Eco-Friendly Acoustic Materials for Certified Separating Walls Between Adjacent Rooms

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Abstract

As Buildings Became With Multi Adjacent Functions And Activities, Checking The Acoustic Performance Of The Separating Walls Which Divide The Building Area Into Number Of Different Adjacent Rooms And Functions, Has Become A Must In Order To Enhance The Indoor Environmental Quality And Achieve The Acoustical Required Comfort. This Became So Clear Especially After The Remarkable Change Of Life Style And Time Periods We Spent In Different Places Due To Latest Circumstances And The Covid19 Epidemic, For Example, Time Spent In Residential Buildings To Stay And Work From Home. One Of The Most Effective Considerations During Designing And Checking The Separating Walls Is Determining The Sound Transmission Classification, Which Known As (Stc) Rating To Check The Room Separators Performance In The Term Of Sound Transmission Either Transmitted Through The Separator Itself Or Flanking From Joints Between The Separator Components And Other Attached Elements Such As Floor And Ceiling. The Study Is Looking After Eco-Friendly Materials By Encouraging The Use Of Recyclable, Earth Materials, Low Embodied Energy And Improved Economic Impact Materials With Determining The Factors That Enhance The Separating Walls Performance That Help To Qualify The Building To Earn "Leadership In Energy And Environmental Design (Leed) In (Usa), Or Green Pyramid Rating System (Gprs) In Egypt" Certifications, In A Way That Achieves The Sustainability Of Environmental And Economic Resources. Therefore, The Idea Of The Research Is To State An Analytical Study And Numerical Comparative Methodology Dealing With Aspects Of Building Science, Include How To Determine The Suitable (Stc) Ratings Values Of Separating Walls Between Adjacent Rooms According To The Rooms Activities And Adjacency Combination Functions To Come Up With A Set Of Results And Recommendations That Achieve The Objectives Of The Research Which Is To Qualify Buildings To Be Certified.

Keywords:

Separating Walls Design - Sound Transmission Classification (Stc) – (Leed) And (Gprs) Rating Systems – Eco-Friendly Materials.

ملخص البحث

عندما أصبحت المباني عبارة عن فراغات متجاورة ومتقاربة ومتعددة الوظائف والأنشطة , فكان لابد من التأكد من أداء الجدران الفاصلة والتي تقسم مساحة المبني إلي عدد من الفراغات المتجاورة والمختلفة الوظائف وذلك لتحسين جودة البيئة الداخلية للفراغات من خلال العزل الصوتي لتحقيق الخصوصية والتي أصبحت مطلوبة بشكل ملح بعد التغيير الملحوظ في نمط الحياة بسبب المستجدات الأخيرة ووباء كوفيد ١٩, مثل الإقامة والعمل من المنزل , فمن أهم الإعتبارات المؤثرة علي تصميم ومراجعة الجدران الفاصلة بين الفراغات المتجاورة هو

تحديد رتبة العزل الصـــوتي والتأكد من تحقيقه الحد الأدني المطلوب طبقا لطبيعة الفراغات المتجاورة في ما يخص إنتقال الصوت سواء من الجدار نفسه أو الإنتقال الجانبي من خلال الفواصل الأنشائية بين عناصر المبني وبعضـها مثل الفاصـل الإنشـائي بين الجدار مع السقف أو مع الأرضـيات , تهتم الدراسـة وتشـجع علي إسـتخدام المواد الصـديقة للبيئة والمعاد تدويرها ومواد التربة والمواد قليلة الأسـتهلاك للطاقة المدمجة والمواد التي لها أثر إقتصـــادي جيد والتي تســـاعد علي تأهيل المبني لكســـب نقاط في حالة تقييمة من أحد أليات تقييم المباني البيئية والمستدامة مثل نظام تقييم المباني المستدامة (الليد) بالولايات المتحدة الأمريكية أو نظام (الهرم الأخضـر) لتقييم المباني المسـتدامة بجمهورية مصـر العربية وذلك في إطار تحقييق الإسـتدامة البيئية والإقتصـادية للموارد , لذلك تكمن فكرة البحث مســتخدما المنهج التحليلي الرقمي المقارني بإســتخدام الأليات العلمية بين حســاب قيمة رتبة العزل الصوتي للجدار الفاصل أثناء التصميم وقياس قيمة رتبة العزل الصوتي للجدار الفاصل بإستخدام المعدات المتخصـصـة إسـتنادا إلي الأسـاليب البسـيطة المعتمدة عالميا للخروج بمجموعة النتائج والتوصـيات التي تحقق أهداف البحث والتي تساعد المعماري في إتخاذ القرارات خلال مرحلة تصميم وتنفيذ الجدار الفاصل بشكل يحقق الحد الأدني لرتبة العزل الصـوتي لضـمان تحقيق جودة البيئة الداخلية ويؤهل المبني لكسـب نقاط إضـافية أثناء التقييم سواء في تقييم البيئة الداخلية أو تقييم المواد المستخدمة.

الكلمات المفتاحية

تصميم الجدران الفاصلة - رتبة العزل الصوتي – نظم تقييم المباني البيئية والمستدامة - المواد الصديقة للبيئة

1. Introduction

According To The World Green Building Council, There Are Number Of Goals To Make A Building Eco-Friendly, **Goal 1:** Minimizing Energy Use In All Stages Of A Building’s Life-Cycle. **Goal 2:** Minimizing Water Use In Buildings. **Goal 3:** Minimizing Waste And Maximizing Reuse. **Goal 4:** Avoiding Materials And Chemicals That Create Harmful Or Toxic Emissions. **Goal 5:** Designing For Ears As Well As Eyes. Acoustics And Proper Sound Insulation Play Important Roles In Helping Peaceful Enjoyment Of A Building. **Goal 6:** Keeping Our Environment Green. **Goal 7:** Creating Resilient And Flexible Structures. **Goal 8:** Connecting Communities And People. **Goal 9:** Considering All Stages Of A Building's Life-Cycle [1][1]

In This Context, The Research Focuses On **Goal 5** That Certain The Importance Of Acoustical Performance With Pursuit To Achieving Other Goals By Achieving The Research Objectives That Help The Architect To Take The Best Decisions During The Design Phase In The Way To Make A Building More Sustainable And Eco-Friendly.

2. Research Objectives And Methodology

2.1 Research Objectives

The Research Main Objective Is To Achieve The Optimization Of Acoustical Performance To The Separators Between Adjacent Rooms Using Ecofriendly Solutions To Qualify Buildings To Be (Leed) Or (Gprs) Certified By Achieving The Following Secondary Objectives: 1- Identifying The Separating Walls As One Of The Building Layers. 2- Studying The Separating Walls Acoustics Performance Within Green Building Rating Systems. 3- Identifying The (Stc)

Rating Role In Buildings Design And Construction Stages. 4- Studying The Numerical Calculations To (Stc) Rating By Worksheets And By Software. 5- Determining The Total Surface Mass m_s (kg/m^2) To Common Traditional Building Materials. 6- Comparing Between (Stc) Ratings For Suggested Separating Walls Types To Support The Egyptian Code For Acoustics Works As An Important Reference For Architect And Supportive To (Gprs) Assessment. 7- Illustrate The Difference Between Field Measurements (Construction Stage) And Calculations (Design Stage) Of Airborne Sound Insulation Of Determine (Stc) Rating. 8- Studying The Ways To Make Buildings Eco-Friendly And Illustrate The Technical Actions To Optimizing The Acoustical Performance To Eco-Friendly And Certified Separators Between Adjacent Rooms.

2.2 Research Methodology

There Are Three Methods Used To Achieve The Research Objectives: **1- Descriptive Method**: Determining The Ways To Make A Building Eco-Friendly, Separating Walls Acoustics Performance Within Green Building Rating Systems As One Of The Building Layers And (Stc) Rating Role In Buildings Design And Construction Stages. **2- Analytical Method**: Analyze The Methods Of (Stc) Rating Numerical Calculations, And Analyze The Egyptian Code For Acoustics Works To Determine The Important Technical Actions Associated With Building Layers To Optimizing The Acoustical Performance To Eco-Friendly And Certified Room Separators. **3- Comparative Method:** Apply The (Stc) Rating Calculation Methods To Determine The Stc Ratings For Suggested Separating Walls Types Using Common And Eco-Friendly Materials, And Apply The (Stc) Rating Calculation Methods In A Comparative Analysis Experiment Between Field Measurements And Worksheet Calculations Of Airborne Sound Insulation Of Determined (Stc) Rating To Separating Wall Between Adjacent Guest Rooms

3. Separating Walls

Separating Walls Are The Walls Which Divide A Building Area Into Number Of Different Adjacent Rooms And Functions, It Should Be Opaque To Provide Sight Privacy And Able To Enhance The Indoor Environmental Quality By Enhancing The Sound Transmission Classification (Stc) According To Its Adjacency Combination Functions.

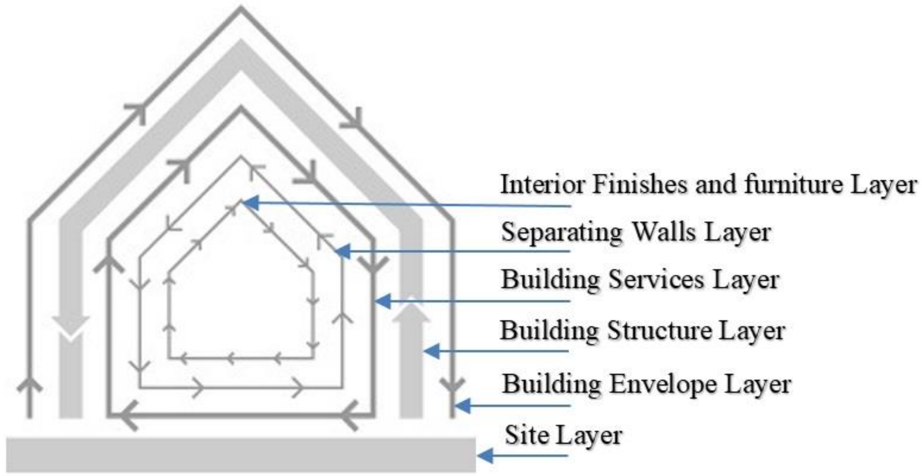


Fig.1. Building Layers, Author Based On [2] [2]

The Previous Fig.1 Illustrates Six Building Layers (Site, Envelope, Structure, Services, Separating Walls And Interior Finishes & Furniture). Separating Walls And Interior Finishes Are The First Layers That Affect Positively Or Negatively The Indoor Environment Quality.

4. Separating Walls Acoustics Performance Within Green Building Rating Systems

Initiatives Have Been Introduced To Consider The Acoustics Performance By Adding (Stc) Rating For Separating Walls Within The Indoor Environmental Quality (Eq) Assessment Element In Its Latest Leed 4.1 In (Usa) As Being Widely Used For All Types Of Buildings, Community And Home Projects In Usa [3] [3], And Latest Gprs In Egypt, These Rating Systems Began To Determine The Minimum Composite Sound Transmission Classifications (Stc) Ratings Required For The Separating Walls Between Adjacent Rooms According To Adjacency Combination Functions As Illustrated In The Following Table.1., To Provide Rooms And Workspaces That Promote Occupants Well-Being, Productivity And Communication Through Effective Acoustic Design. [4] [4]

Table.1. Minimum Composite Sound Transmission Classification Ratings Required For Separating Walls Between Adjacent Rooms According To Adjacency Combination Functions Mentioned In Leed 4.1 And Gprs, Author Based On [5] [6] [5-6]

S.	Adjacency Combinations Functions		Minimum Stc Rating Required	
			Leed	Gprs
1	Collaborative / Multi-Use	Hallway, Stairway	25	37
2	Private	Hallway, Stairway	35	48
3	Collaborative / Multi-Use	Collaborative / Multi-Use	40	45
4	Confidential	Hallway, Stairway	40	52
5	Collaborative / Multi-Use	Private	45	54
6	Private / Residential	Private / Residential	45	52
7	Private / Hotel	Private / Hotel	45	48
8	Retail	Retail	50	45
9	Collaborative / Multi-Use	Confidential	50	52
10	Private	Confidential	50	52
11	Confidential	Confidential	50	52
12	Conference Room	Conference Room	50	45
13	Mechanical Equipment Room	Hallway, Stairway	50	52
14	Mechanical Equipment Room	Occupied Area	60	52

5. Stc Rating Role In Buildings Design And Construction

To Qualify Buildings To Be Eco-Friendly Or (Leed/Gprs) Certified, It Is A Must To Determine The Values Of (Stc) Rating To The Separating Walls Between Adjacent Rooms Using Simple Methods (Worksheet Or Certified Software) At The Design Phase And Measure It For Checking After Construction To Compare It With The Minimum Composite (Stc) Ratings Required Which Are Illustrated In Table.1 And Mentioned In (Leed 4.1) And (Gprs) Rating Systems.

5.1 Numerical Calculation To (Stc) Using Worksheet

The Stc For The Separating Wall Between Adjacent Rooms May Be Calculated Using The Worksheet As Illustrated In The Following Fig.1, And Following Six Steps Based On Materials Thickness, Density And Weight According To (Astm E413-87) Report Or The American Society Of Testing And Materials And (Iso717) Or The International Standard Organization.

Step 1: Write The Transmission Loss ($\Delta\, L_{TL}$) For Each One-Third Octave Band Frequencies From 125 Through 4000 Hz In The Column Labelled ($\Delta\, L_{TL}$) On The Worksheet, Fig.2, After That Calculate It By The Following Formula Eq.1.

$$\Delta\, L_{TL} = 20 \text{ Log } (fM_T) - k_{TL} \qquad (1)$$

Where: f = Frequency (Hz)

M_T = Total Surface Mass ($\frac{kg}{m^2}$)

k_{TL} = Numerical Constant (47.3 dB in metric units) [7] [7]

Separating wall between adjacent rooms type: …………………						
f	$\Delta\, L_{TL}$	STC_{CA}	$\Delta\, L_{TL}$ *Adjusted*	*Trials* STC_w *and* Df		
				STC_{w1}	STC_{w2}	STC_{w3}
125		+16				
160		+13				
200		+10		Step 4		
250		+7				
315		+4				
400		+1				
500	Step 1&2	0	Step 3			
640		−1				
800		−2		Step 5		
1000		−3				
1250		−4				
1600		−4				
2000		−4				
2500		−4		Step 6		
3150		−4				
4000		−4				
			Sum of deficiencies			
			STC			

FIG.2. SOUND TRANSMISSION CLASSIFICATION (STC) WORKSHEET CALCULATION, AUTHOR BASED ON [8][8]

Where: $\Delta\, L_{TL}$ = Transmission Loss For Composite Separating Wall Between Adjacent Rooms (dB)

STC_{CA} = Numerical Constant Values Of Shifted Reference Contour Adjustment Given In International Standard Organization Iso717 In The 16 Test Frequency Bands (dB)

$\Delta\, L_{TL}$ Adjusted = Sound Transmission Loss Adjusted (dB)

STC_w = Sound Transmission Class Wishing To Test(dB), Must Compared With Minimum Stc Rating Required In Table.1.

Df = Deficiencies (dB)

Step 2: By The Following Eq. 2. , Calculate The Total Surface Mass M_T (kg/m^2) Of Composite Separating Wall Between Adjacent Rooms Materials. The Following Table.2 Listed The Common (General Use / Limited Use) Traditional Building Materials With Its Density And Classified In Blocks, Panels And Additive Materials.

$$M_T = m_{s1} + m_{s2} + \ldots + m_{sn} \quad = \frac{\rho 1 * Q1}{A1} + \frac{\rho 2 * Q2}{A2} + \ldots + \frac{\rho n * Qn}{An} \qquad (2)$$

Where:

m_s = Surface Mass Density Of Separating Wall Between Adjacent Wall Materials ($\frac{kg}{m^2}$)

ρ = Density Of Building Material ($\frac{kg}{m^3}$), Table (2) Listed The Density To Common Building Materials

Q = Quantity Of Material (m^3), From The Building Boq Sheet

A = Separating Wall Surface Area (m^2), Assumed Area Of $1m^2$

Table.2. Total Surface Mass m_s (kg/m^2) For Common (General Use / Limited Use) Traditional Building Materials And Its Density, Author Based On [9] [10] [9] [1] 0

	Materials		ρ	A	T	Q	W	m_s	Use
Blocks	1	Well Fired Bricks	1700	1	0.12	0.12	204	204	Gu
	2	Dense Cast Concrete	2100	1	0.1	0.1	210	210	Gu
	3	Lightweight Cast Concrete	1200	1	0.1	0.1	120	120	Gu
	4	Heavyweight Concrete Block	2300	1	0.1	0.1	230	230	Gu
	5	Medium Weight Concrete Block	1400	1	0.1	0.1	140	140	Gu
	6	Lightweight Concrete Block	600	1	0.1	0.1	60	60	Gu
	7	Stone (Structure-Slates)	2700	1	0.1	0.1	270	270	Lu
	8	Straw Bales	80	1	0.45	0.45	36	36	Lu
	9	Compressed Earth	2000	1	0.1	0.1	200	200	Lu
Panels	1	Recycled Steel	8000	1	0.002	0.002	16	16	Gu
	2	Recycled Aluminum	2700	1	0.002	0.002	5.4	5.4	Lu
	3	Concrete With Cement	2400	1	0.1	0.1	240	240	Gu
	4	Plaster Board	950	1	0.01	0.01	9	9	Gu
	5	Gypsum Boards	800	1	0.01	0.01	8	8	Gu
	6	Glass	2400	1	0.01	0.01	24	24	Gu
	7	Timber	650	1	0.01	0.01	1.1	1.1	Gu
Additive Material	1	Polystyrene Foamed	25	1	0.05	0.05	1.25	1.25	Lu
	2	Perlite Expanded	80	1	0.05	0.05	4	4	Lu
	3	Bitumen	1000	1	0.005	0.005	5	5	Lu
	4	Mineral Glass Wool	10	1	0.05	0.05	0.5	0.5	Lu
	5	Mineral Rock Wool	30	1	0.05	0.05	1.5	1.5	Lu
	6	Tile Hanging	1900	1	0.01	0.01	19	19	Gu
	7	Normal Mortar	1750	1	0.02	0.02	35	35	Gu
	8	Dense Plaster	1300	1	0.02	0.02	26	26	Gu
	9	Lightweight Plaster	600	1	0.02	0.02	12	12	Gu
	10	Air Cavity	1.18	1	0.05	0.05	0.059	0.059	Gu
Abbreviations: Gu: In General Use; Lu: In Limited Use									

Where: T = The Common Materials Thickness By (m)

W = The Weight Of Building Material (kg) With The Common Thickness Used (T)

Step 3: Add The Number In The (STC_{CA}) Column Algebraically To (ΔL_{TL}) And Write The Result In The (ΔL_{TL} Adjusted) Column By The Following Formula Eq.3.

ΔL_{TL} Adjusted $= \Delta L_{TL} + STC_{CA}$ (3)

Step 4: Determination Of Sound Transmission Class Wishing To Test (STC_w) By Taking Average To The Values Of (ΔL_{TL} Adjusted) At All Frequencies To Get The First Trial (Stc), Write This Trial (STC_{w1}) At The Top Of The First Column Under Trial (STC_w And Df).

Step 5: For Each Frequency Subtract (ΔL_{TL} Adjusted) From The Current Trial (STC_{w1}) By Formula Eq.4. To Determine The Deficiencies Values.

$Df = STC_w - \Delta L_{TL}$ Adjusted (4)

Step 6: Add Algebraically The Positive Deficiencies Numbers Only For The First TrialSTC_{w1}, And Write The Sum At The Bottom Of The Column And Check The Following:

- If The Sum Of The Deficiencies Is 32 Or Less, The Trial STC_{w1}Is The True Stc, And The Calculation Is Complete.
- If The Sum Of The Deficiencies Is Greater Than 32, Subtract One From The Current Trial STC_{w1}To Get A New Trial STC_{w2} And Repeat Until The Correct Stc Is Found. [8]

Note: Compare The (STC_{w1}) Value With The (Stc) Rating Required According To Adjacency Combinations Functions In Table.1. And Check The Following:

- If The Value Of (Stc) Calculated Is Near Or Equal The (Stc) Rating Required, The Trial Is True
- If The Value Of (Stc) Calculated Is Less Than The (Stc) Rating Required, Change The Separator Materials With More Thickness Or Higher Density.
- If The Value Of (Stc) Calculated Is Greater Than The (Stc) Rating Required, Change The Separator Materials With Less Thickness Or Lower Density.

The Following Fig.2. Show An Example To Stc Numerical Calculation For 10 Cm Structural Stone, Block Density 2700kg/m^3 Using Worksheet.
It's Possible To Repeat The Same Previous Procedures Concept In Any Common, Traditional

Separator type: 10 cm structural stone, block density 2700 kg/m^3						
f	ΔL_{TL}	STC_{CA}	ΔL_{TL} *Adjusted*	*Trials* STC_w *and* Df		
				60	59	STC_{w3}
125	43.3	+16	59.3	0.7	0	
160	45.4	+13	58.4	1.6	0.6	
200	47.3	+10	57.3	2.7	1.7	
250	49.3	+7	56.3	3.7	2.7	Correct STC value, its Df less than 32
315	51.3	+4	55.3	4.7	3.7	
400	53.4	+1	54.4	5.6	4.6	
500	55.3	0	55.3	4.7	3.7	
640	57.5	−1	56.5	3.5	2.5	
800	59.4	−2	57.4	2.6	1.6	
1000	61.3	−3	58.3	1.7	0.7	
1250	63.3	−4	59.3	0.7	0	
1600	65.4	−4	61.4	0	0	
2000	67.3	−4	63.3	0	0	
2500	69.3	−4	65.3	0	0	
3150	71.3	−4	67.3	0	0	
4000	73.4	−4	69.4	0	0	
			Sum of deficiencies	32.3>32	21.8<32	
			STC	59		

From Eq. 1. & Eq. 2.
From Eq. 3.
Average of ΔL_{TL} *Adjusted* values
Greater than 32
Less than 32
From Eq. 4.

Fig.3. Example To Stc Numerical Calculation Using Worksheet For Structural Stone Separating Wall Between Two Adjacent Rooms, Author

And Eco-Friendly Building Materials Types Used In Separating Walls Between Adjacent Rooms.

5.2 Determination Of (Stc) Rating Using Insul Software

Nowadays, Software's Can Be Used To Quickly Calculate And Evaluate Materials Or To Checking The Effects Of Changes On Existing Buildings. Insul Is A Software For Determination Of Sound Transmission Classification Stc Of Walls, Floors, Roofs, Ceilings And Windows, Developed By Marshall Day Acoustics. The Software Based On Analytical Calculations According To Astm Or Iso That Only Need Simple Input Data For The Design And Can Predict Transmission Loss For: 1- Single, Double And Triple Panels With Many Types Of Connections. 2- Sandwich And Corrugated Panels. 3 - Slabs With Or Without Suspended Ceiling. 4- Slabs With Floating Floor. 8- Facades. 5- Single, Double And Triple Glazing Windows. 6- Porous Absorbers. [11] [1] 1

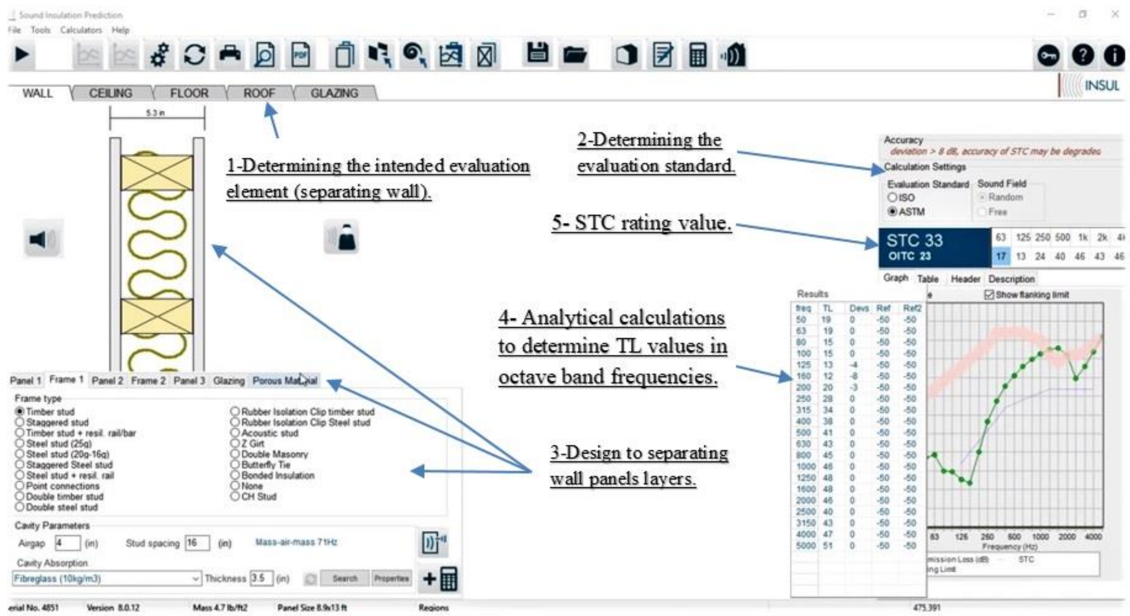


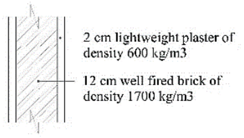
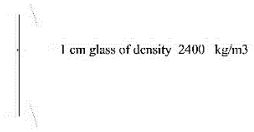
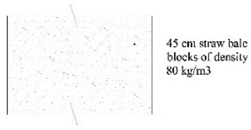
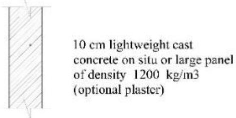
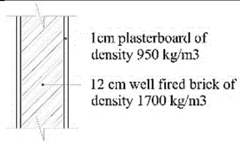
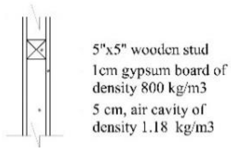
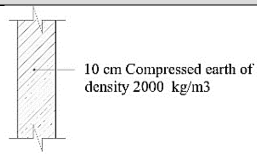
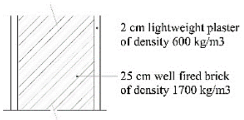
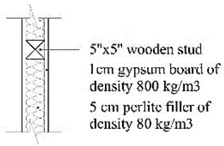
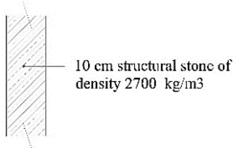
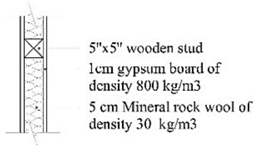
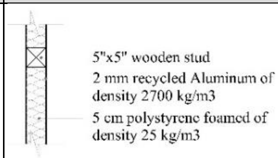
Fig.2. Interface Of Insul Software Illustrate The Stc Numerical Analytical Calculations Steps According To Astm And Iso Standards. [12] [1] [2]

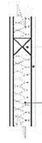
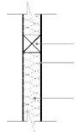
5.3 (Stc) Rating For Separating Walls Types

The Five Main Patterns Illustrated In The Following Table.3 Comes As An Extension To The Separating Walls Types Mentioned On The Egyptian Code For Acoustics And Noise Control, These Patterns Are Illustrated With Their Main Properties That Affect Their Performance Such As (Stc) Rating Values (Calculated By Previous Methods), Deficiencies, Weight And Thickness Were Chosen Depending On Their Composition On The Local Traditional Materials And Commonly Used In The Architectural Field In Egypt, Taking Into Account The Eco-Friendly And Economical Side To Achieve Sustainability, And Was Proposed Based On The Difference In The Following:

a) Nature Of Materials Sources Whether Natural, Fabricated Or Mixed Materials.
b) Density Of Materials.
c) Thickness Of Each Type.
d) Method Of Installation Whether Mechanical Or Non-Mechanical.
e) New, Recyclable And Eco-Friendly Materials.

Table.3. Types Of Separating Walls Between Adjacent Rooms Using Different Materials, With Type Description (Td), Cross Sections, (STC) Rating Calculated Values, Deficiencies (Df), Material Weight (W) And Type Thickness (T), Author.

	Masonry Type (Mt)	Panels Type (Pt.)	Ecological Type (Et)	Concrete Type (Ct)
	Mt.1. (Clay Half Bricks)	Pt. 1. (Glazing Panel)	Et. 1. (Strawbale)	Ct. 1. (Concrete Panel)
Td				
STC	58 dB	38 dB	41 dB	52 dB
Df	26.4 dB/32	29.2 dB/32	23.6 dB/32	29.5 dB/32
W	228 kg/m^2	24 kg/m^2	36 kg/m^2	120 kg/m^2
T	16 cm	1 cm	45 cm	10 cm
	Mt.2. (Clay Half Bricks)	Pt. 2. (Cgb Panel)	Et. 2. (Rammed Earth)	
Td				
STC	58 dB	34 dB	56 dB	
Df	28.6 dB/32	23.7 dB/32	25 dB/32	
W	223 kg/m^2	16 kg/m^2	200 kg/m^2	
T	14 cm	7 cm	10 cm	
	Mt.3. (Clay One Bricks)	Pt. 3. (Igb Panel)		
Td				
STC	63 dB	36 dB		
Df	24.4 dB/32	24.7 dB/32		
W	449 kg/m^2	20 kg/m^2		
T	29 cm	7 cm		
	Mt.4. (Structural Stone)	Pt. 4. (Igb Panel)	Recyclable Type (Rt) Rt. 1. (Aluminyom Panel)	
Td				
STC	59 dB	35 dB	32 dB	

Df	21.8 dB/32	26.4 dB/32	29.1 dB/32	
W	270 kg/m^2	18 kg/m^2	12 kg/m^2	
T	10 cm	7 cm	5.04 cm	
	Mt.5. (Concrete Bricks)	Pt. 5. (Sip Panel)	Rt. 1. (Steel Panel)	
Td				
STC	49 dB	33 dB	41 dB	
Df	30.5 dB/32	24.1 dB/32	31.1 dB/32	
W	84 kg/m^2	15 kg/m^2	34 kg/m^2	
T	10 cm	7 cm	5.04 cm	

Using Comparative Methodology, The Following Fig. 4, Illustrated A Comparison Between The Previous Separating Wall Types In The Previous Table. 3., As A Start To Establish A Product Category System (Pcs) For Building Materials, That Illustrate A Set Of Parallel Technical Integrated Information To Building Material (Product) To Help The Architect To Select The Suitable Material For Each Building Elements.

It Was Some Of Indicators And Observations From Separating Walls Between Adjacent Rooms Types, The Comparison Illustrated In Fig.4 As The Following:

a) Using Plasterboard In Masonry Type (2) With Mechanical Installation, It Reduced The Thickness Of Separating Wall Between Adjacent Spaces By 2 Cm, Comparing With Plaster Mortar In Masonry Type (1), Which Has A Good Impact On Achieving An Economical Area To Room, With The Same (Stc) Rating (58) Decibel.

b) Increasing Separator Mass Or Doubling Thickness As Masonry Type (3) Is Not An Efficient Parameter To Enhance The (Stc) Rating Comparing With Masonry Type (1), So, This Technique Must Be Carried Out Keeping In Mind The Wall Weight And Its Cost To Achieve The Sustainability Of Environmental And Economic Resources.

c) Using Structural Stone In Masonry Type (4) Gave Approximately The Same (Stc) Rating As Masonry Type (1) And (2), But Reduced The Thickness Of Separating Wall By 6 Cm, And Reduced The Materials Consumed In Wall Finishing Layers.

d) Masonry Type (5) Achieved The Best Weight Compared With All Masonry Types, Despite The Low Value Of (Stc), But It Is Suitable For Some Adjacency Combinations, Such As Private With Multiuse Combinations Functions.

e) Recyclable Type Reduced The Embodied Energy, Embodied Carbon And Water Consumption, And May Be Increase The (Stc) Rating By Increasing The Density Of The Panels' Filler, Such As Polystyrene Foamed And Its Thickness.

f) The Advantage Of Concrete Type (1), (On Site Light Weight Concrete), Is Low Weight With High (Stc) Rating, Comparing With Masonry Types And Can Increase Its Performance By Using Insulated Concrete Forms System.

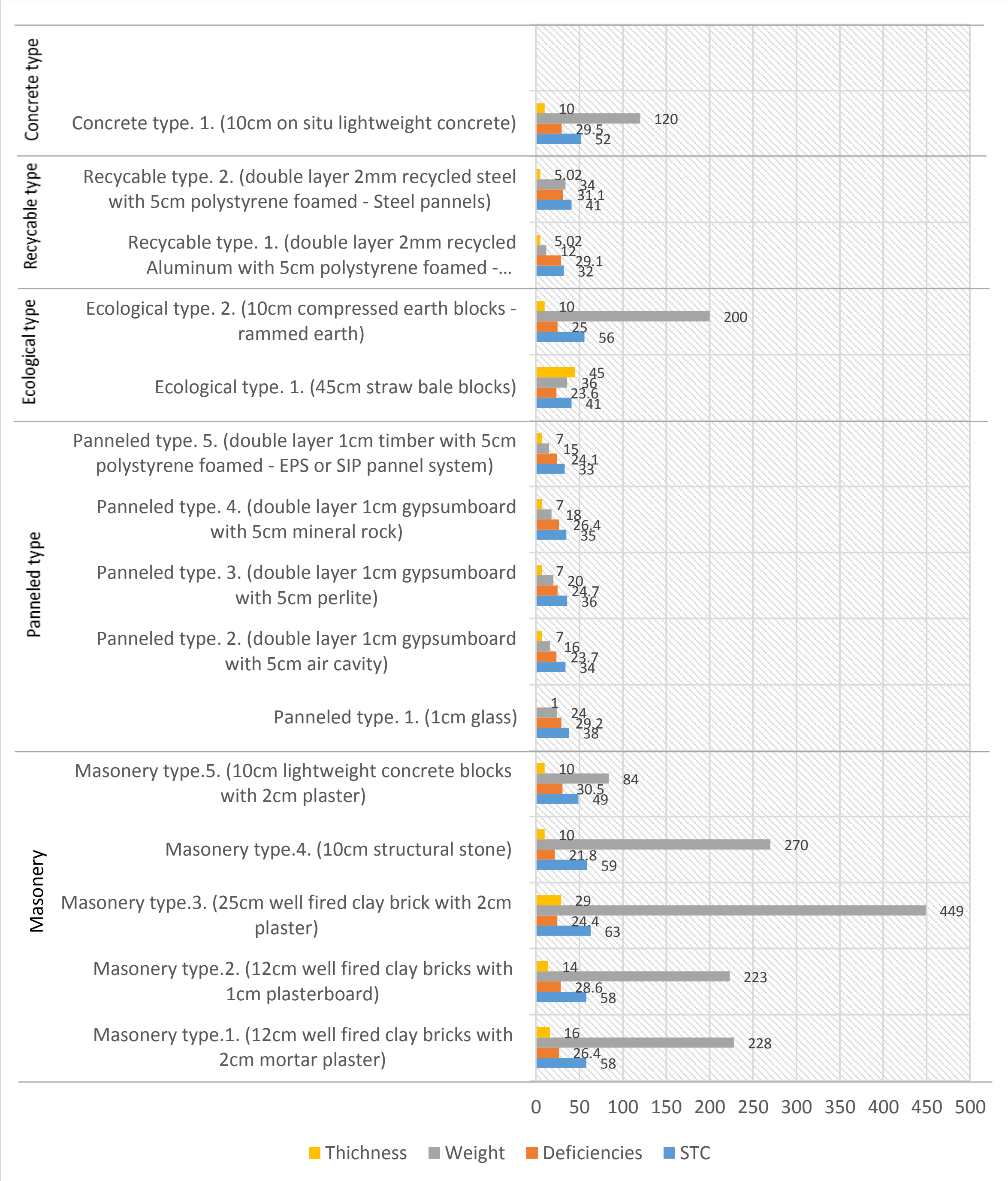
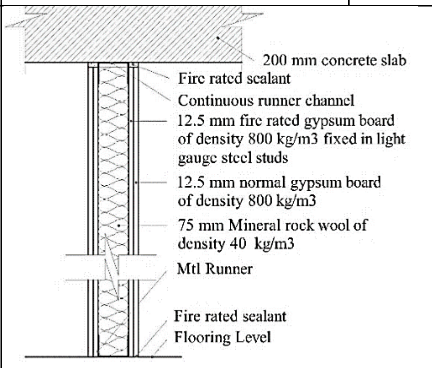
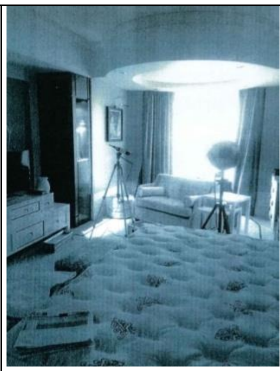


Fig.4. Comparison Between The Separating Walls Types Between Adjacent Rooms Using Different Materials As A Nucleus To (Pcs), Author

6. Difference Between (Stc) Rating Values Calculated And Field Measurment: Case Study

The Case Study Is A Comparative Analysis Experiment Between Field Measurements And Calculations (Worksheet/Software) Of Airborne Sound Insulation Of Determined (Stc) Rating To Separating Wall Between Adjacent Guest Rooms At Nile Cornish Towers Ncp, As Illustrated In The Following Table. 4.

Table.4. Comparative Analysis Between (Stc) Rating Field Measurements And Calculations To Separating Wall Between Adjacent Guest Rooms At Nile Cornish Towers Ncp, Author Based On [13] [1] [3]

Location	Cairo, Egypt	**Designer**	Mga, Usa
Building Type	Hotel	**Consultant**	Ecg, Egypt
Area	8000 M2	**Contractor**	Ccc, Egypt
Rooms Location	Rooms No. 1207&1209 – Tower 2 – Level 12		
Measurements By	Housing And Building National Research Center, Cairo, Egypt – Website: Www.Hbrc.Edu.Eg – Email: Hbrc@Hbrc.Edu.Eg – Fax: 02-33351564 – P. O. Box: 1770 Cairo, Egypt.		
Test Date	July 2018	**Form No.**	Qmp-1018-002-001
Report No.	Bpel-A-Tl2-88-/018	**Sample Code**	Bpel-A-Tl2-88
Section Drawing For The Tested Gypsum Board Separating Wall Between Two Adjacent Guest Rooms		**Picture Shows The Measurement Instruments In The Tested Guest Room**	
Equipment Used For Transmission Loss Tl Test	Ommi Directional Loudspeaker – Power Amplifier – Sound Level Calibrator – Rotating Microphone Boom – Kimo – Sound Level Meter – Preamplifier - Microphone		

	f	**Calculations (Worksheet/Software)**				**Measurements**	
		Δ L_{TL}	**STC_{CA}**	**Δ L_{TL} Adjusted**	**Df**	**Δ L_{TL} Tested**	**Df**
Δ L_{TL} Adjusted Calculations And Δ L_{TL} Tested For Checking Measurements Numerical Results In Octave Band Frequencies	**125**	26.6	+16	42.6	0.4	25.1	0.4
	160	28.8	+13	41.8	1.2	30.6	1.2
	200	30.7	+10	40.7	2.3	25.4	2.3
	250	32.6	+7	39.6	3.4	32.1	3.4
	315	34.6	+4	38.6	4.4	34.3	4.4
	400	36.7	+1	37.7	5.3	38.4	5.3
	500	38.6	0	38.6	4.4	39.3	4.4
	640	40.8	−1	39.8	3.2	39.7	3.2
	800	42.7	−2	40.7	2.3	42	2.3
	1000	44.7	−3	41.7	1.3	46.5	1.3
	1250	46.6	−4	42.6	0.4	49.6	0.4
	1600	48.8	−4	44.8	0	48.3	0
	2000	50.7	−4	46.7	0	45.8	0
	2500	52.6	−4	48.6	0	47.8	0
	3150	54.6	−4	50.6	0	49.6	0
	4000	56.7	−4	52.7	0	47.5	0

<table>
<tr><td></td><td>
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<tr><td>Stc & Sum Of Deficiencies</td><td>43</td><td>28.6</td><td>35</td><td>27.5</td></tr>
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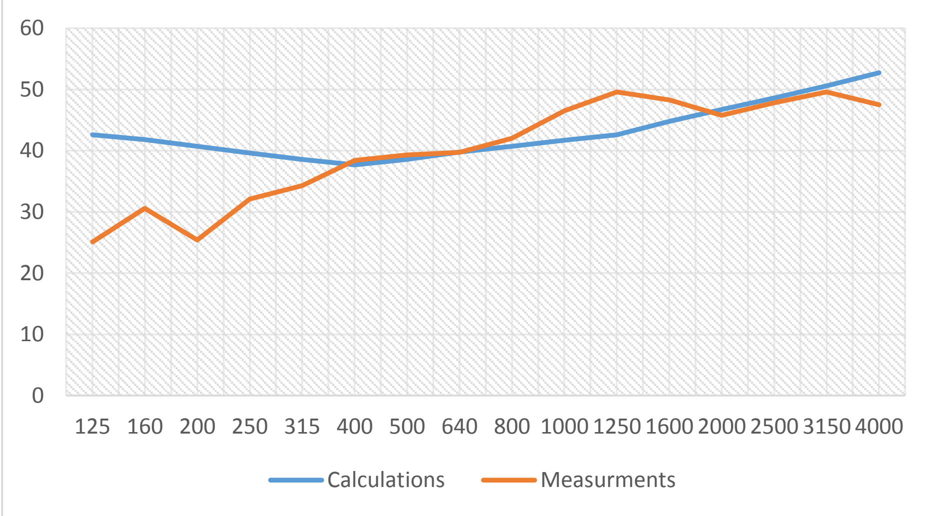
</td></tr>
<tr><td>Comparatives Graph Results In Octave Band Frequencies</td><td>


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</table>

The Main Result Of This Experiment, That The Stc Tested Using Instruments Is Less Than The Stc Calculated By 8 Db (Approximately 20%) Difference Because Of Flanking Transmission From Building Elements Connections, In Addition To, That Both Values Are Less Than The (Stc) Rating Required According To Adjacently Combinations Functions In Table.1 , So, The Designer Must Consider That During Design, And The Executive Engineer Must Consider The Flanking That Occur During Construction To Achieve The Minimum (Stc) Rating Required By Some Acoustical Considerations And Architectural Actions To Achieve The Optimizing Of Certified Acoustical Eco-Friendly Separators Between Rooms.

7. Optimizing Of Certified Acoustical Eco-Friendly Separators Between Adjacent Rooms

To Achieve The Optimization Of Certified Eco-Friendly Separating Walls Between Adjacent Rooms Not From Executive Technical And Architectural Action Consideration Illustrated In The Following Table.5 Only, But The Materials Used Must Offer An Environmental Advantages To Improve The Separating Walls (Stc) Rating And Respect The Following Principles Of Eco-Friendly Materials And Resources Mentioned In (Leed) And (Gprs) To Qualify Building To Gain More Credits During Assessment: [5] - [14][1] 4

a. Use The Environmental Product Declaration (Epd) Certified Materials For Which Life Cycle Information Is Available And Have A Good Environmentally, Economically And Socially Life Cycle Impact.

b. Recommend Flexible Materials In Design And Execution Phases To The Reduction Of Total Construction, Retrofitting And Demolition Waste.

c. Use The Reused Or Recyclable Materials To Reduce The Embodied Energy And Embodied Carbon.

Table.5. Architectural Action To Optimize The Room Separators, Author Based On [15][1]

S.	Building Layer	Action
1	Site Layer	Cluster Urban Planning Options Are Recommended, Because It Enable The Buildings With Open Areas And Landscape To Serve As A Noise Barrier.
2	Envelope Layer	1- Break The Flanking Paths Through The Curtain Wall Sections (Mullions). 2- Specify Fixed Insulation Glass Units Figus With Minimum Spacing 10 Mm Between The Two Different Thickness Glass Panels For Thick Gas Such As Sodium Hexafluoride To Reduce The Coincidence Effect. 3- Although It's Doubling Cost, Secondary Glazing As Illustrated In Fig. 7, Is An Effective Way Of Improving Noise Reduction In Case Of Hinged Or Sliding Windows.
3	Structure Layer	Isolate The Building's Equipment And Services From Building's Structure Is Necessary To Avoid The Impact/Airborne Noise From Travelling Through The Building's Elements.
4	Services Layer	1- Balancing The Machines For Lower Vibrations Using Certified Rubber/Cork/Fibre Pads Resilient. 2- Place The Rotating Equipment In The Basement Floor. 3- Equipment & Mechanical Systems Distribution Planning And Not To Place Any Equipment Next To The Windows. 4- Air Conditioning Ducts Must Be Flexible, Interior Cushioning And Sticky Exterior Paint. 5- Avoid Back To Back Electrical Outlets. 6- Bathrooms Are Assembled In One Place And Back To Back. 7- Use Of Flexible Water Supply/Drainage Pipes With Resilient Fixings And Reducing Bends In Drain Pipes As Possible.
5	Separating Walls Layer	1- Design The Wall With Full Ceiling Height (Above The Ceiling/Below The Raised Floor) With Good Room Distribution. 2- Add A Parallel Wall When The Main Wall Is A Part Of Building Structure. 3- Doors Should Be Solid With Gaskets, Spaced, Oriented And Filled Joints With High Stc Flexible Material. 4- Secondary Doors May Be Effective Way With 30 Cm Minimum Space Between Primary And Secondary Doors.
6	Interior Finishes & Furniture Layer	1- If Possible, Avoid Placing Kitchen Cupboards/Cabinets On Party Walls, And Use Soft Rubber Strips On All Cupboard Drawers. 2- For The Ceiling Finish, The Common Acoustic Treatment In Ceiling Finishes Is 60x60 Acoustic Ceiling Tiles. 3- Tightening The Joints Between The Floor And The Walls By Toe Base. 4- Finishing Walls With Materials That Improve The Acoustical Performance Such As Acoustic Foam Panels, Silent Pictures And Art Diffusor. 5- Using Underlayment Acoustic Treatment (Quiet Floor) Within Concrete Flooring System.

8. Conclusion And Recommendation

The Context In Eco-Friendly Acoustical Materials For Certified Separating Walls Between Adjacent Rooms Deals With Aspects Of Building Science And Produce A Set Of Results And Recommendations As The Following:

- Add A Factor Of Safety To Minimum (Stc) Rating Values Required To Adjacency Combination Functions Mentioned In (Leed) And (Gprs) Rating Systems Because Of Flanking Occurred During Construction Phase.
- Using The Executive Acoustical Technical Actions Help To Reduce The Numerical Gab Between The Calculation And Field Measurement Of The (Stc) Rating.
- The Sound Transmission Loss (Stl) Value Approximately Equal At Frequency 500hz Whether In Calculations Or Field Measurements, That Means The Disturbance In (Stc) Rating Occurred In Lower And Greater Frequencies, So The Calculations And Field Measurements Must Be In Each Of The Sixteen Octave Frequency Bands.
- Although, The Research Encourages The Use Of Ecological Materials, They Are Either Thick Like Straw Bale Or Heavy Weight Like Rammed Earth And Give The Same Efficiency As Other Separating Wall Types, So Researches Must Work On How To Develop Earth Materials To Be Of Lower Thickness And Less Weight With High Acoustic Performance.
- The Economic Area Must Be Taken Into Account When Choosing Any Type From The Suggested Separating Walls Type, Because The Greater The Thickness Of The Separator The More Negative Effect On The Room Area, So The Panel Types Are Distinguished By Their Small Thickness And Low Weight Compared To Other Masonry Types.
- The (Stc) Rating Can Be Increased By Raising The Density Of The Filler Used In Panels' Types, Such As Polystyrene And Mineral Rocks, Not Increasing The Thickness.
- The Research Encourages And Recommend The Use Of Recycled And Reused Materials And Systems To Improve The (Stc) Rating, Such As The Egg Carton.
- Research In Making A Products' Category System (Pcs) Has Become A Must In Order To Provide A Parallel Information Associated For Materials To Facilitate The Process Of Selecting The Suitable Certified And Eco-Friendly Materials.
- Bim Systems Should Be Used To Facilitate The Process Of Developing Alternatives To Choose Materials And Systems For The Separating Walls Design And Execution To Ensure That The Best Selection That Is Merging Between The Economic And Environmental Dimensions.
- The Life Cycle Information Availability Of Acoustical Material Must Be Considered And Certified By Environmental Product Declaration Epd.

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