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KATA PENGANTAR

Puji dan syukur kami panjatkan kehadirat Tuhan Yang Maha Esa karena berkat rahmatNya acara Konferensi Engineering Perhotelan III (KNEP-III) bisa terselenggara dengan sukses pada tanggal 6-7 Juli 2012 di Bali. KNEP-III ini diselenggarakan oleh jurusan Teknik Mesin Universitas Udayana dalam rangkaian kegiatan BKFT ke 47 dan Dies Natalis ke 50 Universitas Udayana, didukung oleh Asosiasi Chief Engineering Perhotelan Bali (ACE Bali) dan Badan Kerjasama Teknik Mesin (BKSTM) seluruh Indonesia.

KNEP III – 2012 ini merupakan forum untuk mendiskusikan dan mengkomunikasikan hasil-hasil penelitian terkini engineering dalam konteks perhotelan; dan topik-topik pendukung lain dalam lingkup Teknik Mesin. Disamping itu untuk meningkatkan kerja sama dengan organisasi profesi engineering perhotelan. Hasil yang dihapakan adalah meningkatnya mutu riset-riset yang akan dilakukan, meningkatnya daya kompetisi untuk mendapatkan grant penelitian, hubungan yang baik inter akademisi dan antara akademisi dengan praktisi.

Konferensi ini mengangkat beberapa Grup topik yang meliputi:

1. **Engineering perhotelan (EP)**: manajemen dan optimasi energi, manajemen air, AC dan Chiller, pompa, perpipaan, maintenance, elektrikal, sistem pengamanan, boiler, building service, bangunan hemat energi, dll.
2. **Konversi energi (KE)**: Perpindahan panas, mekanika fluida, termodinamika, sumber energi alternatif.
3. **Teknik dan manajemen manufaktur (TMM)**: proses permesinan, pembentukan, fabrikasi, sistem manufaktur, CAD-CAM, otomasi industri, sistem pengontrolan.
4. **Teknologi, pengujian dan pengembangan material (TPPM)**: Korosi, pengelasan, pengecoran, polimer dan komposit, analisis kegagalan.
5. **Bidang umum (BU)**: pendidikan Teknik Mesin, metode pengajaran, kebijakan energi, pengelolaan dampak lingkungan.

Adapun jumlah artikel yang dipresentasikan dalam konferensi ini adalah sebanyak 59 makalah yang mencakup ke lima topik di atas.

Kami mengucapkan terima kasih kepada Keynote speaker, para akademisi, peneliti, praktisi dan professional di bidang perhotelan yang telah mengirimkan artikelnya, serta semua pihak yang meliputi panitia pengarah, panitia pelaksana, scientific committee dan sponsor yang telah terlibat dan membantu terselenggaranya kegiatan ini dengan sukses.

Denpasar, Bali 6 Juli 2012

Ir. NPG. Suardana, MT., Ph.D.
Ketua Panitia

DAFTAR ISI

Prediction of sound reduction by the wall

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Abstract

This document explains prediction or estimation of sound reducing ability of several structure walls that would be use for an accommodation building or a container. There are eight groups (A, B, C, D, E, F, G, H type) of composite wall under consider and each wall consist of outside lining (ecoboard or sheet metal steel), light steel frame, insulation and inside lining (polywood, ecoboard, pvc linning or gypsum). Unwanted noise can travel through a building as mechanical vibrations of the structure or as airborne sound. Structural vibrations (e.g. the sound of footsteps in a neighboring room) can be reduced by minimizing the rigid paths connecting the source of sound to the walls of the room. To reduce the transmission of airborne sound it is necessary to consider the sound transmitting properties of the partition walls, and the areas of windows and other openings. There is a general rule called the **mass law**, which predicts the approximate sound reduction in a panel of mass per unit area m kg/m^2 at frequency f Hz. This implies that doubling the mass per unit area of a partition increases the transmission loss by 6 dB; in practice between 4 and 5 dB is more realistic. A double leaf wall can provide much higher sound insulation for a given total mass, as long as the two partitions are well isolated. To meet the design criteria where the sound level pressure of source is 75 dBA and the sound level pressure in the receiver room is 40 dBA then the transmission loss of the wall required is 35 dBA. The walls type that can be selected to reduce the sound level pressure of source at 75 dBA to 40 dBA are wall A, B, C, D, G, or H type.

Kata kunci: Insulation, sound reduction, wall

1. Introduction

This document explains prediction or estimation of sound reducing ability of several structure walls that would be use for an accommodation building or a container. There are eight groups of composite wall under consider and each wall consist of outside lining (ecoboard or sheet metal steel), light steel frame, insulation and inside lining (polywood, ecoboard, pvc linning or gypsum).

2. Abbreviation and units

M	: Mass per unit area, kg/m^2
SRI	: Sound Reduction Index, dB
SPL	: Sound Pressure Level, dB
STC	: Sound Transmission Class
TL	: Transmission Loss, dB
f	: Frequency, Hz

3. Composite wall

Table 1 below shows the wall type under consider. Each wall consists of outer liner (ecoboard or steel), light steel frame, insulation and inner liner (polywood, ecoboard or gypsum). The insulation density that is taken into calculation is 16, 32, 48 and 80 kg/m^3.

4. Noise reduction

Unwanted noise can travel through a building as mechanical vibrations of the structure or as airborne sound. Structural vibrations (e.g. the sound of footsteps in a neighboring room) can be reduced by minimizing the rigid paths connecting the source of sound to the walls of the room. To reduce the transmission of airborne sound it is necessary to consider the sound transmitting properties of the partition walls, and the areas of windows and other openings.

The sound reducing ability of a partition wall depends primarily on its mass per unit area. The **Sound Reduction Index** *SRI* or **Transmission Loss** *TL* of a partition measures the number of decibels lost when a sound of a given frequency is transmitted through the partition. The **Weighted Sound Reduction Index** *Rw* or **Sound Transmission Class** *STC* is a single number derived from transmission loss curves, giving a measure of the average sound reduction at mid frequencies.

Table 1. Wall structure

Material			Thickness [mm]	Density [kg/m3]	Remark
A	Ecoboard 12mm, Light steel, Insulation Rockwool 50mm, Ecoboard 9mm	Ecoboard	12	1000	
		Rockwool	50	16, 32,48,80	
		Ecoboard	9	1000	
B	Ecoboard 12mm, Light steel, Insulation Glasswool 50mm, Ecoboard 9mm	Ecoboard	12	1000	
		Glasswool	50	16, 32,48,80	
		Ecoboard	9	1000	
C	Steel 2mm, Light steel, Insulation Rockwool 50mm, Ecoboard 9mm	Steel	2	7800	for contaniner
		Rokcwool	50	16, 32,48,80	
		Ecoboard	9	1000	
D	Steel 2mm, Light steel, Insulation Glasswool 50mm, Ecoboard 9mm	Steel	2	7800	for contaniner
		Glasswool	50	16, 32,48,80	
		Ecoboard	9	1000	
E	Steel 0.35mm, Light steel, Insulation Rockwool or Glasswool 50mm, Gypsum 12mm	Steel	0.35	7800	
		Glasswool	50	16, 32,48,80	
		Gypsum	12	790	
F	Steel 0.35mm, Light steel, Insulation Rockwool or Glasswool 50mm, Ecoboard 9mm	Steel	0.35	7800	
		Glasswool	50	16, 32,48,80	
		Ecoboard	9	1000	
G	Ecoboard 12mm, Light steel, Insulation Rockwool or Glasswool 50mm, Gypsum 12mm	Ecoboard	12	1000	
		Glasswool	50	16, 32,48,80	
		Gypsum	12	790	
H	Steel 2mm, Light steel, Insulation Rockwool or Glasswool 50mm, Polywood 3.6mm, PVC linning 8mm	Ecoboard	12	1000	for contaniner
		Glasswool	50	16, 32,48,80	
		Polywood	3.6	600	
		PVC Linning	9	1400	

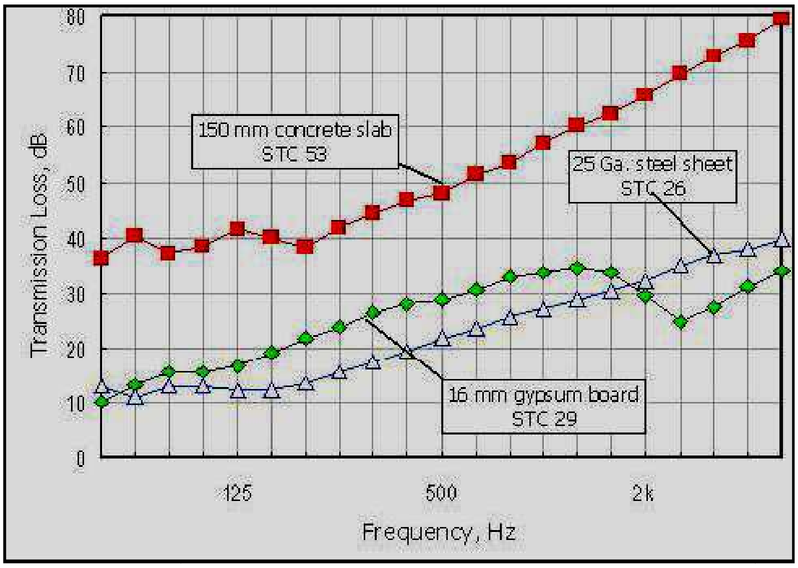

Figure 1. Transmission loss

There is a general rule called the **mass law**, which predicts the approximate sound reduction in a panel of mass per unit area *m* kg/m^2 at frequency *f* Hz:

$$SRI \approx 20\log(f \times m) - 47.5 \text{ dB} \quad (1)$$

This implies that doubling the mass per unit area of a partition increases the transmission loss by 6 dB; in practice between 4 and 5 dB is more realistic. A double leaf wall can provide much higher sound insulation for a given total mass, as long as the two partitions are well isolated.

4.1 Noise rating curves

An alternative approach to evaluating the disturbing effect of background noise is through the use of Noise Rating (NR) curves, based on unweighted sound level measurements in octave frequency bands.

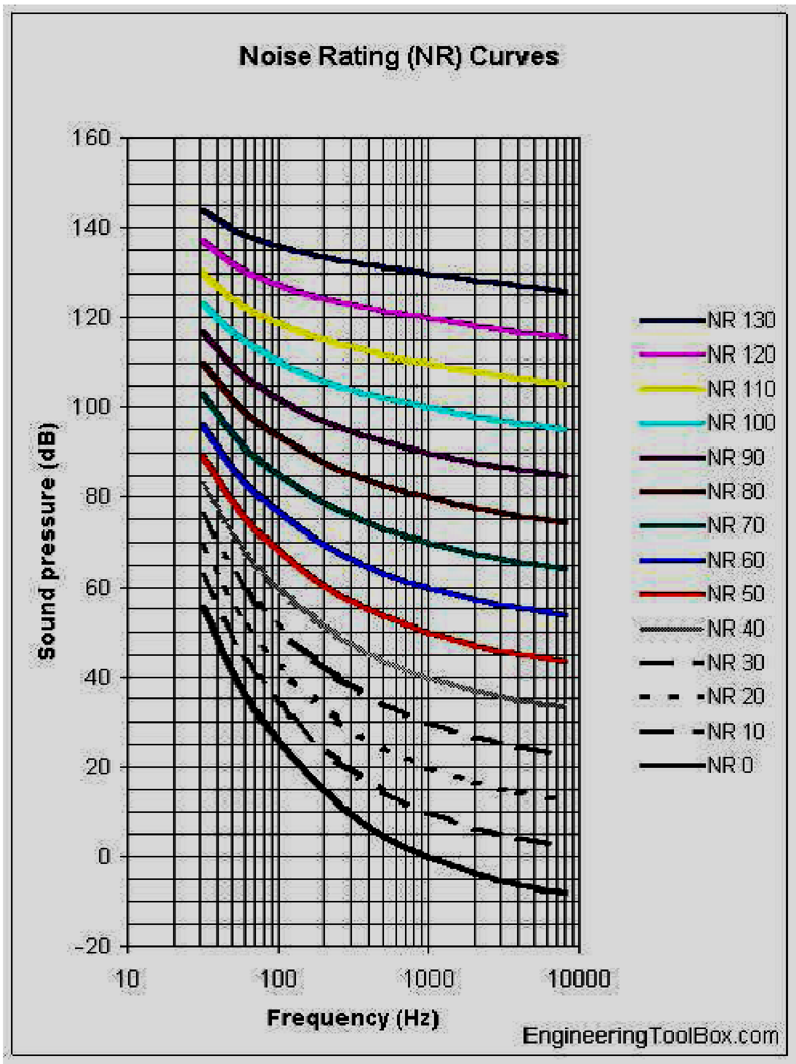

Figure 2. Noise Rating Curve

4.2 Noise Reduction by a Partition Wall

Noise can be isolated by a partition wall. The effectiveness depends on both the transmission loss of the wall and the acoustic properties of the receiving room. A noise source on one side of a partition wall produces a relatively high noise in a room on the other side of wall if there is only a small amount of absorption are present in the receiving room and source room. If larger amounts of absorption are present in the receiving room and source room, the sound level will be reduced.

The sound pressure level in a room with a receiver, separated by a partition wall from a room with a source a source, might be calculated from the following equation:

$$NR = TL - 10\log(S_w/A_r) \quad (2)$$
$$NR = Lp_s - Lp_r \quad (3)$$

Where NR = Noise reduction of partition wall, dB, TL = the transmission loss of partition wall, dB, S_w = the surface are of partition wall, m^2, A_r = the room absorption of receiver room, m^2 sabins. Lp_s = the sound pressure level in the source, dB, Lp_r = the sound pressure level in the receiver room. For the complete NR expected, a similar analysis must be carried out for all the octave band center frequency. To obtain the dBA levels from the octave band data, the correction factors below must be applied:

Table 2. "A" weighting factor

Octave Band Centre Frequency (Hz)	63	125	250	500	1000	2000	4000	8000
Correction Factor	-26	-16	-9	-3	0	1	1	-1

4.3 Additional of Noise Levels

A frequent calculation in noise control engineering involves the addition of noise levels. The formula for calculating the total or combined effect of two or more sound pressure levels is

$$L_T = 10\log(\sum 10^{(Li/10)}) \quad (4)$$

Where L_T = the total sound pressure level, dB or dBA, L_i = the individual sound pressure level, dB or dBA.

5. Transmission Loss Prediction

Table 3 below shows the result calculation of the Transmission Loss for the eight group of wall. It has been calculated using Mass Law formula (Eq. 1) where the frequency is the octave band center frequency from 63, 125, 250, 500, 1000, 2000, 4000 and 8000 Hz and the mass per unit area if found from the density and thickness of material used for the wall structure.

A material for attenuating sound is designed to redistrict the passage of an airborne acoustic disturbance from one side to the other. An attenuating material is nonporous, dense and relatively heavy; it usually has structural properties such as steel, lead, plywood, gypsum, wallboard, brick, concrete block and vinyl sheet loaded with lead.

It has been mentioned that the transmission loss of an attenuating material is increase with frequency. The following are the procedure to select the wall type wall to meet the design criteria:

a. First determine approximately how much noise reduction is required. This can be obtained by:

$$NR = Lp - Lc$$

Where, NR = the noise reduction required, dB or dBA
Lp = the sound pressure level at the hearing zone, dB or dBA
Lc = the design criteria level, dB or dBA.

It is often necessary to measure the octave band spectrum and the overall A-level at the position of interest.

In this project, Lp = 75 dBA and Lc = 40 dBA thus NR = 35 dBA

b. Determine the transmission loss of the partition wall required.

In this case, TL = NR = 35 dBA

c. To estimate in what octave band the maximum noise reduction is required.

In this case, the octave band selected is 125 Hz.

d. Select the wall type (A, B, D, E, F, G, or H) where the octave band is 125 Hz and the Transmission Loss is either equal or greater than 35 dBA.

6. Noise Control Criteria and Material Selection

In this project, the recommended design criteria for noise control inside building is 40 dBA, the octave band recommended design noise levels are given in Table 4.

Table 3. Prediction Transmission Loss, dB

WALL	Density	Frequency (Hz)								Material
		63	125	250	500	1000	2000	4000	8000	
A	D-16	6	24	42	60	78	96	114	132	Ecoboard 12mm, Light steel, Insulation
	D-32	12	30	48	66	84	102	120	138	Rockwool 50mm, Ecoboard 9mm
	D-48	15	33	51	69	87	105	123	141	
	D-80	20	38	56	74	92	110	128	146	
B	D-16	6	24	42	60	78	96	114	132	Ecoboard 12mm, Light steel, Insulation
	D-32	12	30	48	66	84	102	120	138	Glasswool 50mm, Ecoboard 9mm
	D-48	15	33	51	69	87	105	123	141	
	D-80	20	38	56	74	92	110	128	146	
C	D-16	8	26	44	62	80	98	116	134	Steel 2mm, Light steel, Insulation
	D-32	14	32	50	68	86	104	122	140	Rockwool 50mm, Ecoboard 9mm
	D-48	18	35	53	71	90	108	126	144	
	D-80	22	40	58	76	94	112	130	148	
D	D-16	8	26	44	62	80	98	116	134	Steel 2mm, Light steel, Insulation
	D-32	14	32	50	68	86	104	122	140	Glasswool 50mm, Ecoboard 9mm
	D-48	18	35	53	71	90	108	126	144	
	D-80	22	40	58	76	94	112	130	148	
E	D-16	-7	11	29	47	65	83	101	120	Steel 0.35mm, Light steel, Insulation
	D-32	-1	17	35	53	71	89	107	126	Rockwool or Glasswool 50mm, Gypsum
	D-48	3	21	39	57	75	93	111	129	12mm
	D-80	7	25	43	61	79	97	115	133	
F	D-16	-7	11	29	47	65	83	101	119	Steel 0.35mm, Light steel, Insulation
	D-32	-1	17	35	53	71	89	107	125	Rockwool or Glasswool 50mm, Ecoboard
	D-48	2	20	38	56	74	92	111	129	9mm
	D-80	7	25	43	61	79	97	115	133	
G	D-16	6	24	42	60	78	96	114	132	Ecoboard 12mm, Light steel, Insulation
	D-32	16	34	52	70	88	106	124	142	Rockwool or Glasswool 50mm, Gypsum
	D-48	19	37	55	73	91	109	127	145	12mm
	D-80	24	41	60	78	96	114	132	150	
H	D-16	6	29	53	78	102	126	150	174	Ecoboard 12mm, Light steel, Insulation
	D-32	12	35	60	84	108	132	156	180	Rockwool or Glasswool 50mm, Ecoboard
	D-48	15	39	63	87	111	135	159	183	9mm
	D-80	20	43	67	92	116	140	164	188	

Table 4. Recommended design noise control

Octave Band Centre Frequency (Hz)	63	125	250	500	1000	2000	4000	8000
Recommended, dB	35	40	37	35	35	35	35	35

Thus, the wall types that meet to the design criteria are:

WALL	Density	Frequency (Hz)								Material
		63	125	250	500	1000	2000	4000	8000	
A	D-80	20	38	56	74	92	110	128	146	Ecoboard 12mm, Light steel, Insulation Rockwool 50mm, Ecoboard 9mm
B	D-80	20	38	56	74	92	110	128	146	Ecoboard 12mm, Light steel, Insulation Glasswool 50mm, Ecoboard 9mm
C	D-48	18	35	53	71	90	108	126	144	Steel 2mm, Light steel, Insulation Rockwool
	D-80	22	40	58	76	94	112	130	148	50mm, Ecoboard 9mm
D	D-48	18	35	53	71	90	108	126	144	Steel 2mm, Light steel, Insulation Glasswool
	D-80	22	40	58	76	94	112	130	148	50mm, Ecoboard 9mm
G	D-48	19	37	55	73	91	109	127	145	Ecoboard 12mm, Light steel, Insulation
	D-80	24	41	60	78	96	114	132	150	Rockwool or Glasswool 50mm, Gypsum 12mm
H	D-32	12	35	60	84	108	132	156	180	Steel 2mm, Light steel, Insulation Rockwool or
	D-48	15	39	63	87	111	135	159	183	Glasswool 50mm, Polywood 3.6mm, PVC linning
	D-80	20	43	67	92	116	140	164	188	8mm

7. Summary

a. To meet the design criteria where the sound level pressure of source is 75 dBA and the sound level pressure in the receiver room is 40 dBA then the transmission loss of the wall required is 35 dBA.
b. The walls type that can be selected to reduce the sound level pressure of source at 75 dBA to 40 dBA are wall A, B, C, D, G, or H.

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