INNOVATION
ENGINE FOR GROWTH

Minerals for Noise Reduction

SPE Automotive TPO Conference 2018

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IMERYS Performance Additives
North America

IMERYS

Outline

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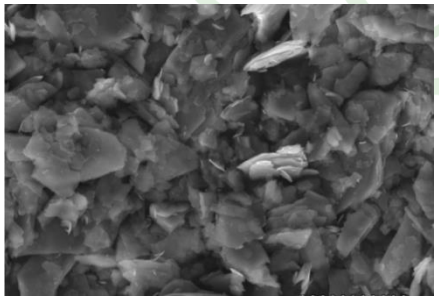
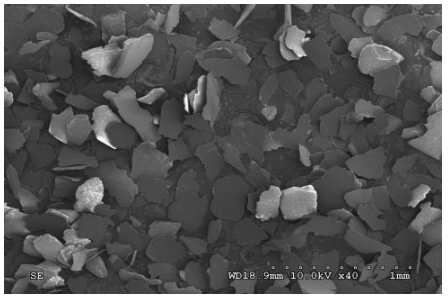
- Objectives/Approach
- Noise Reduction Modes & Test Results
  - DMA
  - CenterPoint
  - STL
- Mechanicals
- In-house testing
- Conclusions

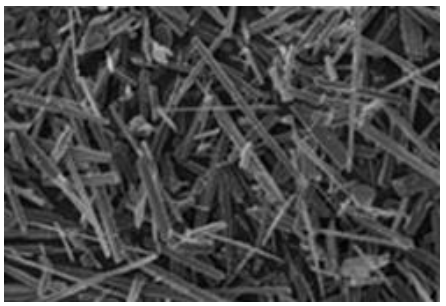
Talc



Mica



Wollastonite



IMERYS - Leading Global Supplier of Performance Minerals

€4.6 billion
Revenue*

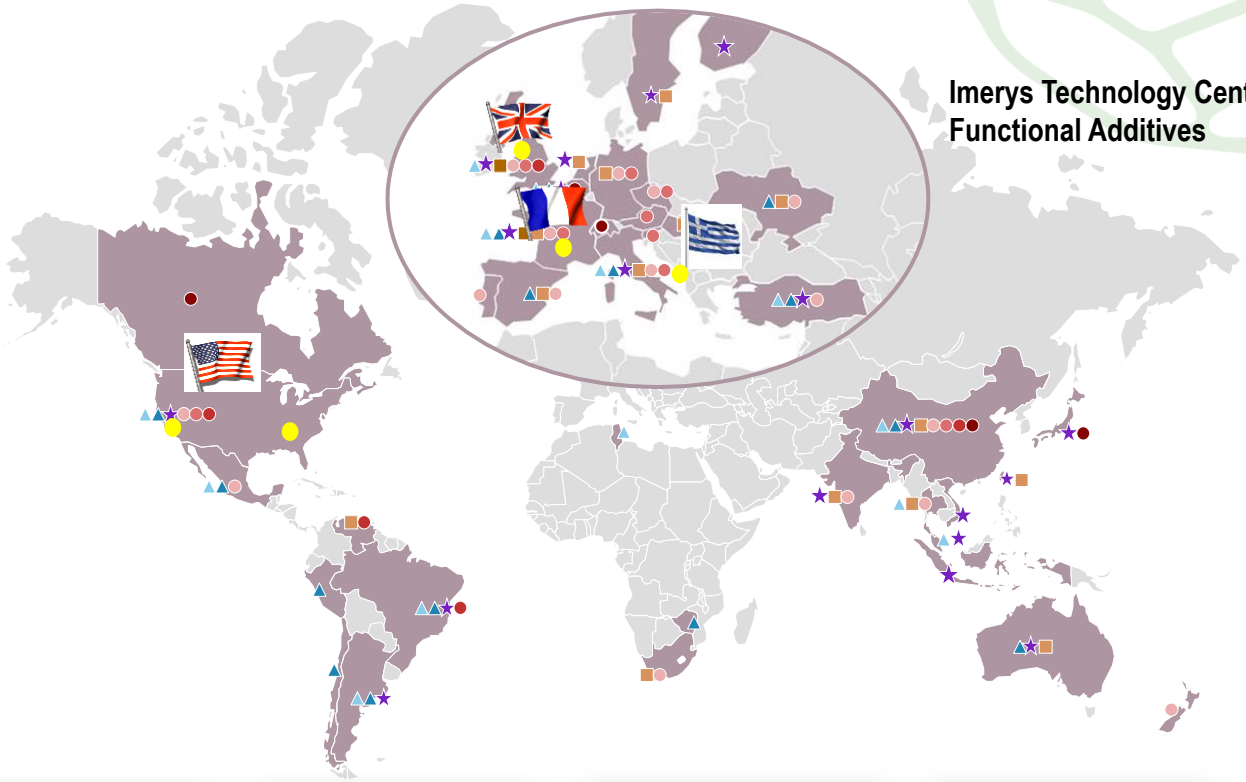
+50
Countries

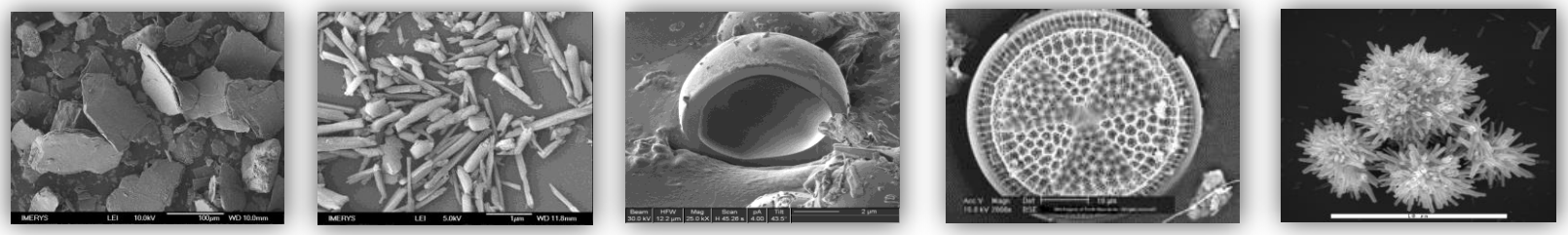
18,300
Employees

+ 90
New products in 2016

270
Operating sites

#1 or #2
On most of our markets





Over +30 Functional Minerals

IMERYS

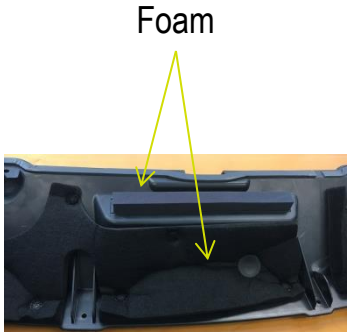
Background

Vehicle Interior Noise

- Noise: Environment pollution
- Car noise: Caused by powertrain, wind/air and tire/road
- Electric/hybrid vehicles: Induction machines whines, higher vibration level, wind/air and tire/road. Zero BSR (buzz, squeak and rattle)[1]

Current strategies (noise, vibration and shock control)

- Absorptive: Foams, coatings, perforated sheet metal
- Barrier: Mass-Loaded Plastics, Sealants and Sealing Tapes
- Vibration: Isolators, dampers, constraint layers
- Barrier/Foam composites
- Silencers



References
1) Sound & Vibration/April 2011, The Future of Electric Vehicle Noise Control
2) Images: https://earglobal.com/media/5748/floortreatment.jpg (accessed on 07.22.2018)

Screening Objectives

Objectives

- Evaluate performance of mineral grades for noise reduction
- Capture perfromance space in various noise tretaments
  - Barrier
  - Damper
  - Absorption
- Undestand relative mechnical performanc of various mineral grades
- Identify difference in noise and mechanical performance as a function of particle size

Approach

Experimental

- Melt compound via 25mm co-rotating/intermeshing TSE (46:1, L/D)
- ASTM test specimen prepared via 66T Arburg injection molding unit

Sound Testing

- Dynamic mechanical analysis
- CenterPoint
- Sound transmission loss

Mechanical

- Test specimen conditioned 1 week at 23 ˚C/50% Rh prior to testing
- Testing conducted via ASTM standards/guidelines (D792, D1238, D256, D790, D638 and D648), and other internal methods

Materials

- PP Homopolymer - Ineos PP- H13M00
  - MFI = 13.5 g/10 min (@230 ˚C, 2.16 kg)
  - Flex Modulus = 1655 MPa
- Addivant Polybond 3000
  - Maleated PP
  - MFI = 405 g/ 10 min (@190 ˚C, 2.16 kg)
- Strucktol RP 11
  - Processing Aid (viscosity modifier)

- **Minerals**
  - Talc
    - Coarse (4.5 µm), fine (1.2 µm) and HAR (2.3 µm)
  - Mica
    - Coarse (150 µm) and fine (30 µm)
  - Wollastonite
    - HAR Coarse (18 µm, laser) and HAR medium (12 µm, laser)
  - $CaCO_3$
    - Fine (3 µm) and Ultra-fine (1.1 µm)
  - Graphite
    - Coarse (<150 µm) and fine (39 µm, d90)
  - $BaSO_4$ (3 µm, laser)
  - Chopped GF (10 µm x 4mm)

Noise Reduction Process

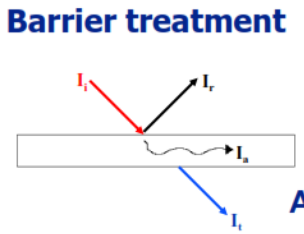
- **Type of sound**
  - Airborne noise (sound)
  - Structure-borne noise (vibration)

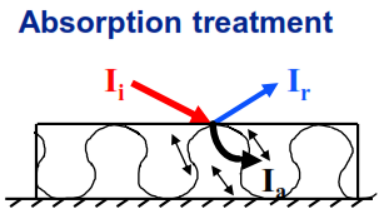
- **Type of treatments to reduce the noise**

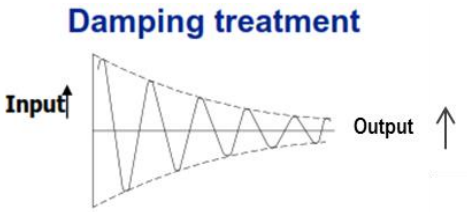
  - Barrier treatment
    - Airborne Noise

  - Absorption treatment
    - Airborne Noise

  - Damping treatment
    - Structure-borne noise







- All treatments are frequency dependent
- Performance of damper is also temperature dependent

Noise reduction testing

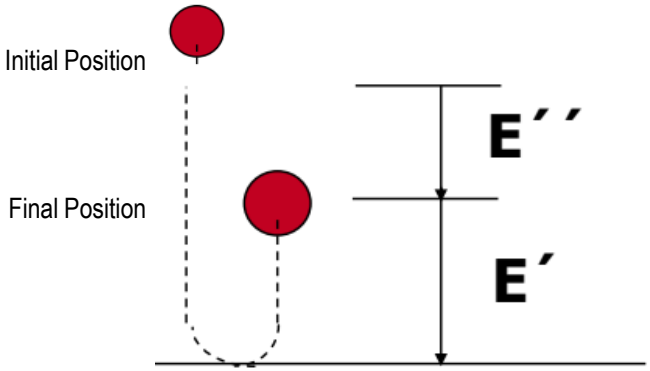
1) Dynamic Mechanical Analysis
2) CenterPoint
3) Sound Transmission Loss

Dynamic Mechanical Analysis

Damping

- Reduction of kinetic energy present in a system, through transformation into another form of energy
- Damping performance is commonly expressed in terms of loss factor

Viscoelastic material



Loss tangent, tan δ

$$\tan \delta = \frac{E''}{E'}$$

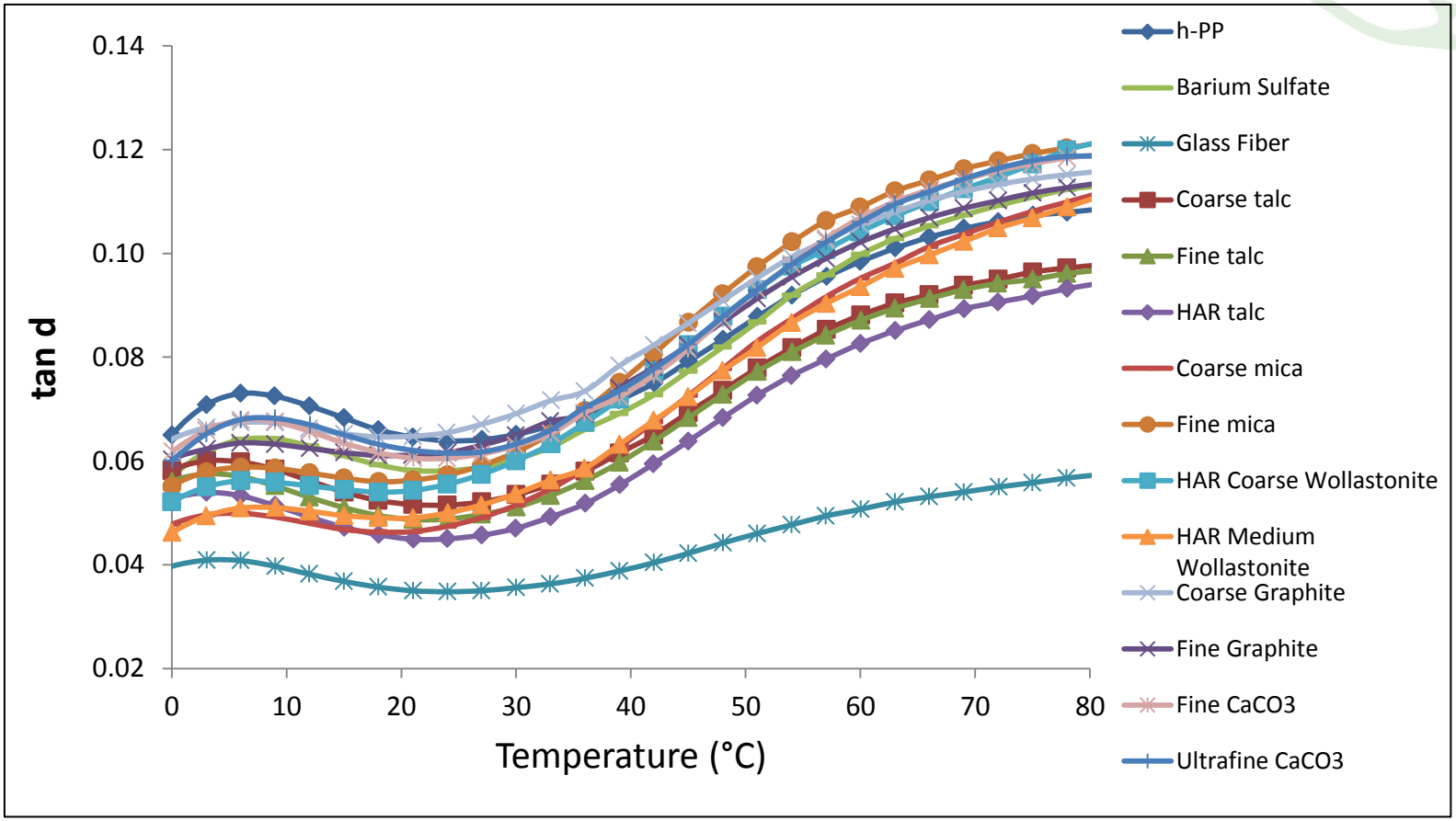
E´´: Loss modulus (viscous factor, dissipates energy)

E´: Storage modulus (elastic factor stores energy)

DMA
Three point bending mode

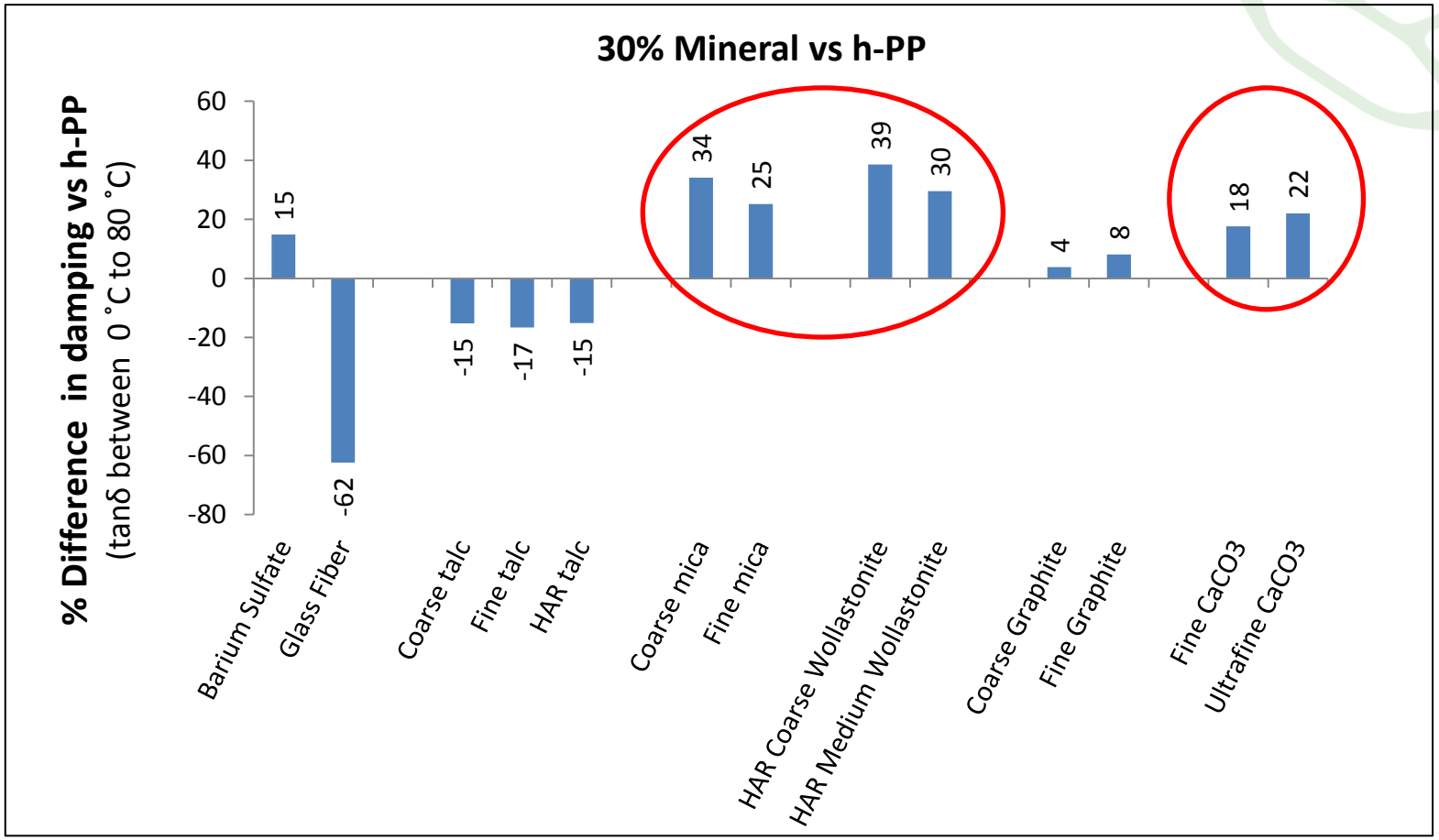
Test Results - Dynamic Mechanical Analysis

DMA performed in three point bending mode at 10 Hz frequency from -3 ˚C to 80 ˚C
30% Mineral filled PP



- Wide range of performances with mineral filled compounds
- Glass fiber filled compounds have lowest viscoelastic loss

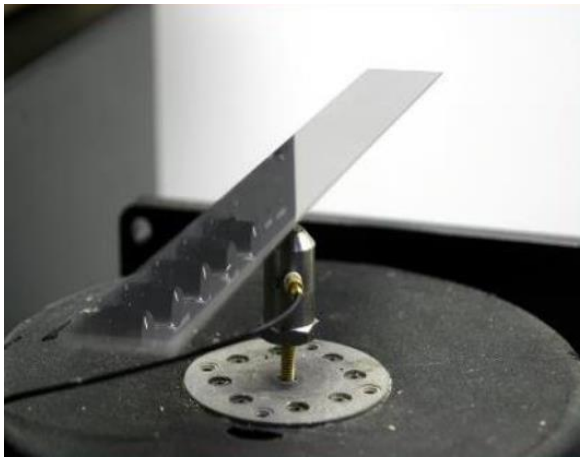
Test Results - Dynamic Mechanical Analysis



Mica, wollastonite and $CaCO_3$ grades show superior damping behavior as compared to the neat resin

CenterPoint Test (ISO16940)

- Test performed at 23 ˚C and 60 ˚C
- Loss factor at resonant frequencies are interpolated to 200, 400 and 800 Hz

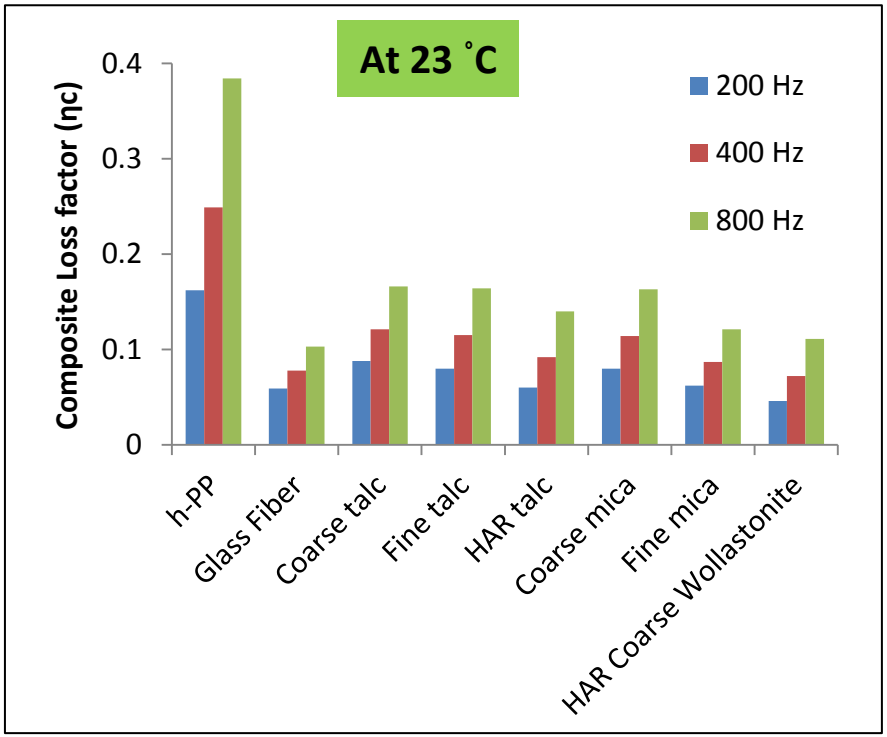


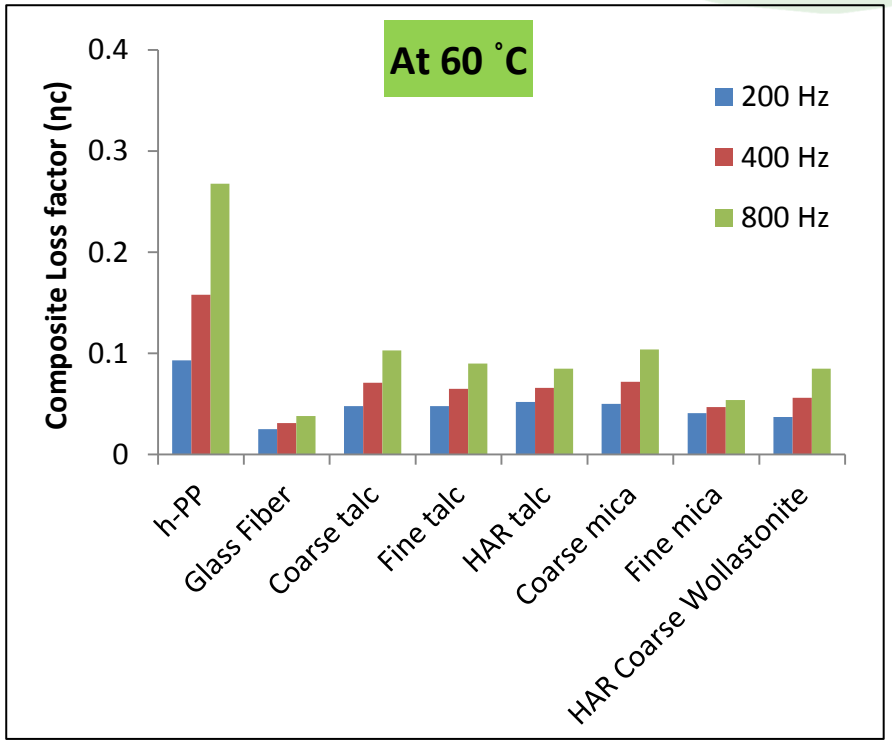
Obtains the response (acceleration) as the bar is excited with specific force

$$\text{Loss factor } (\eta) = \frac{\text{Amount ofenergy lost or dissipated}}{\text{Maximum potential energy in the vibrating system}}$$

Test Results - CenterPoint (ISO 16940)

- Test performed at 23 ˚C and 60 ˚C
- Loss factor at resonant frequencies are interpolated to 200, 400 and 800 Hz

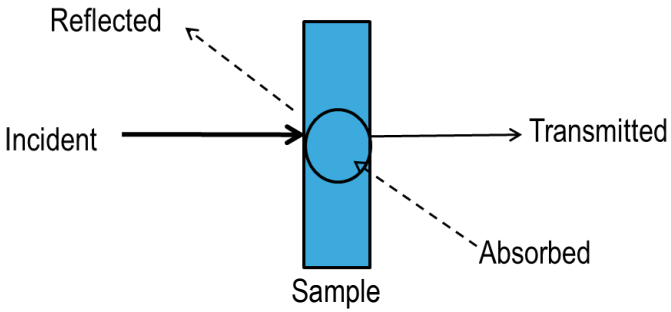


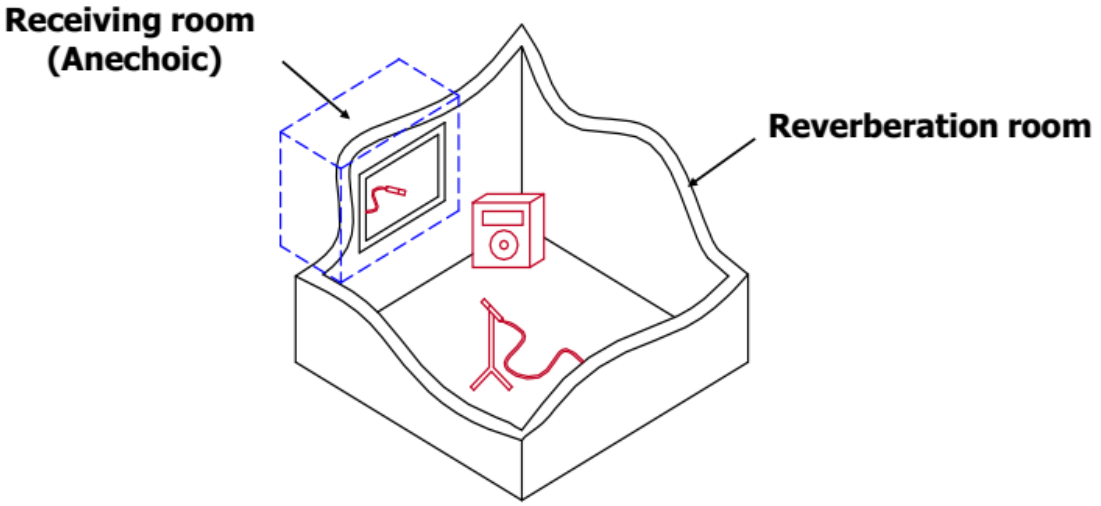


- Performance is temperature dependent
- Neat resin shows better performance at both the temperatures
- Talc, mica coarser grades to be superior to their fine counterparts

Sound transmission loss testing (per SAE J1400 (2017))

Sound transmission loss (STL)

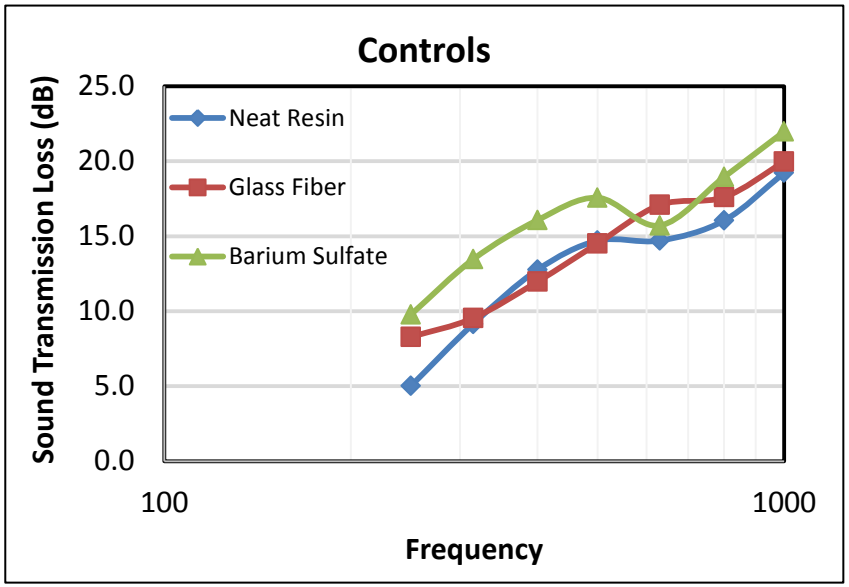


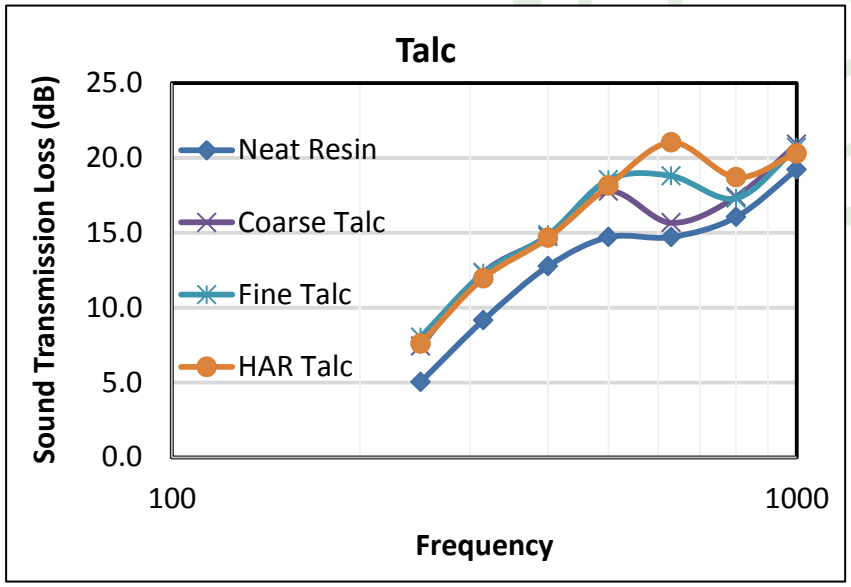


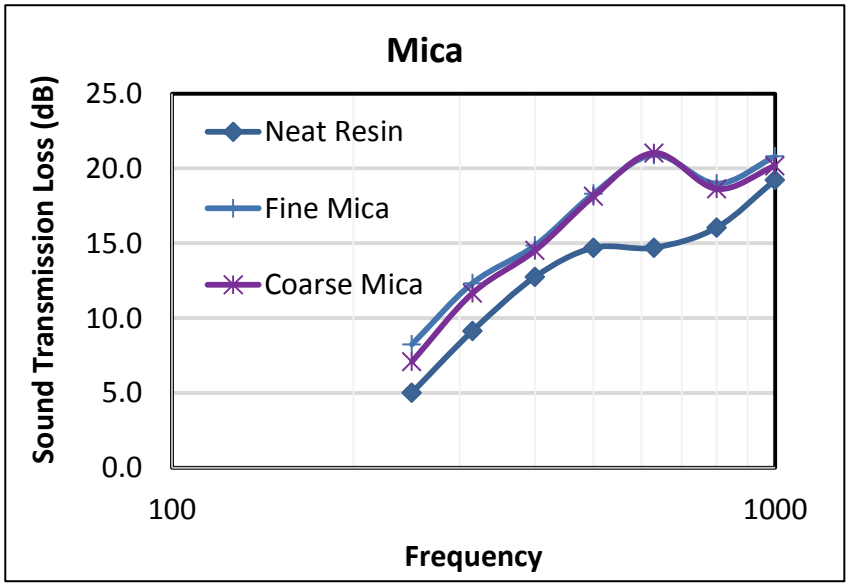
$$\tau = \frac{\text{sound transmitted}}{\text{sound incident}}$$

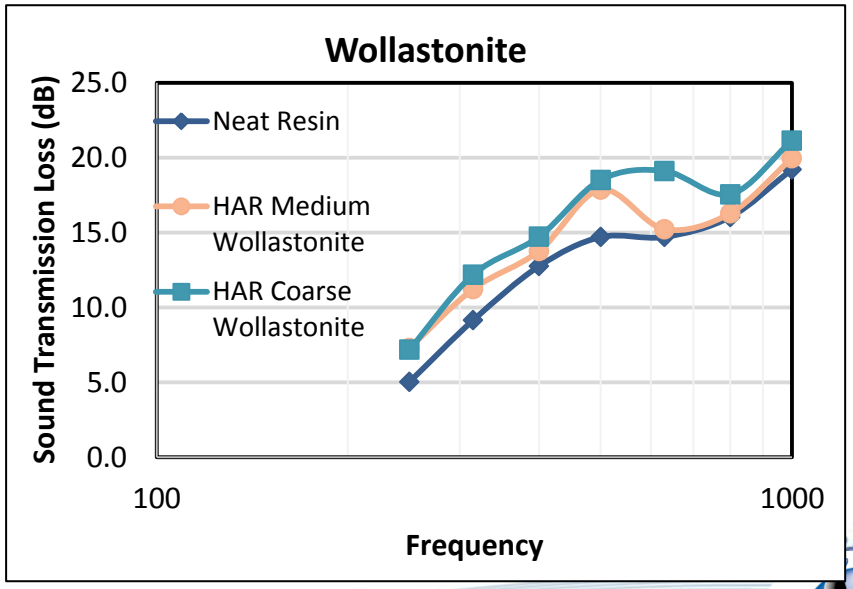
$$STL = 10 \log\left(\frac{1}{\tau}\right) \; dB$$

Test Results - Sound transmission loss testing (SAE J1400)

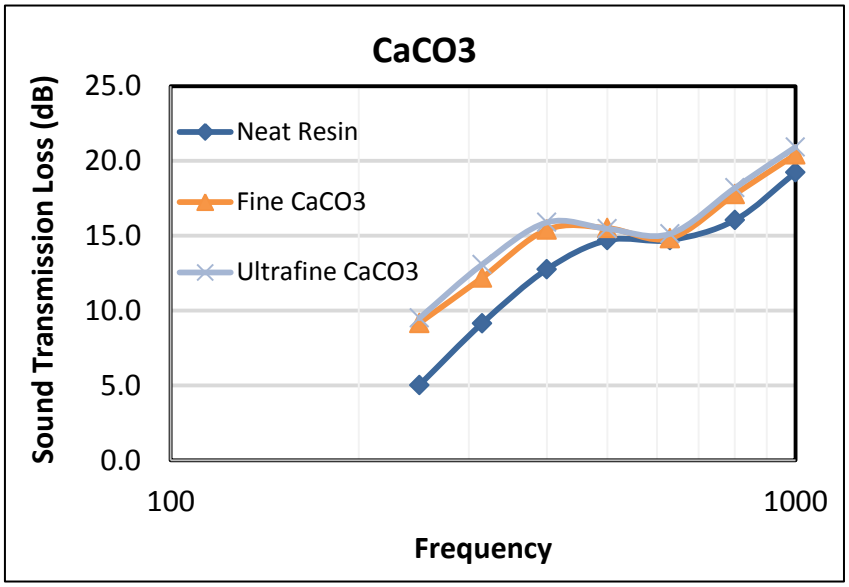


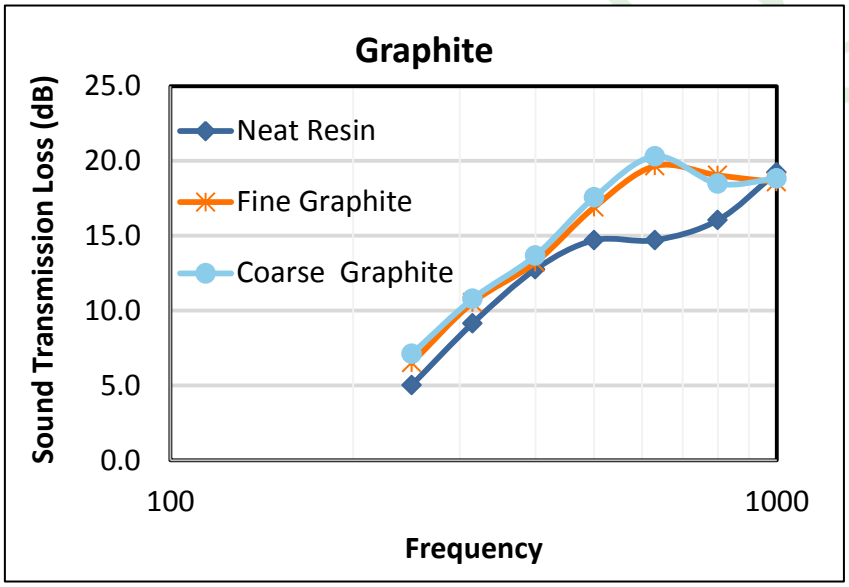






Test Results - Sound transmission loss testing (SAE J1400)



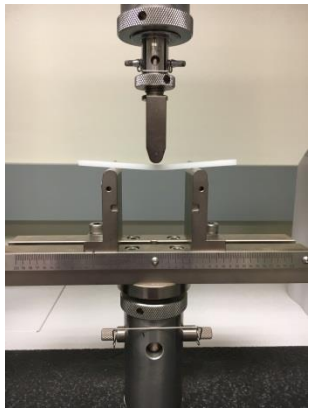


- All mineral filled compounds show 2-3 dB STL as compared to the neat resin
- Performance is density dependent; morphology has minimal influence

Summary: Noise reduction testing

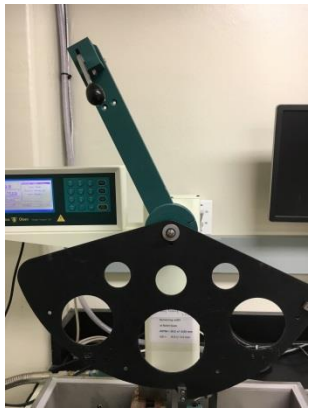
- No universal solution for different types of noise treatments
- Dynamic mechanical analysis which imparts viscoelastic loss indicates mica, wollastonite and $CaCO_3$ are better than h-PP
  - **Recommendations**: **Suzorite® Mica** and **Nyglos®, Aspect® Wollastonite** line of products
- CenterPoint test which imparts vibrational damping shows **coarser grades** to be superior than their fine counterparts
  - **Recommendations**:
    - Room Temperature: **JetFil®** and **Suzorite®** coarser grades
    - Elevated temperature: **JetFil®, Suzorite®** and **Nyglos®** coarser grades
- STL data indicate improved barrier performance using all the mineral filled compounds (surface density effect)
  - **Potential Recommendations: JetFil®, Suzorite®** and **Nyglos®** line of products

Mechanical and thermal testing



Flex

Tensile



Izod Impact

Mechanical Properties

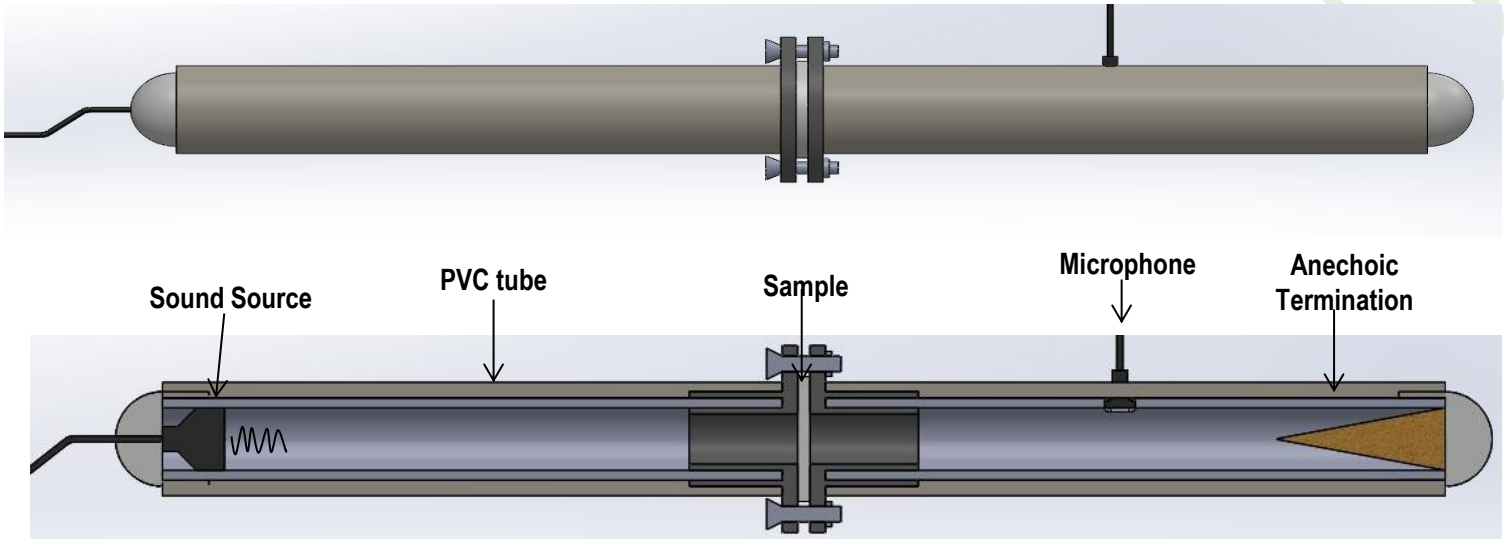
At 30% loading, tested in ASTM

		Measured Density, g/cc	Flexural Modulus (Young's Automatic), MPa	Tensile Strength, MPa	Notched Izod, J/m (RT)	HDT (66 psi), deg C
h-PP		0.913	1497	38	7	113
Glass Fiber		1.112	5350	104	73	161
Barium Sulfate		1.197	1884	34	22	120
Talc	Coarse	1.138	3496	37	23	142
	HAR	1.157	4636	42	23	145
Mica	Coarse	1.135	4887	32	20	141
	Fine	1.137	4126	33	22	140
Wollastonite	HAR Coarse	1.140	4378	32	23	140
	HAR Medium	1.146	4958	36	21	143
$CaCO_3$	Fine	1.133	2344	36	24	126
	Ultrafine	1.128	2370	33	22	121
Graphite	Coarse	1.103	4219	34	20	146
	Fine	1.101	5100	36	20	147

- Various possibility among different minerals
- Range of properties within various grades of mineral

Internal Benchmarking via Impedance Tube

In-house Impedance Tube (Transmission mode - ASTM E2611)



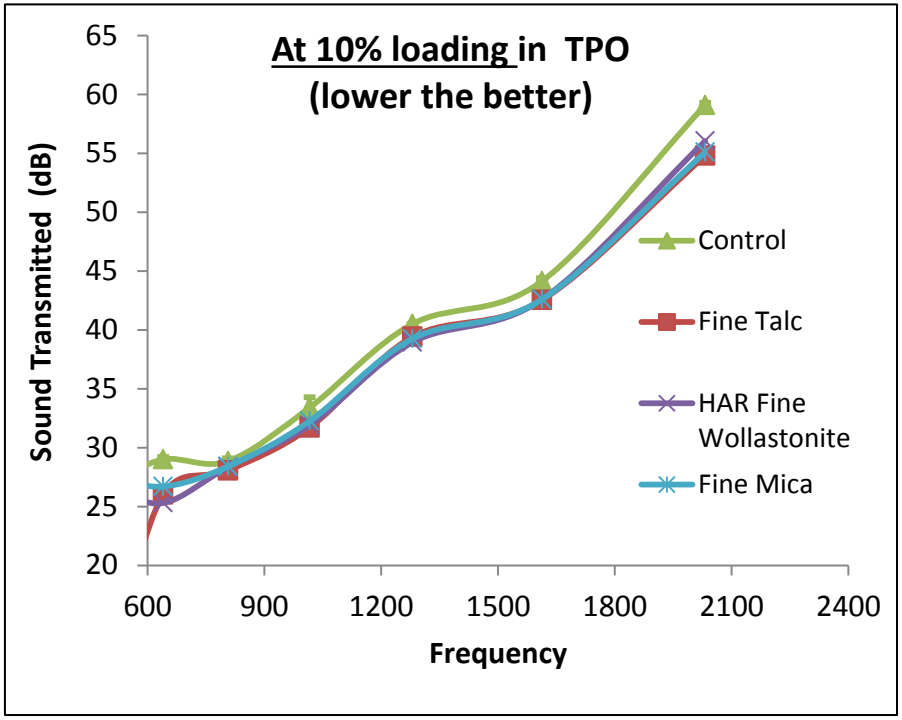
References

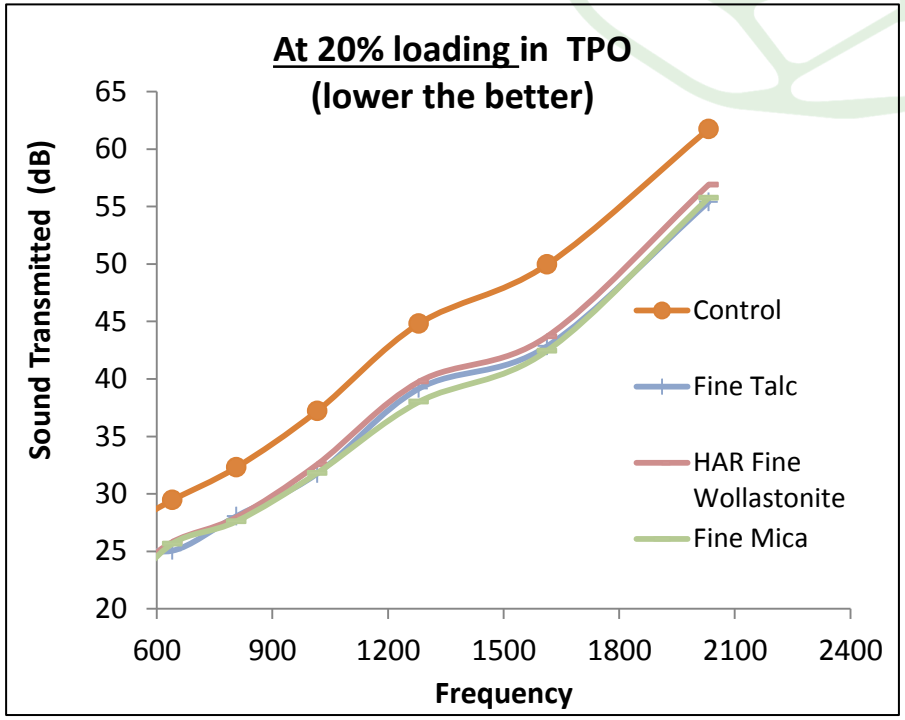
- 121st ASEE Annual Conference and Exposition Paper ID 8776
- ASTM E2611-17

Testing TPO formulation (10 and 20% loading)

- PP Copolymer – Braskem T16200Q4 / Pinnacle 2135H
- PP Homopolymer – Braskem F1000HC
- POE – Dow Engage 8200
- AO – Addivant Anox BB0011
- Minerals

TPO compounds- Sound Transmission Data





- Barrier performance is density dependent; higher density yields higher barrier
- Clear distinction between control and 20% filled compounds
- Difference is narrower at 10% loading

Conclusion

- Noise reduction using minerals:
  - **No universal solution**
  - Selection is dependent on type of noise treatment; also needs to meet mechanical properties
    - **Visco-elastic** damping: improvement with addition of mica, wollastonite and/or ground calcium carbonate
    - **Vibration** damping: improvement with coarser mineral grades
    - **Barrier**: improvement with mineral addition; performance appears to be density dependent

- Range of mechanical properties possible among various minerals and within specific mineral type

Conclusion

Selection is dependent upon specification requirements and cost

- Talc
  - Good stiffness-impact balance, color, compatibility, nucleation, vibrational and barrier. Exact grade depending on specification
  - **Recommendations:** Macro-crystalline/**Jetfil®**, **Jetfine®** grades (balance of vibrational-barrier and mechanical performance), Micro-crystalline/**Nicron®, Mistrocell®** (foaming, absorption)
- Mica
  - Material of choice for vibrational damping; bitumen/heavy layers
  - **Recommendations: Suzorite®** for maximum reinforcement, dimensional stability, potentially for all noise modes
- Wollastonite
  - Improves viscoelastic damping and barrier performance
  - **Recommendations: Nyglos®, Aspect®** for superior mechanical properties, flow and color

Thank you for your attention !

Acknowledgment

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- Isaac Robledo
- Rahul Doke
- Gary Cook

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