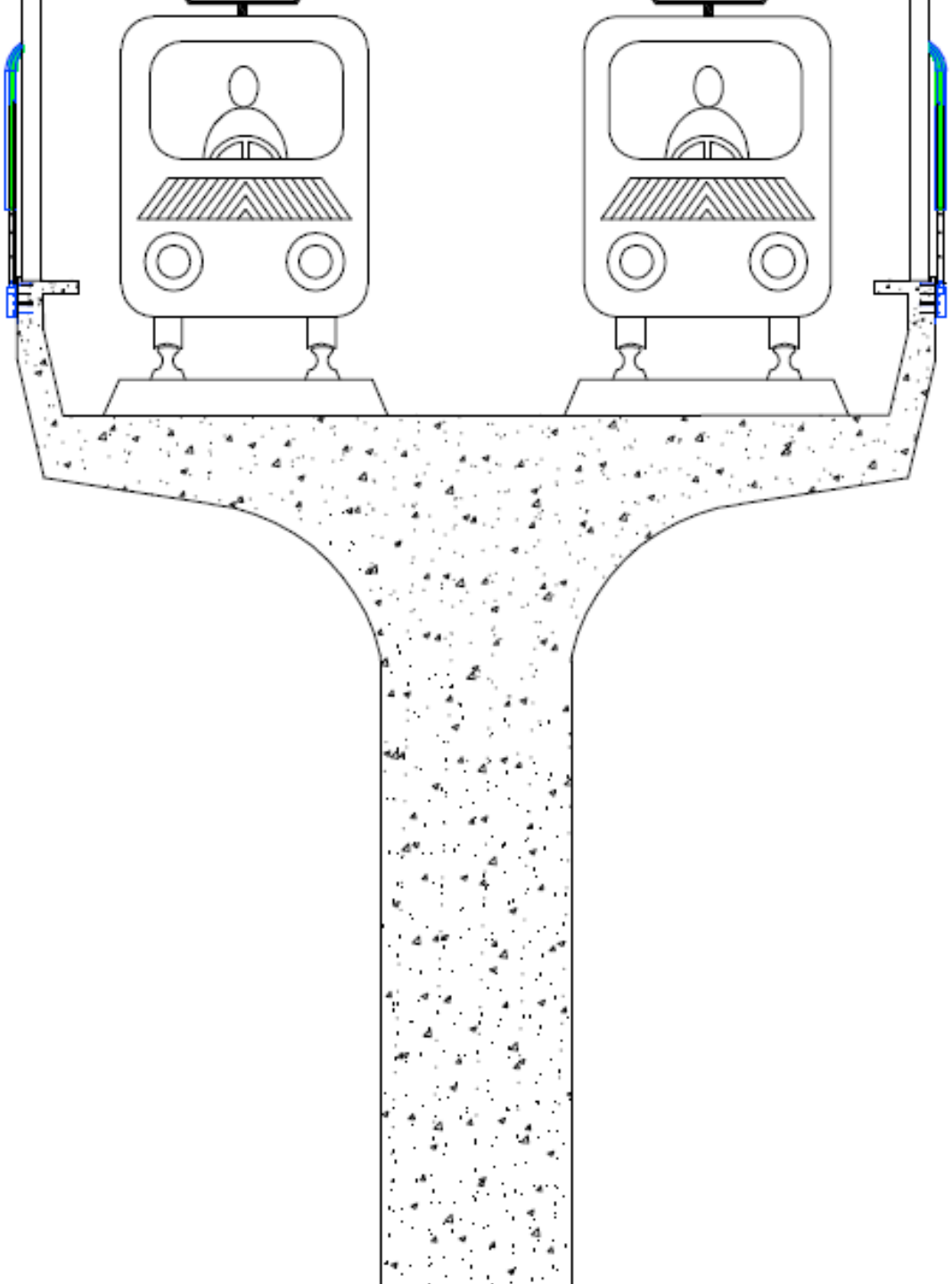
Barrier Suggested= 9.365km

% barrier Suggested= 13



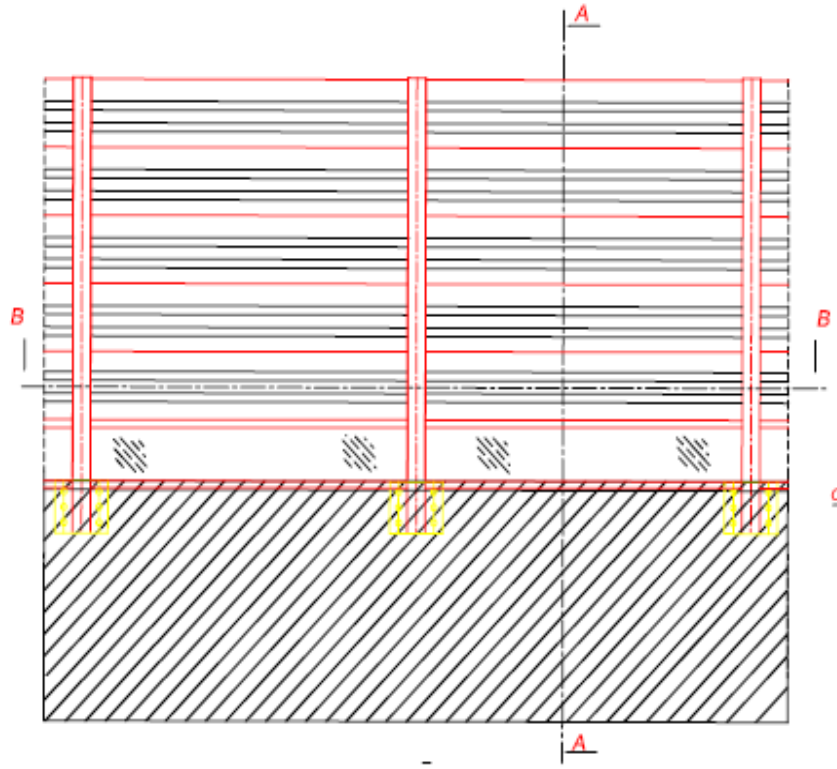

1499
1130
997
938
930
1660
1486
1465
305
305
165
125
300
300
300
OFC
CABLE
133
1507
*
℄ OF RAIL
℄ OF TRACK


SPACE

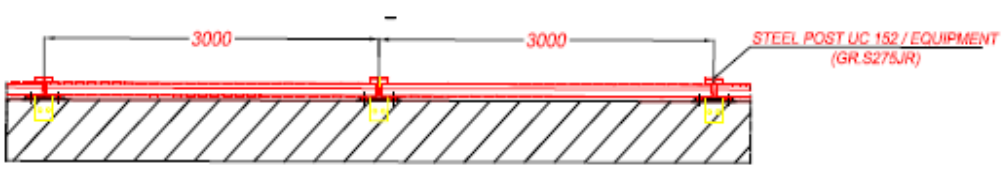


The Cost of Type-I is Rs. 12050/m²

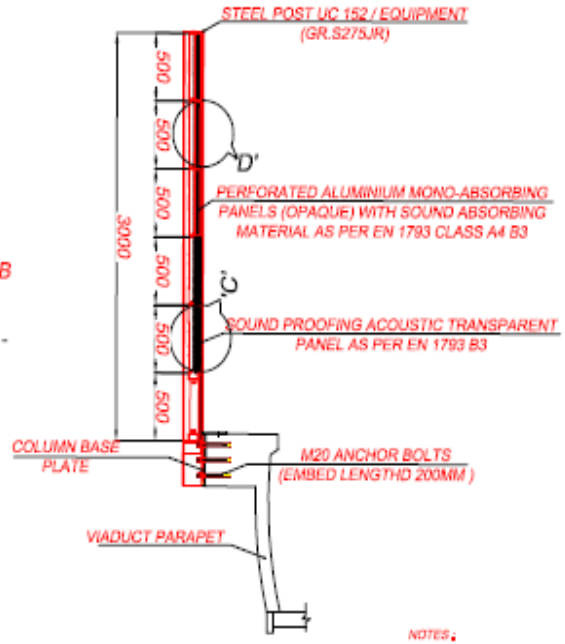
TYPE-1



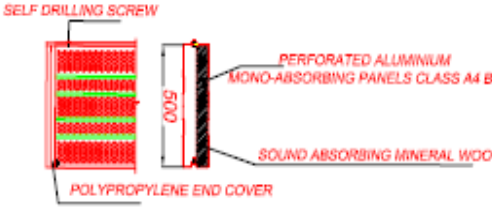
ELEVATION



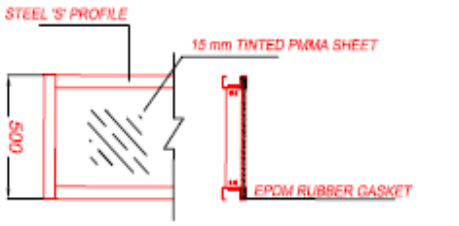
SECTION B-B



SECTION A-A



PERFORATED ALUMINIUM-MONO-ABSORBING OPAQUE
PANEL CLASS A4 B3
DETAIL - D



SOUND REFLECTING ACOUSTIC TRANSPARENT PANEL CLASS B3
DETAIL - C

NOTES:

6. EMERGENCY EXIT TO BE PROVIDED AS INSTRUCTED BY CONSULTANT / CLIENT
5. PERFORATED ALUMINIUM MONO-ABSORBING PANEL (OPAQUE) SAND WITCHED WITH WATER REPELLENT SOUND ABSORBING MINERAL WOOL TO BE CLASS A4 B3 AS PER EN 1793
4. ALL PANELS TO CONFIRM TO THE REQUIREMENT OF EN 1794 FOR WIND LOADS
3. ALL PANELS TO CONFIRM TO THE REQUIREMENT OF EN 1793 PART 1 & 2 : 1999

CATEGORIES OF ABSORPTIVE PERFORMANCE	
CATEGORY	DL_α(dB)
A0	Not determined
A1	< 4
A2	4 to 7
A3	8 to 11
A4	12 to 15
A5	> 15

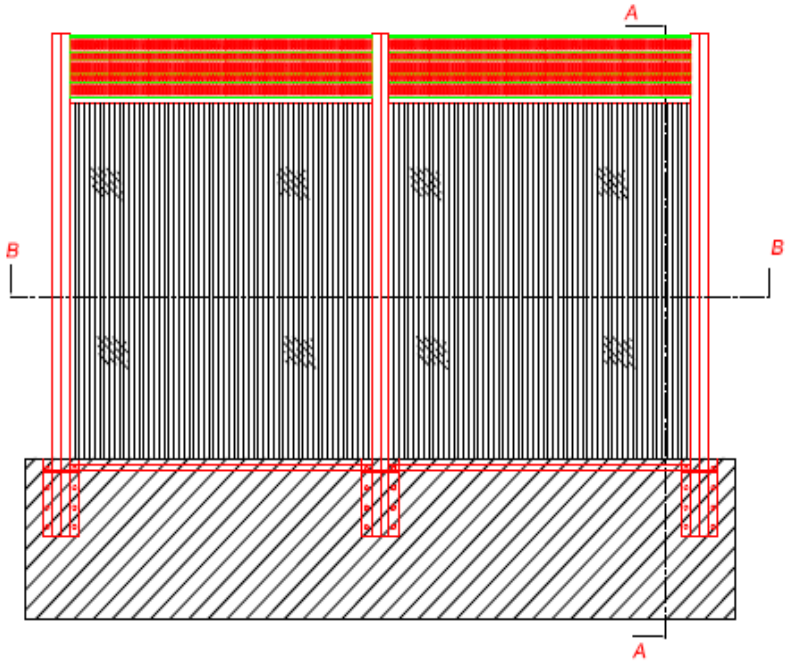
CATEGORIES OF AIRBONE SOUND INSULATION	
CATEGORY	DL_R (dB)
B0	Not determined
B1	< 15
B2	15 to 24
B3	25 to 34
B4	> 34

2. ANCHORS OF CLASS 8.8, HOT DIP GALVANIZED WITH RE 500 CHEMICAL GROUT OR EQUIVALENT
1. ALL DIMENSIONS IN MM ONLY

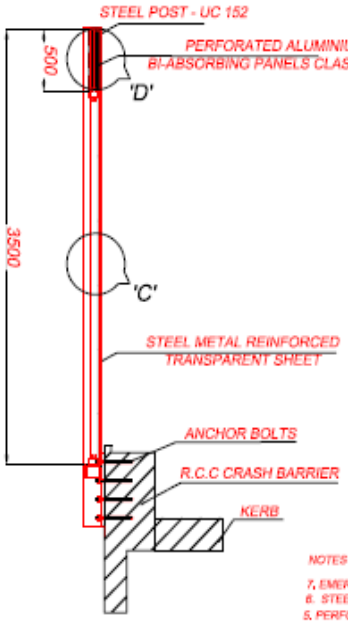
CSIR CRRI
CENTRAL ROAD RESEARCH INSTITUTE, NEW DELHI
CUSTOMER:
SITE:
NAME OF WORK:
DRAWING NO. CRRI-010 | SHEET NO. 1 | DATE 28-07-2015

HYDERABAD METRO RAIL

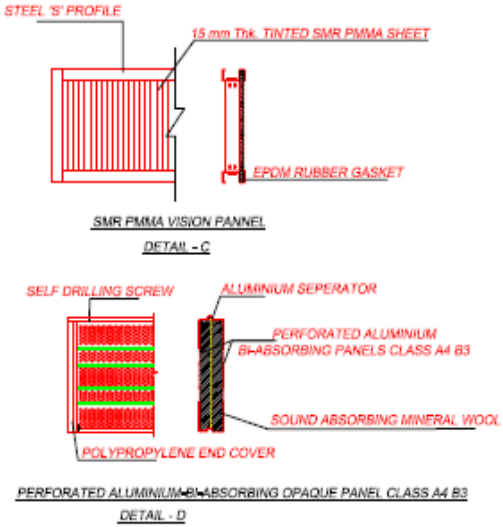
The Cost of Type-II is Rs. 12850/m²

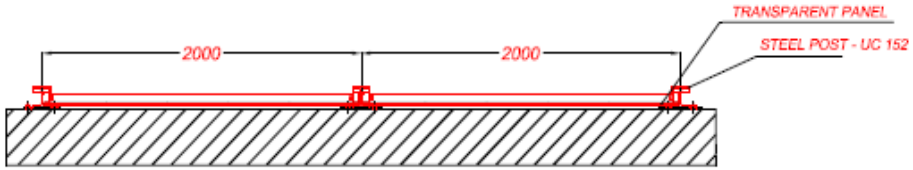


ELEVATION



SECTION A-A





SECTION B-B

NOTES :

7. EMERGENCY EXIT TO BE PROVIDED AS INSTRUCTED BY CONSULTANT / CLIENT
6. STEEL METAL REINFORCED TRANSPARENT SHEET TO BE 15MM THICK TINTED PMMA
5. PERFORATED ALUMINIUM BI-ABSORBING PANEL (OPAQUE) SAND WITCHED WITH WATER REPELLENT SOUND ABSORBING MINERAL WOOL TO BE CLASS A4 B3 AS PER EN 1793
4. ALL PANELS TO CONFIRM TO THE REQUIREMENT OF EN 1794 FOR WIND LOADS
3. PERFORATED ALUMINIUM BI- ABSORBING PANEL TO CONFIRM TO THE REQUIREMENT OF EN 1793 PART 1 & 2 : 1999

CATEGORIES OF ABSORPTIVE PERFORMANCE	
CATEGORY	DL_α(dB)
A0	Not determined
A1	< 4
A2	4 to 7
A3	8 to 11
A4	> 11

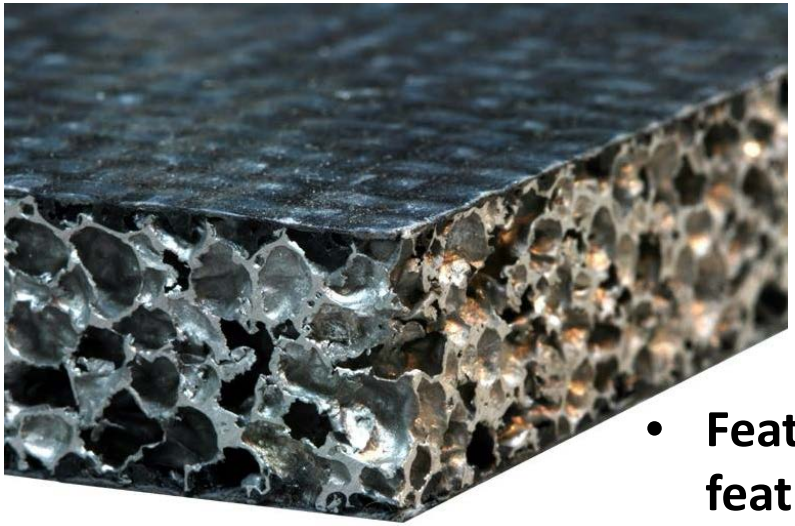
CATEGORIES OF AIRBONE SOUND INSULATION	
CATEGORY	DL_R (dB)
B0	Not determined
B1	< 15
B2	15 to 24
B3	> 24

2. ANCHORS OF HILTI MAKE OR EQUIVALENT WITH RE 500 CHEMICAL GROUT
1. ALL DIMENSIONS IN MM ONLY

CSIR CRRI	CENTRAL ROAD RESEARCH INSTITUTE, NEW DELHI	CUSTOMER:	MSRDC
		SITE:	JJ FLYOVER, MUMBAI
		NAME OF WORK:	TYPE-2 MIXED TYPE OF NOISE BARRIER (TRANSPARENT)AT SELECT LOCATION ON JJ FLY OVER

DRAWING NO.	CRRI-001	SHEET NO.	2	DATE	02-11-2012	GALVANIZING	IS 4759	REV. NO.	0

Aluminum foam sandwich panel



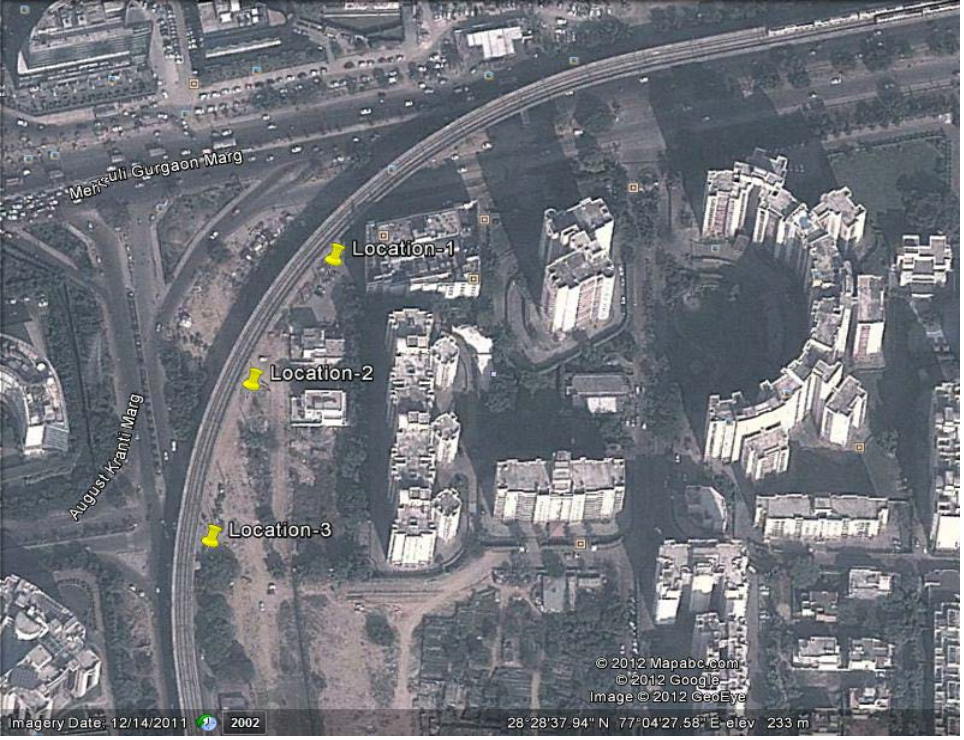
- **Features of aluminum foam panel: Due to the features of aluminum foam including noise absorption, light weight, nonflammability and eco-friendless, the sandwich panels have reinforced function.**

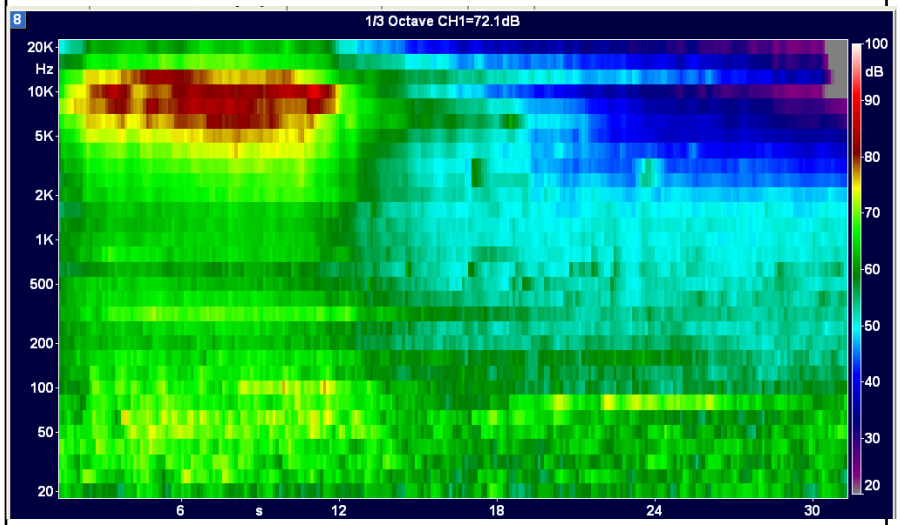
- **Special features of aluminum foam sandwich panel - Excellent lightness - High strength, nonflammability - Better noise absorptiveness and insulation performance than honeycomb and corrugate panels**

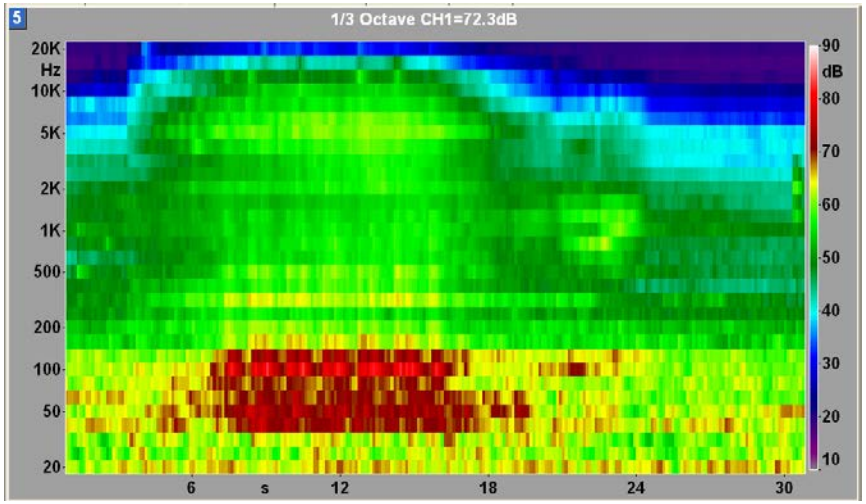
Noise absorption panel for tunnel

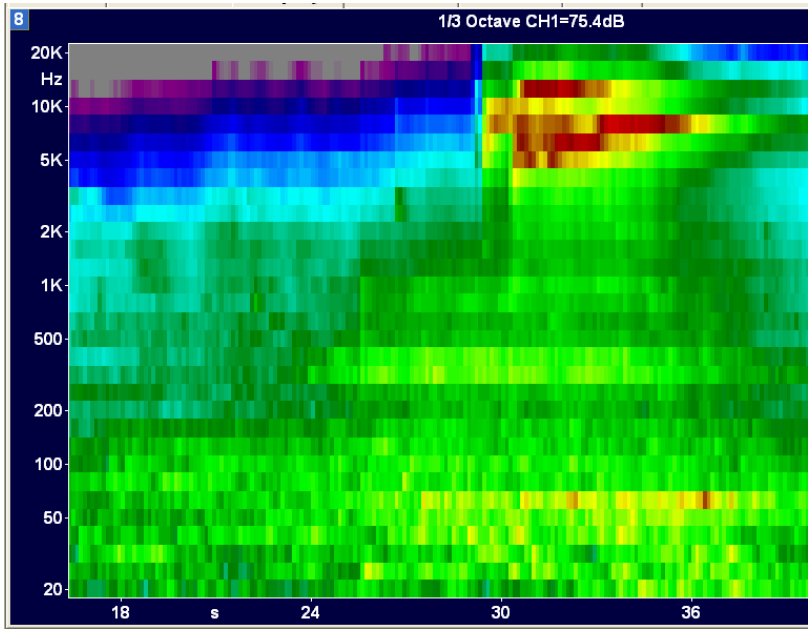
At Washing Yard= Aluminium Foam NRC=0.7 has been provided
Cost will be Rs.14000/m2
Yard is not included in draft report, it will be included in final report.

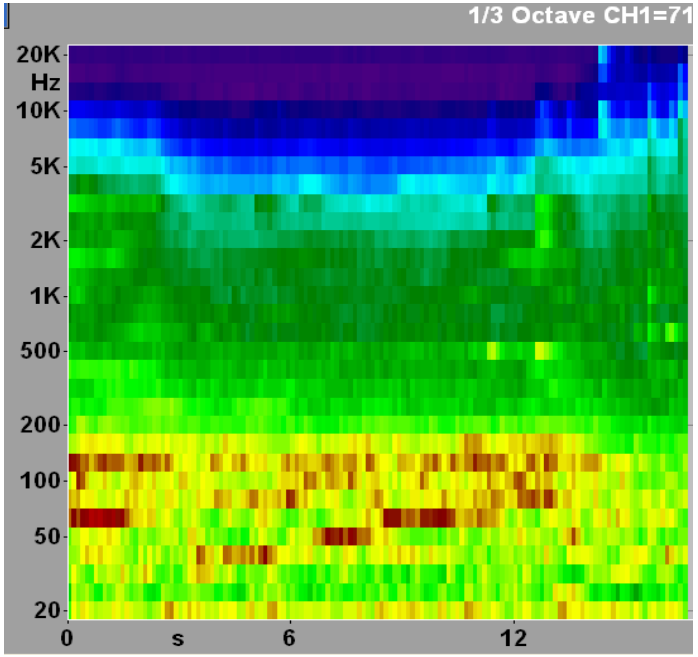
IFFCO CHOWK GURGOAN, DMRC

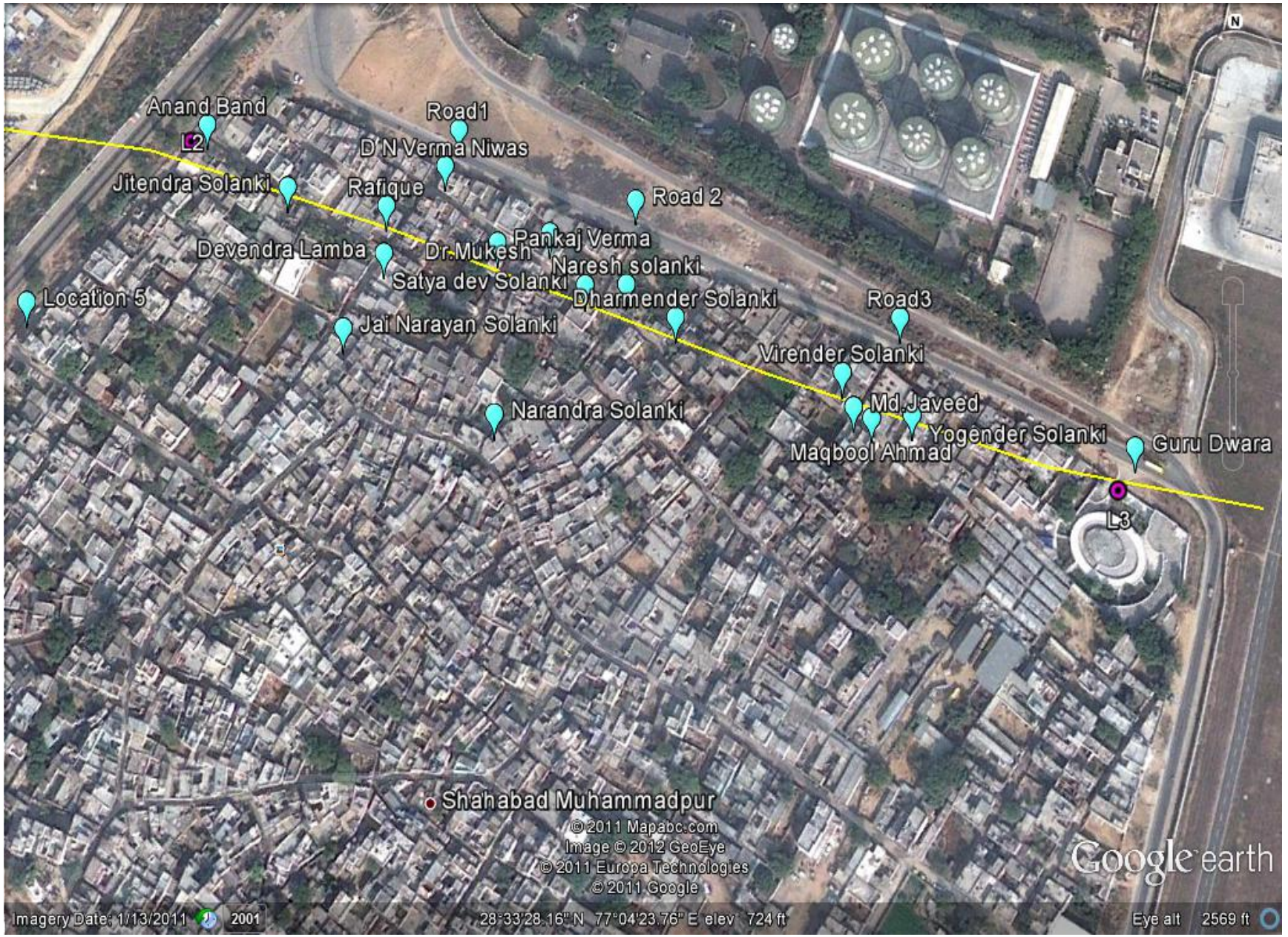

Mehrauli Gurgaon Marg
Location-1
Location-2
August Kranti Marg
Location-3
© 2012 Mapabc.com
© 2012 Google
Image © 2012 GeoEye
Imagery Date: 12/14/2011
2002
28°28'37.94" N 77°04'27.58" E elev 233 m

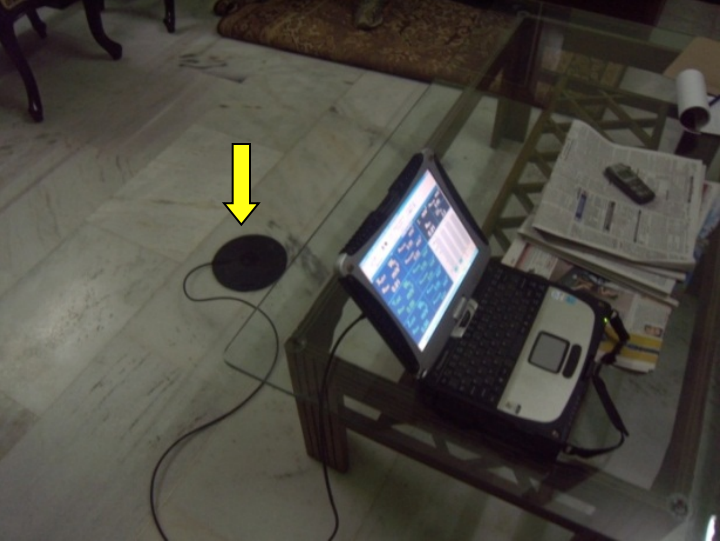

8
1/3 Octave CH1=72.1dB
20K
Hz
10K
5K
2K
1K
500
200
100
50
20
6
s
12
18
24
30
100
dB
90
80
70
60
50
40
30
20

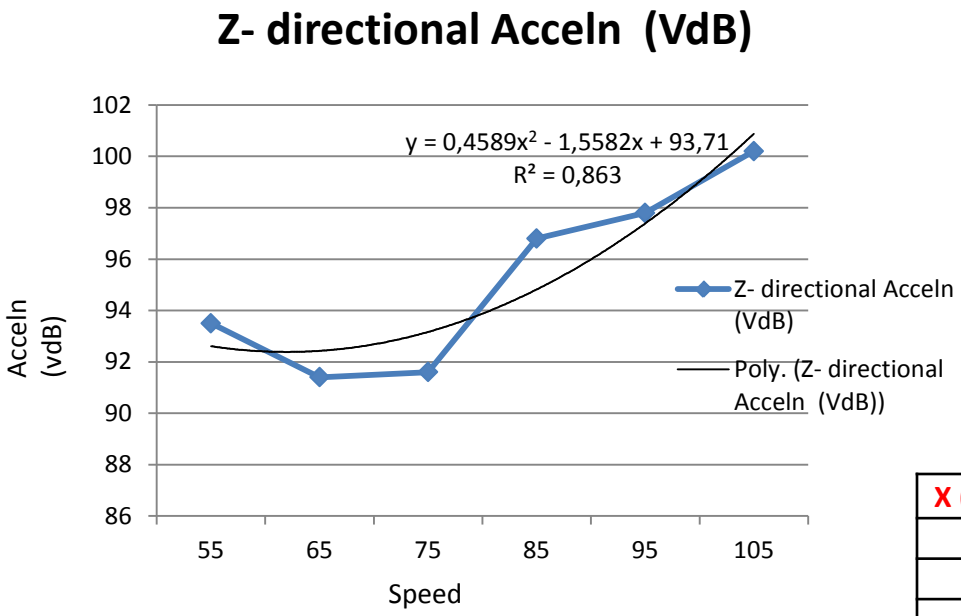

5
1/3 Octave CH1=72.3dB
20K
Hz
10K
5K
2K
1K
500
200
100
50
20
6
s
12
18
24
30
90
dB
80
70
60
50
40
30
20
10


8
1/3 Octave CH1=75.4dB
20K
Hz
10K
5K
2K
1K
500
200
100
50
20
18
s
24
30
36


1/3 Octave CH1=71
20K
Hz
10K
5K
2K
1K
500
200
100
50
20
0
s
6
12

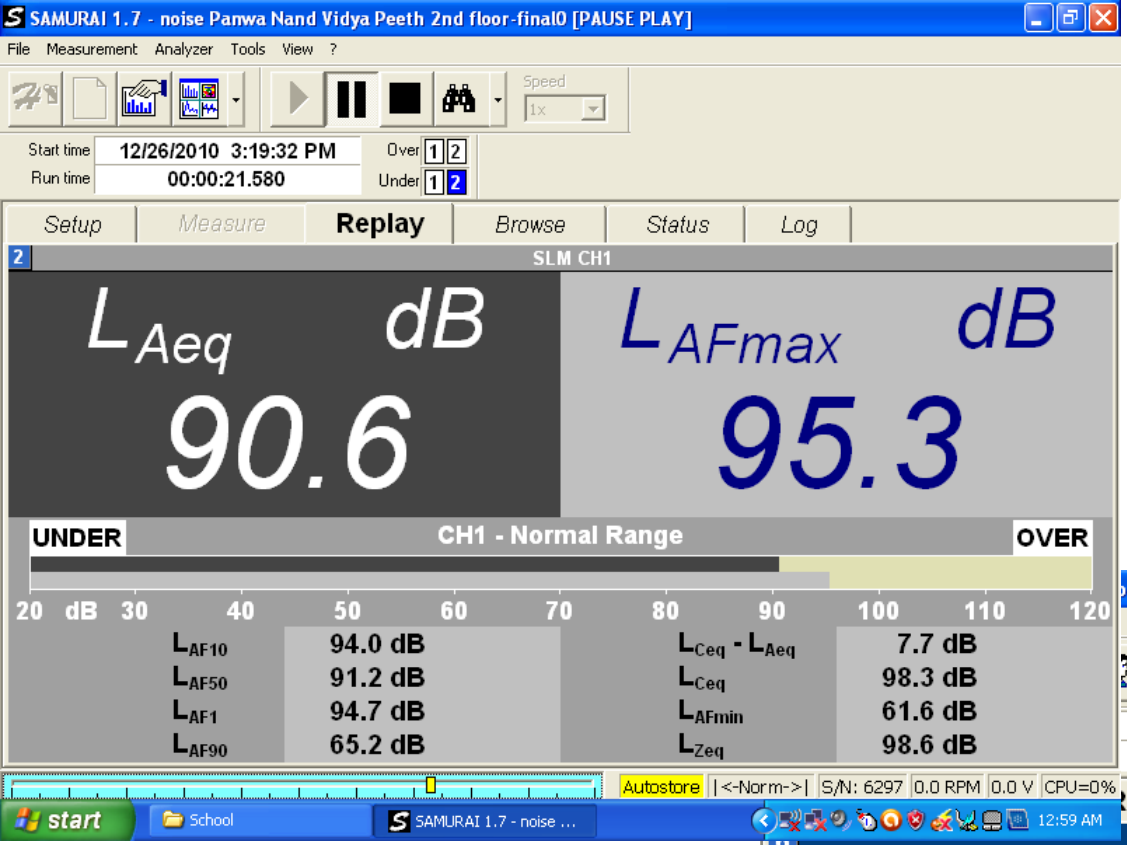

Anand Band
L2
Road1
D'N Verma Niwas
Jitendra Solanki
Rafique
Road 2
Pankaj Verma
Devendra Lamba
Dr.Mukesh
Naresh solanki
Satya dev Solanki
Location 5
Dharmender Solanki
Road3
Jai Narayan Solanki
Virender Solanki
Md.Javeed
Narandra Solanki
Yogender Solanki
Maqbool Ahmad
Guru Dwara
L3
Shahabad Muhammadpur
© 2011 Mapabc.com
Image © 2012 GeoEye
© 2011 Europa Technologies
© 2011 Google
Google earth
Imagery Date: 1/13/2011
2001
28°33'28.16" N 77°04'23.76" E elev 724 ft
Eye alt 2569 ft

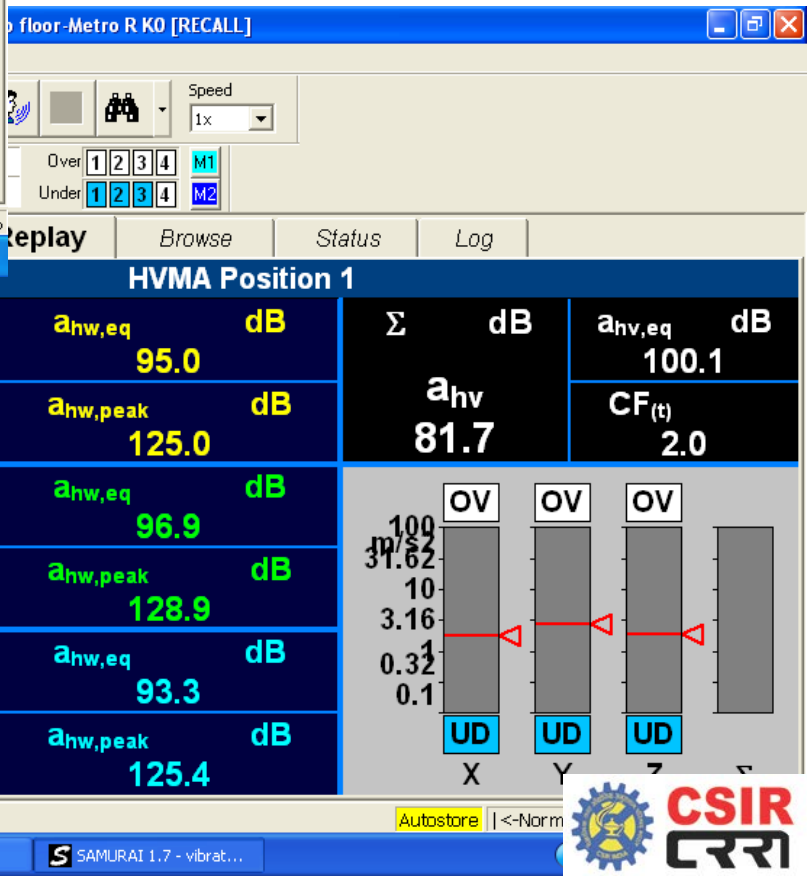




S.No.	Speed	Noise
1.	65	72.2
2.	60	68.9
3.	50	67.0

X (m/s²)	Y(m/s²)	Z(m/s²)	X(VdB)	Y(VdB)	Z(VdB)	Speed
0.01	0.01	0.05	81.9	81.2	93.5	55
0.01	0.01	0.04	81.2	79.5	91.4	65
0.01	0.01	0.04	80.6	78.2	91.6	75
0.05	0.06	0.07	94.1	95.3	96.8	85
0.06	0.07	0.08	95.5	96.5	97.8	95
0.03	0.02	0.1	88.9	85	100.	


SAMURAI 1.7 - noise Panwa Nand Vidya Peeth 2nd floor-final0 [PAUSE PLAY]
File Measurement Analyzer Tools View ?
Speed
1x
Start time 12/26/2010 3:19:32 PM
Run time 00:00:21.580
Over 1 2
Under 1 2
Setup Measure Replay Browse Status Log
SLM CH1
L_{Aeq} dB
90.6
L_{AFmax} dB
95.3
UNDER
CH1 - Normal Range
OVER
20 dB 30 40 50 60 70 80 90 100 110 120
L_{AF10} 94.0 dB
L_{AF50} 91.2 dB
L_{AF1} 94.7 dB
L_{AF90} 65.2 dB
$L_{Ceq} - L_{Aeq}$ 7.7 dB
L_{Ceq} 98.3 dB
L_{AFmin} 61.6 dB
L_{Zeq} 98.6 dB
Autostore | <-Norm-> | S/N: 6297 | 0.0 RPM | 0.0 V | CPU=0%
start
School
SAMURAI 1.7 - noise ...
12:59 AM


floor-Metro R K0 [RECALL]
Speed
1x
Over 1 2 3 4 M1
Under 1 2 3 4 M2
Replay Browse Status Log
HVMA Position 1
X_{ch1} W_h
a_{hw} dB
77.8
$a_{hw,eq}$ dB
95.0
$a_{hw,peak}$ dB
125.0
Y_{ch2} W_h
a_{hw} dB
79.3
$a_{hw,eq}$ dB
96.9
$a_{hw,peak}$ dB
128.9
Z_{ch3} W_h
a_{hw} dB
65.0
$a_{hw,eq}$ dB
93.3
$a_{hw,peak}$ dB
125.4
Σ dB
a_{hv}
81.7
$a_{hv,eq}$ dB
100.1
$CF_{(t)}$
2.0
OV OV OV
100 m/s²
31.62
10
3.16
1
0.32
0.1
UD UD UD
X Y Z Σ
Autostore | <-Norm
start
School
SAMURAI 1.7 - vibrat...

SAMURAI 1.7 - school-top floor Metro Rail Kolkata0 [RECALL]

File Measurement Analyzer Tools View ?

Speed 1x

Start time 12/26/2010 2:49:20 PM
Run time 00:00:28.400
Over 1 2
Under 1 2

Setup | Measure | Replay | Browse | Status | Log

5 1/3 Octave CH1=82.1dB

20K Hz 10K 5K 2K 1K 500 200 100 50 20

0 s 6 12 18 24 30

100 dB 90 80 70 60 50 40 30 20

Create/Edit the audio comment for the new or recalled measurement

Autostore | <-Norm-> | S/N: 6297 | 0.0 RPM | 0.0 V | CPU=0%

start | School | SAMURAI 1.7 - schoo... | 12:54 AM

SAMURAI 1.7 - noise Panwa Nand Vidya Peeth 2nd-2nd floor-final0 [PAUS

File Measurement Analyzer Tools View ?

Speed 1x

Start time 12/26/2010 3:29:11 PM
Run time 00:00:29.500
Over 1 2
Under 1 2

Setup | Measure | Replay | Browse | S

5 1/3 Octave CH1=85.7

20K Hz 10K 5K 2K 1K 500 200 100 50 20

s 6 12 18 24 30

90 80 70 60 50 40 30 20

Autostore | <-Norm-> | S/N: 6297 | 0.0 RPM | 0.0 V | CPU=0%

School | SAMURAI 1.7 - noise ... | 12:57 AM

HYDERABAD METRO RAIL

CSIR CRRI

Location	Noise **Level Leq(A)**	Vibration **V(dB)**		
		X Direction	Y Direction	Z Direction
Inside Metro Rail	87.9	**147.5**	**136.4**	**158.0**
At Platform	84.1	112.4	109.2	111.3
Site office (ground floor)	75.3	110.8	109.8	108.9
Pier of hospital	76.2	115.1	108.7	109.6
At Pier	75.5	122.8	105.9	115.2
Below the track	74.7	97.2	92.6	91.1
4th floor (Panwa Nand Vidya Peeth School)	90.1	125	**128.9** **3.6m/s2**	**125.4** **3.4m/s2**
3rd floor (Panwa Nand Vidya Peeth School)	79.3	98.2	73.6	98.7
2nd floor (Panwa Nand Vidya Peeth School)	**90.6**	102.6	**115.2**	108.4
le Hospital (on	74-76	-	-	-

Noise & Vibration Data

Calculation for Exposure Points

1.4x3.9 = 5.46 1.4x3.2 = 4.48

Critical at metro railway pier location = 5.46

Critical at hospital location = 4.48

CRRI has monitored the vibration on various places. The acceleration at Metro Railway Pier is 3.9 m/s2 and at the pier of hospital are 3.2 m/s2. This is very high in compare to the EU norms.

Daily exposure A(8)

If a person is exposed to more than one source of vibration (perhaps because they use two or more different machines or activities during the day) then a *partial vibration exposure* is calculated from the magnitude and duration for each axis and for each exposure. The partial vibration values are combined to give the overall daily exposure value, $A(8)$, for that person, for each axis. The daily vibration exposure is then the highest of the three single axis values.

Step 1: Determine the three frequency weighted r.m.s acceleration values a_{wx}, a_{wy} and a_{wz}, for each task or vehicle, from manufacturer's data, other sources, or measurement.

Step 2: For each vehicle or task, find the partial daily exposures in the three directions, x, y and z using:

$$A_{x,j}(8) = 1.4 a_{wx} \sqrt{\frac{T_{exp}}{T_0}}$$

$$A_{y,j}(8) = 1.4 a_{wy} \sqrt{\frac{T_{exp}}{T_0}}$$

$$A_{z,j}(8) = a_{wz} \sqrt{\frac{T_{exp}}{T_0}}$$

Where

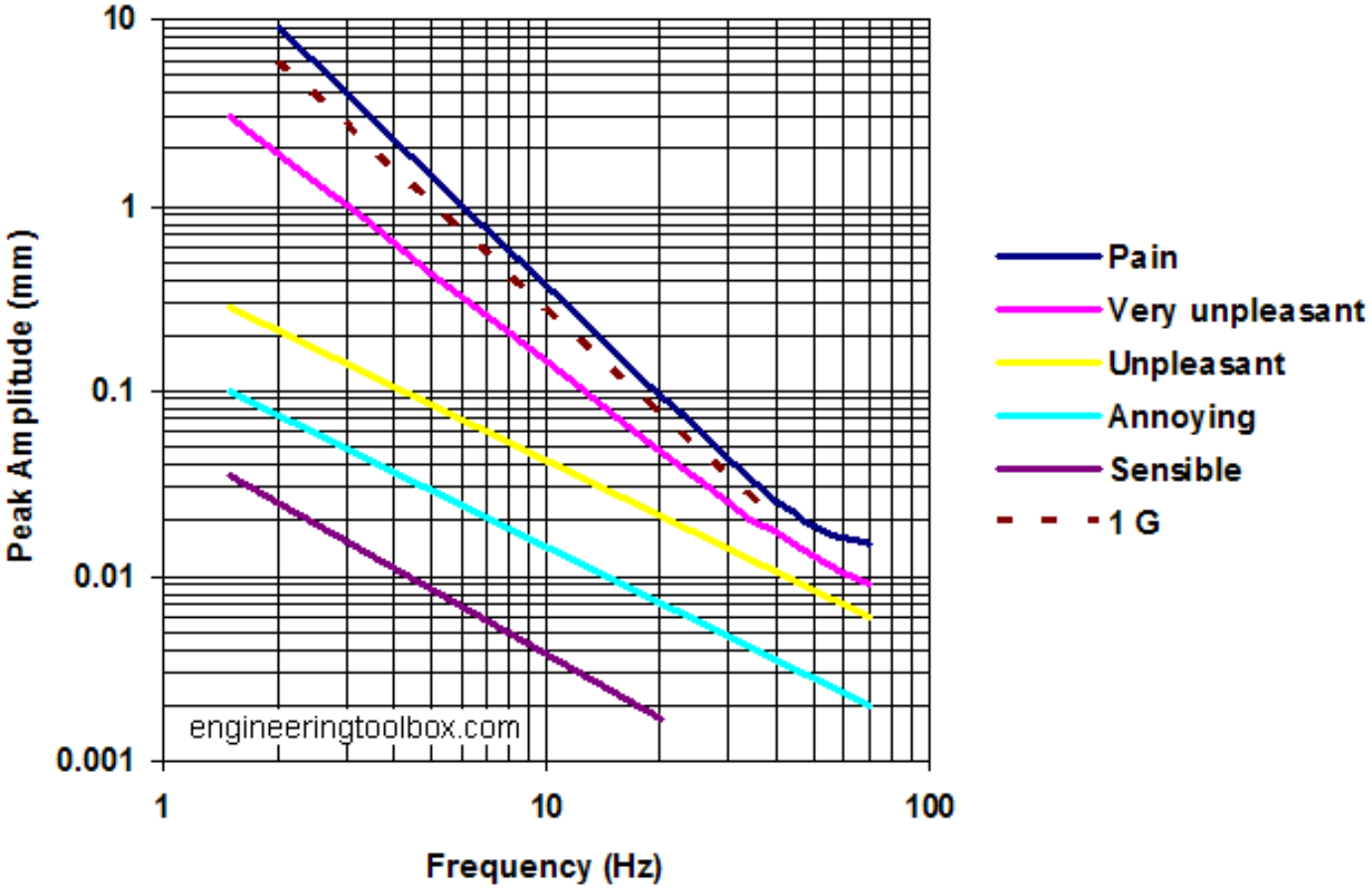
- T_{exp} is the daily duration of exposure to the vibration and
- T_0 is the reference duration of eight hours.

Each partial vibration exposure represents the contribution of a particular source of vibration (machine or activity) to the worker's total daily exposure. Knowledge of the partial exposure values will help you decide on your priorities: the machines or activities or processes with the highest partial vibration exposure values are those that should be given priority for control measures.

Step 3: For each axis (j), the overall daily vibration exposure can be calculated from the partial vibration exposure values, using:

$$A_j(8) = \sqrt{A_{j1}(8)^2 + A_{j2}(8)^2 + A_{j3}(8)^2 + \ldots}$$

where $A_{j1}(8)$, $A_{j2}(8)$, $A_{j3}(8)$, etc. are the partial vibration exposure values for the different vibration sources.



Vibration Level - Acceleration *(m/s²)*	Human Perception
< 0.315	Not uncomfortable
0.315 - 0.63	A little uncomfortable
0.5 - 1	Fairly uncomfortable
0.8 - 1.6	Uncomfortable
1.25 - 2.5	Very uncomfortable
> 2	Extremely uncomf

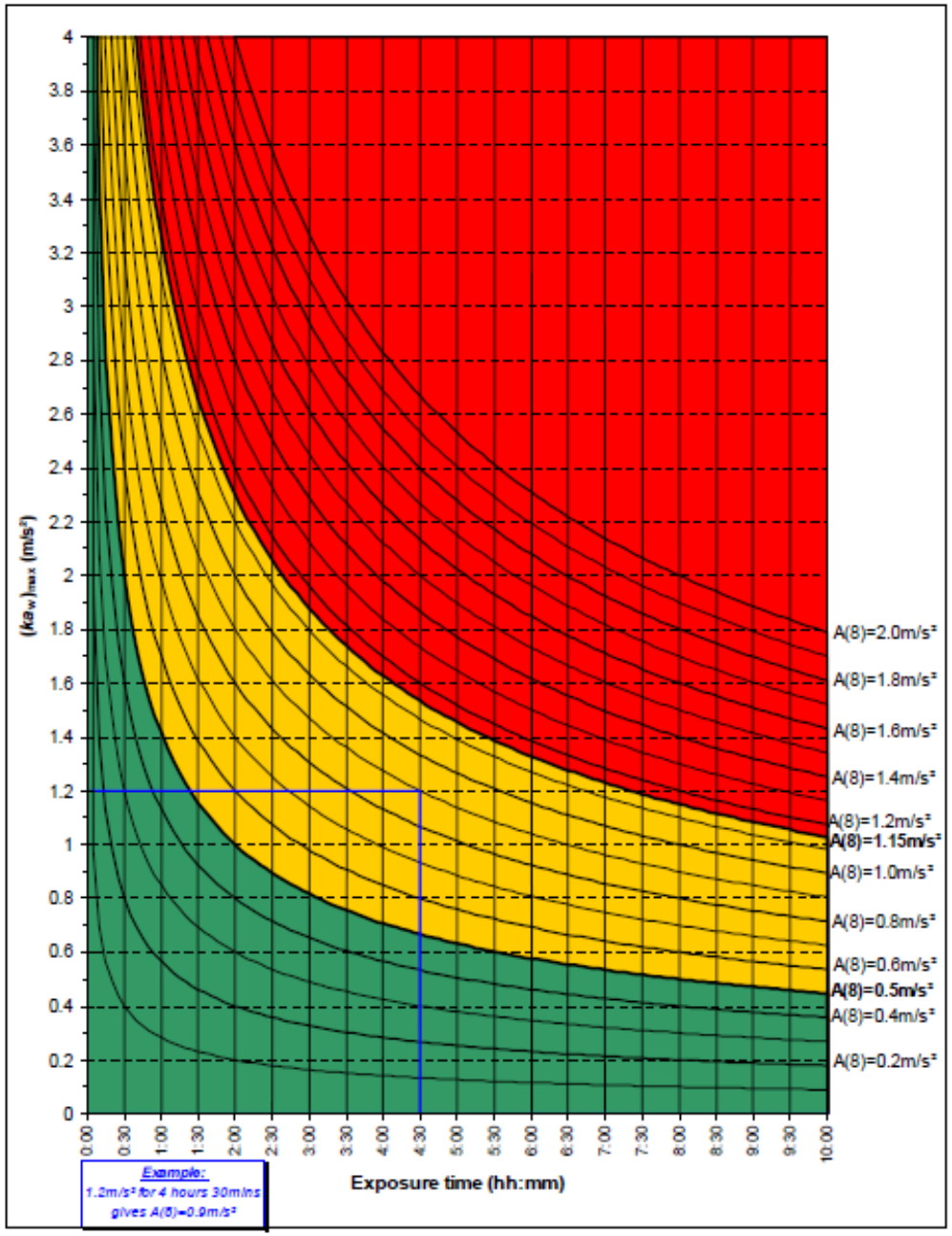


Figure D.1 Daily exposure graph

	Rms weighted acceleration (ms-2)	
Extremely uncomfortable	3.15	
	2.5	
	2.0	Very Uncomfortable
	1.6	
Uncomfortable	1.25	
	1.0	
	0.8	Fairly Uncomfortable
	0.63	
A little uncomfortable	0.5	Not uncomfortable
	0.4	
	0.315	
	0.25	

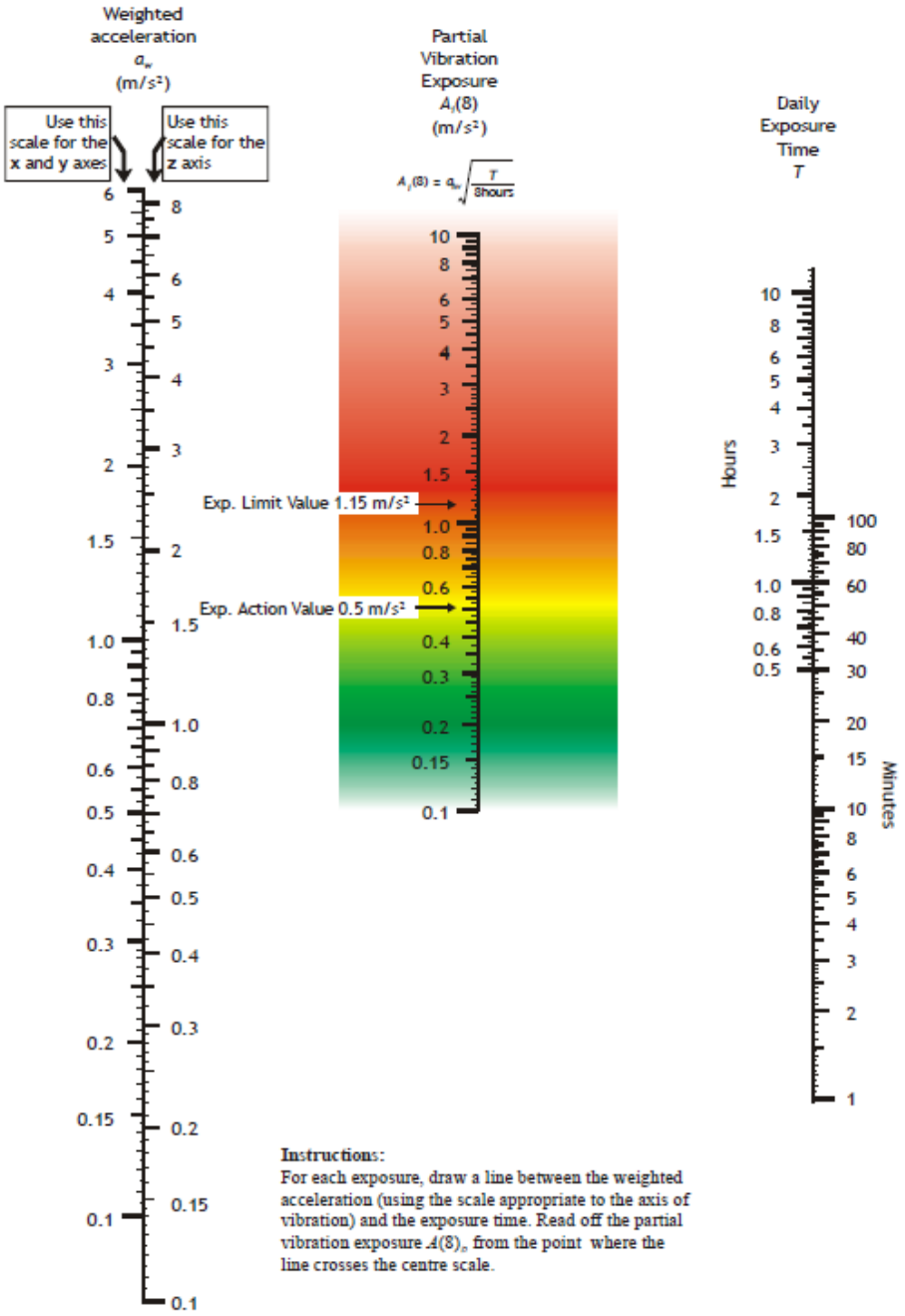


Figure D.2 Nomogram for A(8) values

Acceleration x k (m/s²)	15m	30m	1h	2h	3h	4h	5h	6h	8h	10h	12h
2	50	100	200	400	600	800	1000	1200	1600	2000	2400
1.9	45	90	180	360	540	720	905	1100	1450	1800	2150
1.8	41	81	160	325	485	650	810	970	1300	1600	1950
1.7	36	72	145	290	435	580	725	865	1150	1450	1750
1.6	32	64	130	255	385	510	640	770	1000	1300	1550
1.5	28	56	115	225	340	450	565	675	900	1150	1350
1.4	25	49	98	195	295	390	490	590	785	980	1200
1.3	21	42	85	170	255	340	425	505	675	845	1000
1.2	18	36	72	145	215	290	360	430	575	720	865
1.1	15	30	61	120	180	240	305	365	485	605	725
1	13	25	50	100	150	200	250	300	400	500	600
0.9	10	20	41	81	120	160	205	245	325	405	485
0.8	8	16	32	64	96	130	160	190	255	320	385
0.7	6	12	25	49	74	98	125	145	195	245	295
0.6	5	9	18	36	54	72	90	110	145	180	215
0.5	3	6	13	25	38	50	63	75	100	125	150
0.4	2	4	8	16	24	32	40	48	64	80	96
0.3	1	2	5	9	14	18	23	27	36	45	54
0.2	1	1	2	4	6	8	10	12	16	20	24

Daily Exposure time

Figure D.3 Exposure points table (rounded values)

At 8 m distance	Daily exposure value	Vibration dose value	Exposure points	VdB
X=0.56 Y=1.23 Z=1.60	X_{20}=0.321 Y_{20}=0.57 Action may be taken Z_{20}=0.51	X_{20}=0.676 Y_{20}=1.126 Z_{20}=1.06	145 Action to be taken	76 Action to be taken
	X_8=0.125 Y_8=0.275 Z_8=0.256	X_8=0.476 Y_8=1.045 Z_8=0.97		
At 3m distance				
X=0.98 Y=1.76 Z=2.21 extremely un comfort level	X_{20}=0.68 Y_{20}=0.80 Z_{20}=1.22	X_{20}=0.958 Y_{20}=1.582 Z_{20}=1.40	>400 Action must be taken	90 Action must be taken
	X_8=0.219 Y_8=0.394 Z_8=0.353	X_8=0.833 Y_8=1.496 ; near to limit value Z_8=1.326		


HYDERABAD
METRO RAIL
CSIR
CRRI

Land Use Category	GBV Impact Levels (VdB re 1 micro-inch /sec)			GBN Impact Levels (dB re 20 micro Pascals)		
	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
Category 1: Buildings where vibration would interfere with interior operations.	65 VdB[4]	65 VdB[4]	65 VdB[4]	N/A[4]	N/A[4]	N/A[4]
Category 2: Residences and buildings where people normally sleep.	72 VdB	75 VdB	80 VdB	35 dBA	38 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA

Notes:

1. "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2. "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
3. "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.
4. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration-sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.
5. Vibration-sensitive equipment is generally not sensitive to ground-borne noise.

Degree of Hearing Loss (WHO classification)

Who (1980) recommended the following classification on the basis of pure tone audiogram taking the average of the thresholds of hearing for frequencies of 500, 1000 and 2000 Hz with reference to ISO : R. 389-1970 (international calibration of audiometers).

Hearing loss and difficulty in hearing speech:

Hearing threshold in better ear (average of 500, 1000, 2000)	Degree of impairment (WHO classification)	Ability to understand speech
0-25	Not significant	No significant difficulty with faint speech.
26-40	Mild	Difficulty with faint speech.
41-55	Moderate	Frequent difficulty with normal speech.
56-70	Moderately sever	Frequent difficulty even with loud speech.
71-91	Severe	Can understand only shouted or amplified speech
above 91	Profound	Usually cannot understand even amplified speech.