

*Multi-family White Paper #4*

## Addressing Floor/Ceiling Noise Issues in Multifamily Construction

### Overview

*Current multifamily floor/ceiling assemblies are problematic as they require multiple layers of materials and trades that produce risk-prone STC and IIC results. Worse, the most common standard floor/ceiling designs fail to meet occupant quality requirements when used with hardwood or tile floors, leading to dissatisfied customers, brand erosion and often threats or actual lawsuits. The modern multifamily floor assembly is built around wood trusses, I joists, I beams etc. with several treatments above and below intended to meet sound and fire requirements. This paper discusses the known problems with the current assembly and makes some recommendations of new materials to address these issues.*

This paper covers three topics:

- A. Issues in understanding Floor/Ceiling Assembly acoustics (IICs and STCs)
- B. Liability in conventional Floor/Ceiling designs
- C. An alternative QuietHome Floor/Ceiling design

## A. Background on Floor/Ceiling Noise Issues

The main issue in Floor/ceiling designs is with the Impact Insulation Class (IIC) requirements. IIC is a measure of how much “footfall” noise travels through a floor assembly to be heard from below. Usually, this is presented as a single composite number which represents a formulaic curve-fit. Recently there has been much talk in the acoustic community that the IIC curve-fitting protocol does not properly address real noise concerns, particularly at high frequencies which receive little weight in the current IIC composite number. So instead, engineers are urged to review the entire IIC curve (rather than simply the composite number) to reveal the true performance of the system.

While code requires IIC 50 lab or IIC 45 field, in most multifamily dwellings even meeting these numbers has led to myriad complaints from buyers and renters. In recent years, hardwood, marble, quarry stone, ceramic tile and hard vinyl tile floors have gained in popularity over carpet and have come to represent “luxury”. From an IIC standpoint, this is unfortunate for the architect, developer and builder, as adding carpet to any flooring system absorbs footfall noise, and thus reliably eliminates IIC complaints. However with hardwood, stone and tile floors, high frequency noise (often referred to as “high heel” noise) becomes dominant. And while the IIC composite number is not reflective of “high heel noise” energy, the full  $1/3^{\text{rd}}$  octave band measurements clearly reveal the problem. It is important to understand that while the conventional assembly may fail in several ways, even failing to meet code, even a fully functioning assembly (i.e. IIC 50 lab, 45 field) will likely result in complaints when a hardwood floor is installed above.

STC is the measure of sound transmission through a partition (in this case a floor and ceiling) while IIC is a measure of impact noise (such as footsteps) heard in the unit below. Most multifamily construction in the US is required (per building code) to meet lab tested results of STC 50 and IIC 50, or field tested results of STC 45 and IIC 45. Of course, the higher the better for both numbers. However, the composite number is not all-telling, as many developers have discovered in recent years.

In general, achieving the desired Sound Transmission Class (STC) rating is faintly straightforward for today's conventional assemblies. The major source of complaints is with IICs, not STCs. Hence, this paper will disproportionately address that class of problems.

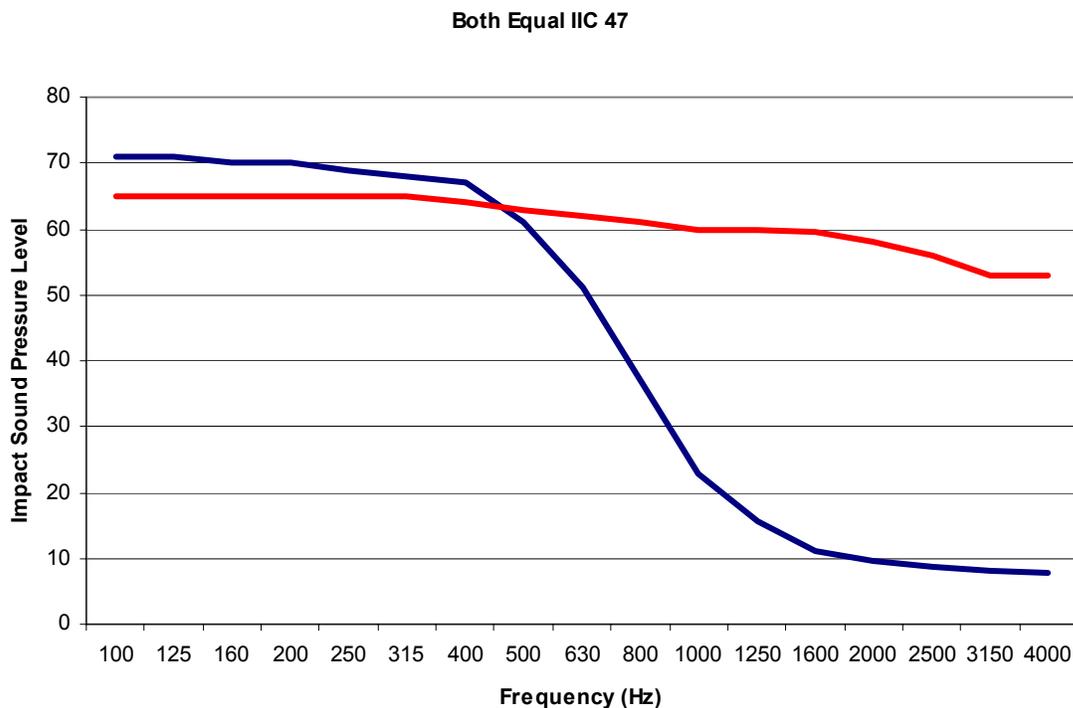
## All IIC's Are Not Equal

The IIC standard is such that a fair amount of high-heel noise will be heard even with an IIC of 60, due to the way the measured data is fit to the curve. Hence, people have begun looking deeper at the raw data (the actual 1/3<sup>rd</sup> octave band sound pressure measurements) rather than simply a composite number, in order to better understand why such complaints exist.

The problems stem from the poured gypsum, underlayment, and RC designs. All of these are susceptible to short-circuits which eventually require rework. Ideally, Floor/Ceiling Assembly was designed to eliminate the cementitious underlayment, sound isolation membrane and resilient channel, and reduce the sharp “click-clack” floor noise transmission. The new design uses internally damped panels and saves time by replacing multiple vendors, trades and inspections needed by conventional designs. The design solves the difficult “high heel shoe” footfall problem and, unlike the conventional assemblies, cannot be shorted out.

IIC is usually given as a composite number (such as IIC47). This number is generated by fitting a curve as prescribed in ASTM E989. IIC stands for “Impact Insulation Class” and measures how floor impact noise travels to the owner in the unit below. By using a “tapping machine”, metal hammers hit the floor system hundreds of times a minute as the noise is measured in the room below. However, as acoustic engineers already know and builders have learned, the current IIC curve fit does not represent actual customer needs or complaints. The issues include a likely over-weighting of very low frequency sounds, and under-weighting of high frequency noise (such as high-heel noise) and no improvement in scoring for over-achieving at any frequency band. The result is that one floor system with an IIC47 can cause occupants to disparage a brand and complain often, while a different assembly that also measures a composite score of IIC47 could be one of the quietest living environments around, even though both have similar upstairs neighbors with hardwood floors.

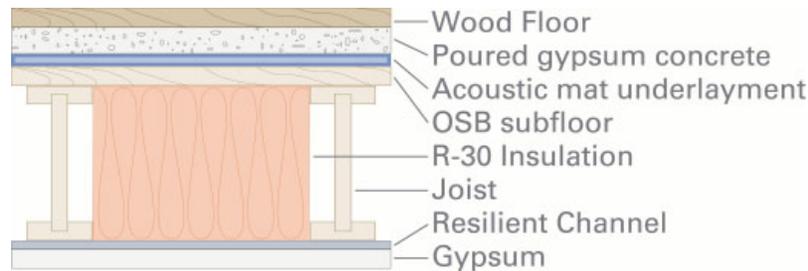
**Figure 1** illustrates the IIC curves for two different floor assemblies that both score IIC47. In this standard IIC plot, the lower the Impact Sound Pressure Level, the better (lower SPL means less noise was measured below). Most complaints in the industry occur due to footfall noise that is present from 500Hz to 4Khz, including high-heel noise. The assembly represented by the blue line outperforms the red by 48dB at 2000Hz, critical for High Heel noise.



## B. Current Conventional Floor/Ceiling Designs

STC (spec)	58	Excellent
FSTC (expected)	52-56	Appropriate for mid-market multifamily
FSTC (failed condition)	43-49	Code violation or marginal
IIC (spec)	53	Appropriate for mid-market multifamily
FIIC (expected)	46-50	Code compliant
FIIC (failed condition)	27-43	Not code compliant

**Figure 2: Conventional Design Detail**



*Figure 2 shows a typical floor/ceiling assembly. The assembly is specified at STC58 and IIC53.*

### Conventional Design Risk Assessment

There are significant, frequent known risks and field failures in this popular floor ceiling assembly.

- Short Circuits.** In this condition, the gypsum cement leaks through or over the sound mat, creating a hard cement connection from the floor, down the joist to the drywall below. This risk can be reduced by carefully taping all the seams in the sound isolation membrane, paying special attention to the corners. This requires constant field supervision and QA. Unfortunately, there is no way to inspect for this short-circuit as it happens under the poured gypsum concrete and will not be known until the build is complete. This failed condition is discovered in forensic examination (i.e. complaint or lawsuit) when a floor is demolished for inspection.
- Open Circuits.** Cementitious material cracks from two known reasons: (i) when water evaporates the cement always cracks; and (ii) when the foundation settles, the cement cracks. Cracks from drying and settling are very common, and can create IIC and STC problems. This risk can be reduced by using high-quality poured gypsum concrete with embedded polymers. This polymeric material costs close to \$4.00/sq foot installed instead of \$2.50. Some builders choose low cost lightweight concrete (can run under \$1.50 installed) and this low-grade alternative to Maxxon Gyp-Crete experiences the highest failure rate.
- Mold Generation.** Mold from water that is poured into the structure with the poured gypsum concrete. The thousands of gallons of water must evaporate from the concrete, which continues to vacate the concrete for several weeks (even though one may walk on it within 3 days or less, water continues to leave the material for weeks). This is a major cause of mold since the drywall is an efficient water absorber and will grow mold within a few days in this environment. The mold risk can be reduced by reversing the ordinary construction method: wallboard should not be installed for at least three weeks after the concrete is poured. Most builders report that schedule will not permit this method, and almost all put up the drywall first and then pour the concrete floor.
- Schedule Risk.** The pour must occur with an outside contractor on a fixed schedule often set weeks or up to three months in advance. Builders report that they suffer schedule risk from two sources: (i) if they are late with framing, the cement contractor might not be able to reschedule easily, causing a delay; or (ii) if the framing is completed ahead of schedule, the cement contractor might not be able to show up until the date originally schedules, hence causing an unnecessary delay.

5. **Underlayment Failure.** The weight of the cementitious underlayment can crush the acoustic layer. This will significantly reduce the IIC performance in the high frequencies (i.e. high-heel shoe problem).
6. **Resilient Channel Failure.** RC failure is reported as shorted in 90% of field construction today, and our own work with developers has shown similar failures. There are 20 known and documented causes of failure in RC<sup>1</sup> and it has become increasingly difficult to train installers to watch for each of these during and after installation. Any shorting in RC will significantly reduce both STC and IIC.<sup>1</sup>
7. **High Heel Noise Problem.** Most of the litigation and warranty contingent liability is to remediate high-heel and footfall noise complaints. The high-frequency tapping of high heels is the most common complaint resulting from installs of this assembly, even when it has no installed failures or shorts. While the designed IIC appears acceptable, the composite IIC number does not reveal the actual underlying frequency curve.
8. **Weight Penalty.** Whereas weight is not a failure risk, it can add cost. The cementitious materials plus the acoustic mat add about 10 pounds per square foot. This method therefore adds about 15,000 pounds per condo extra weight. Structural engineers are examining whether eliminating the cement layer can produce a design with somewhat lighter support structures, thus saving cost.

## Contingent Liability & Direct Cost of Complaints

The failure risks are well known and significant. A major U.S. builder reported that 14% of their floor/ceiling assemblies failed, and that these failures were only measured in response to serious homeowner complaints. The actual failure rate appears to be much higher. In failed installs, the IIC measurements have been observed as low as FIIC 36 and can reach FIIC 27 with a completely shorted assembly (this has been lab tested), which means that both the RC and poured gypsum concrete have completely shorted out. The remediation cost to completely replace the floor/ceiling assembly (essentially tear out the finished floor and underlayment as well as the ceiling) can exceed \$32,000 per condo. The contingent liability net cost equates to an additional \$2 to \$3 per square foot for retrofits, repairs, and rebuilds of floor/ceiling assemblies if the failure or complaint rate is 14%.

## Litigation Risk

The #1 cause of construction litigation is mold and moisture; the #2 cause is noise; and the #3 cause is foundation settling<sup>2</sup>. Homeowner Associations are increasingly threatening to sue. Reportedly, 90% of all actions are settled out of court. A typical settlement for noise is \$32,000 per condo. The floor/ceiling noise issue has become a serious issue for all developers.

## Brand Damage

Even more important than the direct financial costs is the “off book” cost of brand degradation. A company is only worth its brand, so hurting the brand and the reputation it stands for ultimately hurts the company’s bottom line more dramatically than any other mistake company executives can make. Brand equity occurs at two levels: (i) the Developer’s national reputation; and (ii) the reputation of the local project. Both brands need to be protected. Saving a few dollars a square foot might be appealing until word gets around that everyone in the new Community can hear their upstairs neighbors or that a certain builder builds poor quality units.

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<sup>1</sup> See “Resilient Channels: A Proven Liability” [www.quietsolution.com/technical\\_docs.html](http://www.quietsolution.com/technical_docs.html)

<sup>2</sup> Keynote Address, NAHB Multifamily “Pillars of Industry” Conference, Palm Springs, March 2004

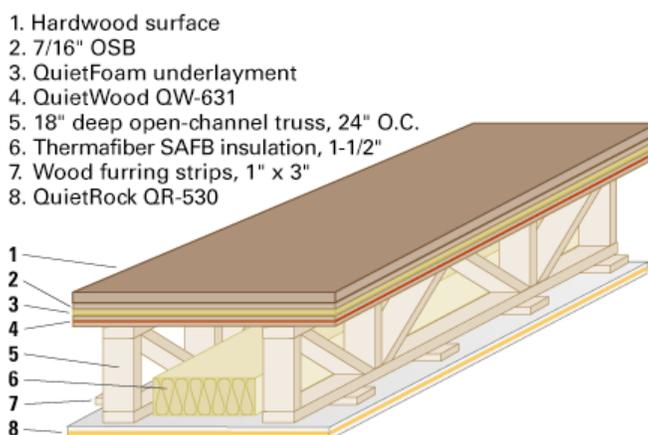
## C. The QuietHome™ Floor/Ceiling Assembly

STC (spec)	58	Excellent
FSTC (expected)	56	Appropriate for mid-market multifamily
IIC (spec)	51	Appropriate for mid-market multifamily
FIIIC (expected)	49	Code compliant

**STC: 58, IIC: 51**

Tested at National Research Council Labs (NRC), Ottawa, Canada, June 2004.

**Figure 3: QuietHome™ Design**<sup>3</sup>



### QuietHome Benefits:

1. **Saves significant time and schedule risk.** The major benefit is a faster, more controlled build schedule. Eliminates three vendors, two trades and two field inspections. Cuts supply chain logistics risk and schedule complexity that lead to delays.
2. **Delivers more reliable STC and IIC ratings.** Enables use of hardwood and tile floor coverings in luxury projects by damping the critical 1500-2500 Hertz band. Removes possibility of short-circuit failures due to actions of trades or homeowner.
3. **Eliminates poured gypsum concrete.** Radically reduces chance of mold, as this underlayment introduces hundreds of gallons of water into each housing unit, which often gets absorbed into the gypsum. Eliminates chance of acoustical short-circuit failure from material leaking into and hardening the sound isolation membrane or cracking over time (e.g. due to foundation settling). Eliminates one supplier, vendor and field inspection. The overall assembly is lighter weight. This enables the architect to re-engineer the structure to accommodate lesser loads.
4. **Eliminates resilient channels (RC Channel).** Removes known liability with 90% risk of field failure (short-circuiting) from 20 known causes identified by acoustical engineers and builders. Eliminates one supplier, vendor and field inspection.
5. **Costs approximately the same or less.** The QuietHome design (QuietWood + QuietRock assembly) costs approximately the same in direct materials and labor compared to conventional designs. When considering reduced litigation, rework and brand loss, QuietHome is significantly less expensive in total cost.
6. **Reduces high heel noise.** The QuietHome design is the first major breakthrough in over a decade aimed at combating high frequency noise between floors.

<sup>3</sup> This design shows hardwood topping. Similar results are obtained for marble, quarry stone, ceramic tile and vinyl tile.

## Solving the “High Heel Shoe on Hardwood” Problem

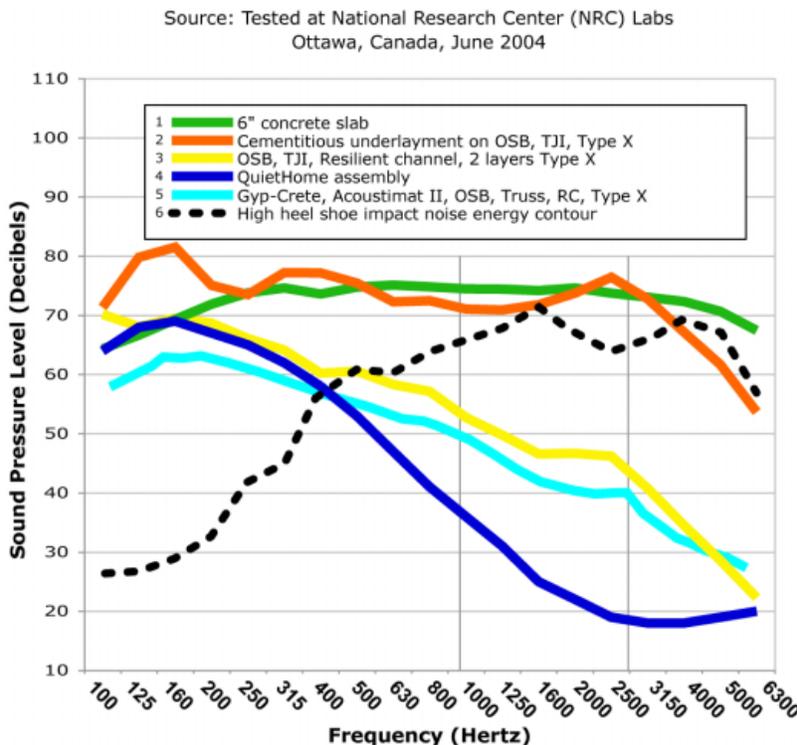
In most markets, hardwood floors are required in quality multifamily units. The problem with hardwood floors is that they are severe transmitters of noise. The most-reported problem is “high heel shoes”, transmitting a sharp cracking (“click-clack”) noise to the housing unit below. Much of the energy transmitted by hard shoe bottoms such as high heels into hardwood floors occurs in the higher frequencies. Hence, focusing on high decibel loss in the 1000 to 2500 Hertz range reduces most of the offensive noise, and one of the most-heard complaints. Soft footfall (such as those from socks) on hardwood floors produces very low frequency rumble on all wood-joint systems, regardless of assembly. Moreover, people tend to be less sensitive to those low rumbles, versus the click-clack of hard shoes on hard surfaces.

**Figure 4** shows the actual frequency curves for the QuietHome floor/ceiling assembly compared to four conventional assemblies with hardwood surface: (1) 6” concrete slab; (2) cementitious underlayment such as Gyp-Crete plus sound insulation membrane such as Acoustimat II on TJI truss; (3) use of resilient channel with TJI truss; and (4) the combination shown in Figure 1, cementitious underlayment plus sound insulation membrane plus resilient channel on open truss, per spec (vs. field). **Figure 5** shows the difference (subtraction) in decibels between QuietHome and the four conventional designs.

The Figures show that the QuietHome floor/ceiling assembly takes out 20 dB or more compared to a conventional assembly in the critical frequencies. The common use of cementitious underlayment actually exacerbates the “high heel shoe” problem by transmitting more energy in the high frequency bands, 1000 to 2500 Hertz, where hard shoes make the most noise (even with a higher final IIC score).

### QuietHome Design vs. Three Conventional Designs

**Figure 4: QuietHome Outperforms Conventional Designs\* by 20-30dB in the Critical “High Heel Shoe” Noise Zone, 1000 to 2500Hz**



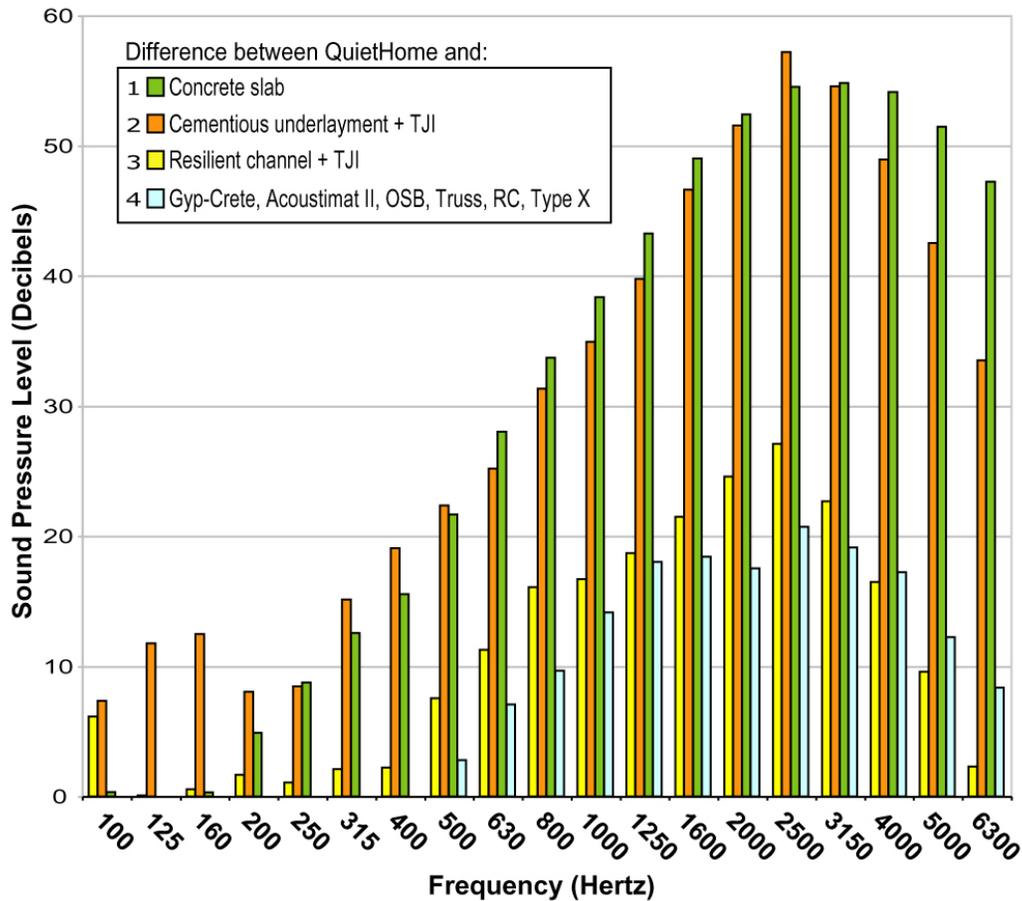
Notes: The first three conventional assembly test results are from NTC/CNRC by A.C.C. Warnock and J.A. Birta, “Detailed Report for Consortium on Fire Resistance and Sound Insulation of Floors: Sound Transmission and Impact Insulation Data in 1/3 Octave Bands”, IRC Internal Report IR-811, July 2000. Assembly 4 is unique (i.e. not specifically tested at NRC) and is a composite of lab and vendor test reports.

**Figure 4** represent the difference, in dB, between the QuietHome assembly and four assemblies described in the legend. For example, at 2500 hertz, the QuietHome assembly tested 55 dB down compared to 6" concrete slab; and 28 dB down compared to the resilient channel/TJI assembly. These curves are weighted and curve-fit to produce a standard IIC rating, but the decomposition in their 1/3 octave bands allows the analyst to focus specifically on certain offensive frequencies, or those noises that cause the most complaints.

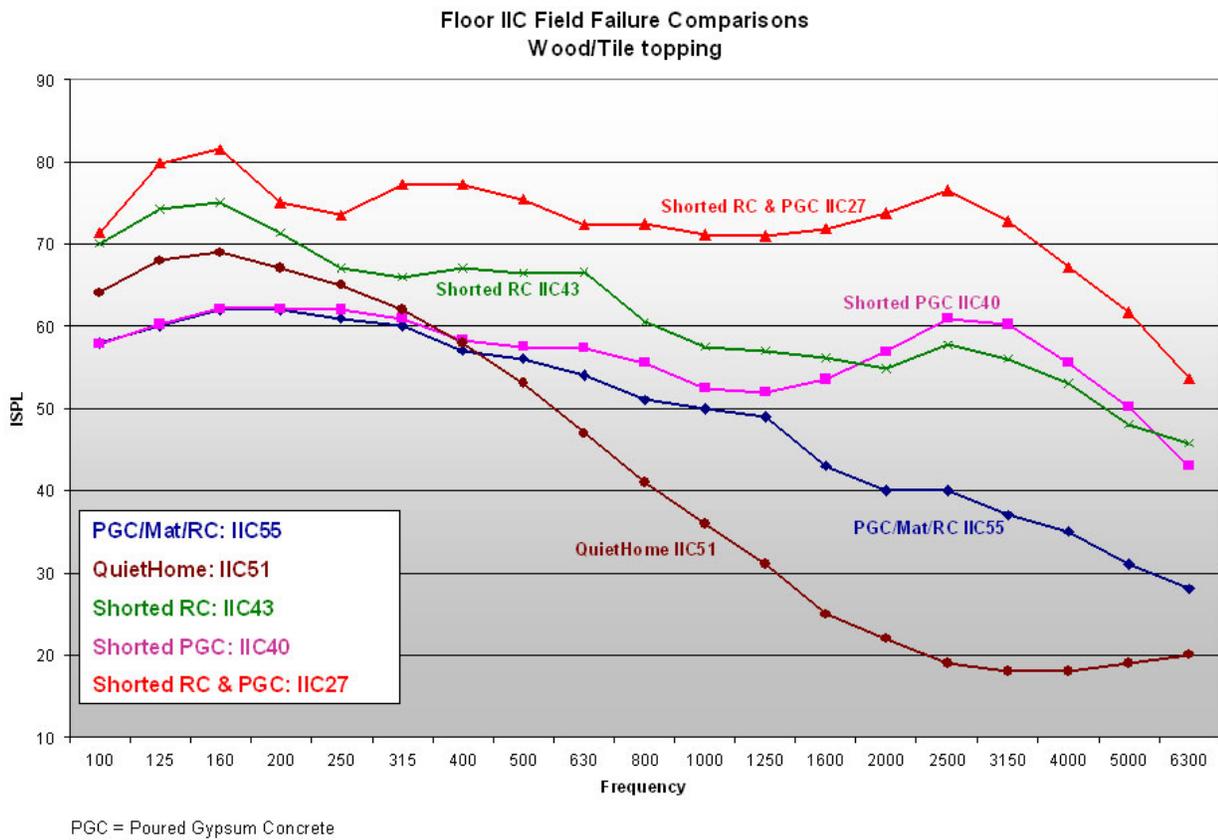
**Figure 5** represents in bars the same data as in Figure 4. It graphically shows the difference between the three conventional assemblies and QuietHome. The zero baseline on the Y axis (dB) represents QuietHome results for Design A. The bars represent the dB difference per given frequency, measured in 1/3 octave bands.

**Figure 5: QuietHome Outperforms Conventional Designs\* by 20-30dB in the Critical "High Heel Shoe" Noise Zone, 1000 to 2500Hz**

Source: Tested at National Research Center (NRC) Labs  
Ottawa, Canada, June 2004



**Figure 6: IIC Ratings of Conventional vs. Quiet Home Floor/Ceiling Assemblies**



*Figure 6 shows the possible IIC results as layers are inadvertently shorted out in the standard assembly. The higher the number, the greater the perceived noise coming from the "high heel" problem.*

## Summary

The conventional multifamily floor/ceiling assembly has been investigated and reviewed. Myriad complaints are common with this design due to poor high-frequency impact insulation performance as well as multiple points of failure described above. A new QuietHome assembly has been proposed which improves high-frequency insulation performance and eliminates most points of failure. The result provides builders with a fresh approach in dealing with noise complaints and litigation, enhanced brand loyalty, and reduced cost.