Increasing Impact Insulation Ratings in Occupied Condominiums

Scott Harvey and **Josh Curley**, Phoenix Noise & Vibration, Frederick, Maryland

More than 100 condominium units were constructed with a floor/ceiling system consisting of an unidentified "acoustic" floor underlayment and resilient channel sandwiched between two layers of gypsum board, resulting in numerous impact noise complaints from condo owners. After initial field impact insulation class (FIIC) testing revealed ratings as low as 31 FIIC (required 45 FIIC), remedial mitigation options were developed to meet two design criteria: 1) develop a floor/ceiling system to meet the required impact insulation class rating; 2) the floor cannot be modified. Three mitigation options were designed before a spring-isolated ceiling system was selected for use in three trial condo units. After removing the existing ceiling and prior to the installation of ceiling gypsum board, an inspection was conducted to verify that the spring grid was properly installed. Post-mitigation testing revealed FIIC ratings of 48 to 49. Following the successful test results and satisfied testimonials from the condo owners, a decision was made to replace existing ceilings with the spring-isolated system throughout all affected condo units.

Phoenix Noise & Vibration was contacted regarding impact noise complaints made by multiple condo owners throughout a condominium development that was near completion and almost at full occupancy. The majority of the condo units had ceramic tile flooring.

After field impact insulation class (FIIC) testing established ratings well below the building's 45 FIIC requirement, an investigation of the building's design and actual construction revealed two factors responsible for the floor/ceiling system's inadequate reduction of impact noise transmission. The investigation was followed by extensive remedial mitigation designs aimed at meeting the building's FIIC requirement, demolition and installation of the prototype design in a few condo units, and post-remedial construction FIIC results of 48 to 49.

The performance of the remedial floor/ceiling design in the prototype condo units prompted the decision to replace the ceilings in all condo units (more than 100). Each unit was also to be (acoustically) inspected to verify that the remedial design had been properly installed to function as intended, providing sufficient reduction of impact noise between living spaces.

After much coordination and cooperation between all involved parties, remedial work was completed for all condo units with praise from the condo owners for the improved isolation from their neighbors.

Initial FIIC Testing and Investigation

Field testing (Units A and B shown in Figure 1) was first conducted for two floor/ceiling systems with results of 30 and 38 FIIC. Each condo has the same layout, with a large great room (including the foyer, kitchen, dining room, and living room), three bedrooms, and two bathrooms. FIIC testing was limited to the great room, since it was the only room which met the minimum volume requirement listed in ASTM E 1007.*

After initial field testing, questions arose as to whether the floor/ceiling details included in the condo building's architectural drawings were properly implemented during construction. In particular, records proving which floor underlayment had actually been installed could not be provided. According to the architectural drawings, floor/ceiling partitions were to consist of:

- Ceramic tile
- 3/4-inch Levelrock (Gypcrete)
- SRM-25 sound mat

Based on a paper presented at Inter-Noise 2012, the 41st International Conference on Noise Control Engineering, New York, NY, August 2012.

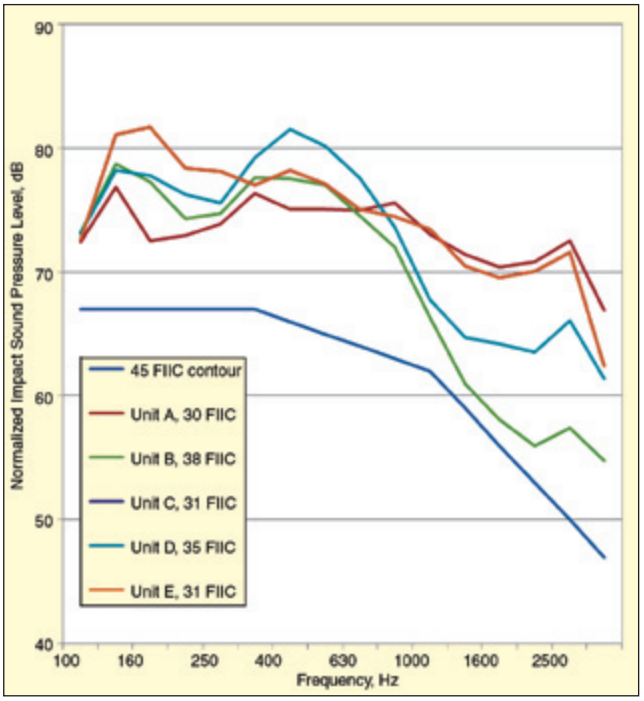

Figure 1. Pre-mitigation FIIC ratings of tested condo units.

- 3/4-inch tongue-and-groove subfloor
- 16-inch wood joists
- 3-1/2-inch batt insulation
- Resilient channel
- Two layers of 5/8-inch Type X gypsum board

An investigation was conducted in several condo units by removing sections of ceiling gypsum board, revealing resilient channel "sandwiched" between the layers of ceiling gypsum board (see Figure 2) and double-screwed resilient channel (see Figure 3). Following the investigation, it was revealed that the local fire marshal had required resilient channel to be installed in this way for fire safety reasons, and that two flooring contractors had been used for the buildings. These contractors had used unknown underlayments that may not have been the underlayments listed in the building's architectural details.

Floor/Ceiling Design

After extensive exploration of the various remedial mitigation options available, the decision was made to approach a solution by only removing the existing ceiling while leaving the existing floor untouched. This decision was made after much research and discussion; however, the final decision was influenced by the following factors:

- Removing the floor was determined to be more expensive and complex compared to complete removal of the ceiling.
- No acoustical floor underlayment alone could improve the FIIC rating by the 7 to 15 necessary to meet the building requirement without increasing the finished floor height excessively.
- Most acoustical floor underlayments are only effective and tested in conjunction with proper ceiling resilient channel installation.
- Remedial mitigation through the floor would require a much thicker underlayment than the (non-acoustical) underlayment

*American Society for Testing and Materials (ASTM) E 1007 – *Standard Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures.*

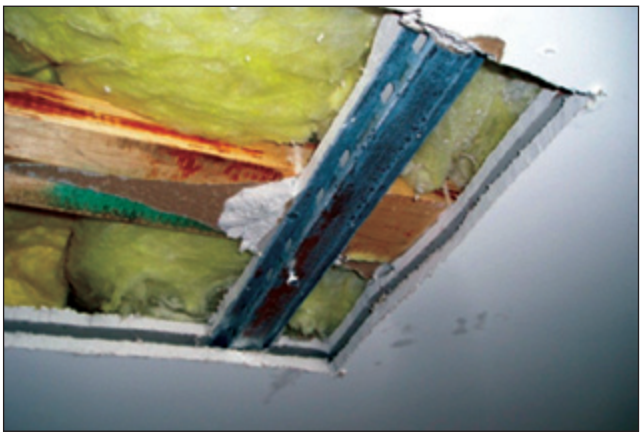

Figure 2. Resilient channel "sandwiched" between layers of gypsum board in original ceiling.

Figure 3. Double-screwed ceiling resilient channel (in original ceiling).

used, raising the existing floor height and causing problems with toilets, bath tubs, cabinets, etc.

Since resilient channel was known to be installed incorrectly and would need to be removed and replaced anyway, modifying the ceiling design was a more sensible approach than trying to address the problem by correcting only the floor or both the ceiling and the floor. This decision was supported by the conjecture that when evaluated separately, a feasible ceiling could be designed to sufficiently resolve the problem, while the same could not be said about the performance of a feasible floor modification alone.

Mitigation Design Options. Three remedial mitigation options (presented below) were developed and presented for consideration, each of which would provide the required minimum 45 FIIC rating. While FIIC data for the specific floor/ceiling system designs was not available (since the floor underlayment was unknown), estimations of the performance of each option were made based on test data for similar floor/ceiling systems.

- **Option 1:** Two layers of 5/8-inch Type X gypsum board attached to hat channel suspended in isolation clips attached to the joists (estimated 45 to 50 FIIC).
- **Option 2:** Two layers of 5/8-inch Type X gypsum board attached to a hat channel/cold-rolled channel (CRC) grid suspended on spring isolators attached to the joists (estimated 50-53 FIIC).
- **Option 3:** Same as Option 2, replacing the 5/8-inch Type X gypsum board with "sound engineered" gypsum board (estimated 50-55 FIIC).

Option 3 was selected due to the highest expected performance of the three. Following the selection of a remedial design option, spring-load calculations were completed to ensure proper load distribution throughout the entire grid system, verifying that no spring would be over- or under-loaded when accounting for the weight of the sound-engineered drywall and the grid structure materials. (The spring layout design was confirmed by the spring manufacturer; see Figure 4 for spring installation details.)

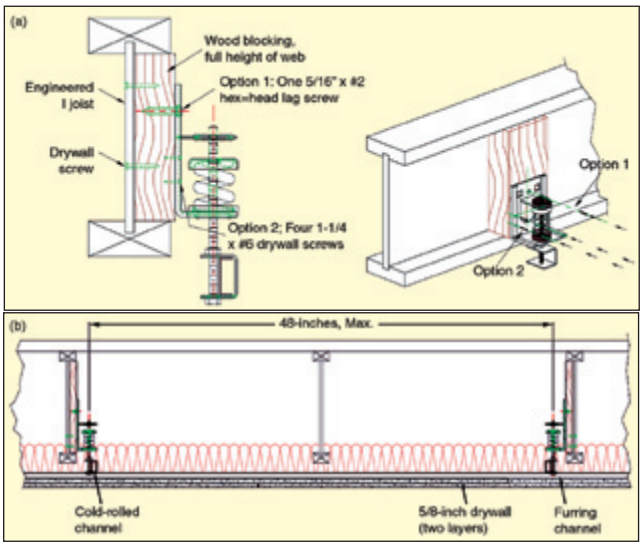

Figure 4. Spring and grid installation (courtesy of Kinetics Noise Control.

Demolition and Installation Guidelines. In addition to designing the remedial floor/ceiling system, guidelines were developed to instruct contractors on the demolition of the existing ceiling and installation of the spring-isolated grid. This included instructions detailing removal of existing drywall, particularly around room perimeters, and installation of springs and the ceiling grid.

Construction drawings were developed indicating the load capacity required at each spring location, distance requirements between springs, distance from springs to structural elements, and prospective locations of a furring channel. Furring channel locations shown were suggested locations; actual furring channel layout was left up to the judgment of the contractor based on their understanding of what would be required to support the ceiling gypsum board. Details were also provided for isolating the grid system from elements such as sprinklers, recessed lights, electrical boxes, and bulkheads.

Prototypes

Before committing to installing the remedial mitigation design in all condo units, three units were chosen as prototypes to test the design's effectiveness, as its performance had been based upon estimates of similar floor/ceiling systems. FIIC ratings were measured in all three units (Unit C, D, and E data shown in Figure 1) prior to demolition to compare the pre- and post-mitigation data.

Inspections. The existing ceiling was completely removed from the three prototype units and the spring grid was installed (springs, CRC, and furring channel), stopping prior to hanging the ceiling gypsum board. At this time, a thorough inspection was conducted to verify proper installation of the spring grid, paying attention to the following:

- Correct spring in the correct location
- Spring alignment
- Proper spring compression
- Distances between springs
- CRC and furring channel isolated from the room perimeter
- Secure CRC and furring channel installation
- Ceiling elements (sprinklers, HVAC vents, etc.) properly isolated from the grid
- Sufficient insulation throughout the ceiling cavity

The inspection was conducted to identify any elements that would either prevent springs from compressing once the gypsum board was installed or compromise the ceiling's isolation from the rest of the structure. Installation errors were identified and corrected shortly after the inspection, then reinspected before approving the grid system for installation of ceiling gypsum board.

Post-Mitigation Testing. FIIC ratings of the three prototype units were measured one week after the pre-gypsum board inspections, revealing FIIC ratings of 48, 49, and 48, and FIIC value increases of 13, 18, and 17, respectively. (Pre- and post-mitigation data are shown in Figures 5, 6, and 7.) Each of the three prototype units

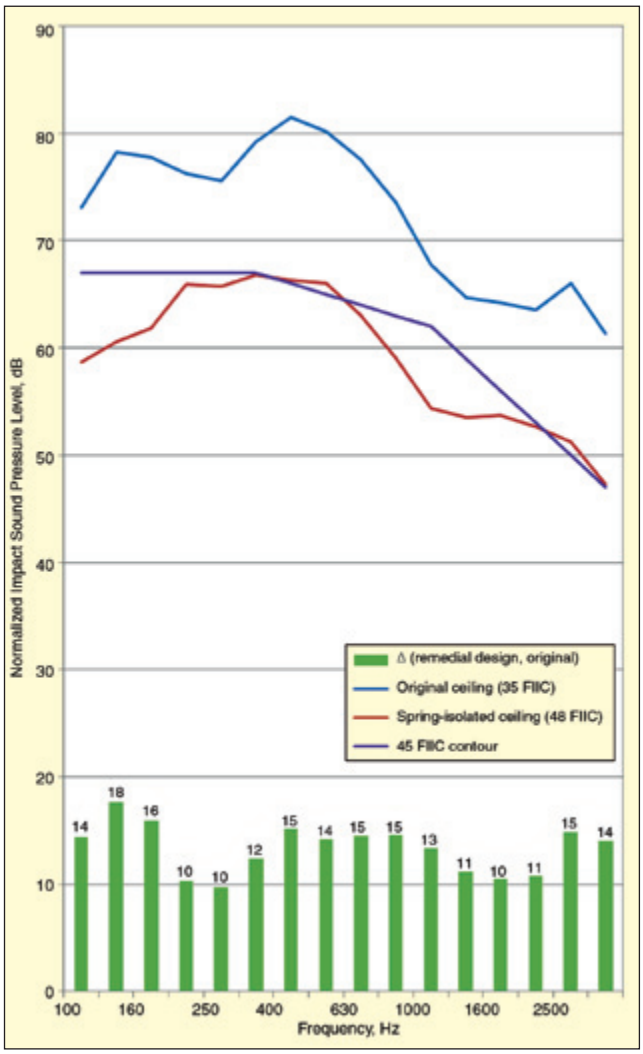

Figure 5. Pre- and post-mitigation test results (Unit C).

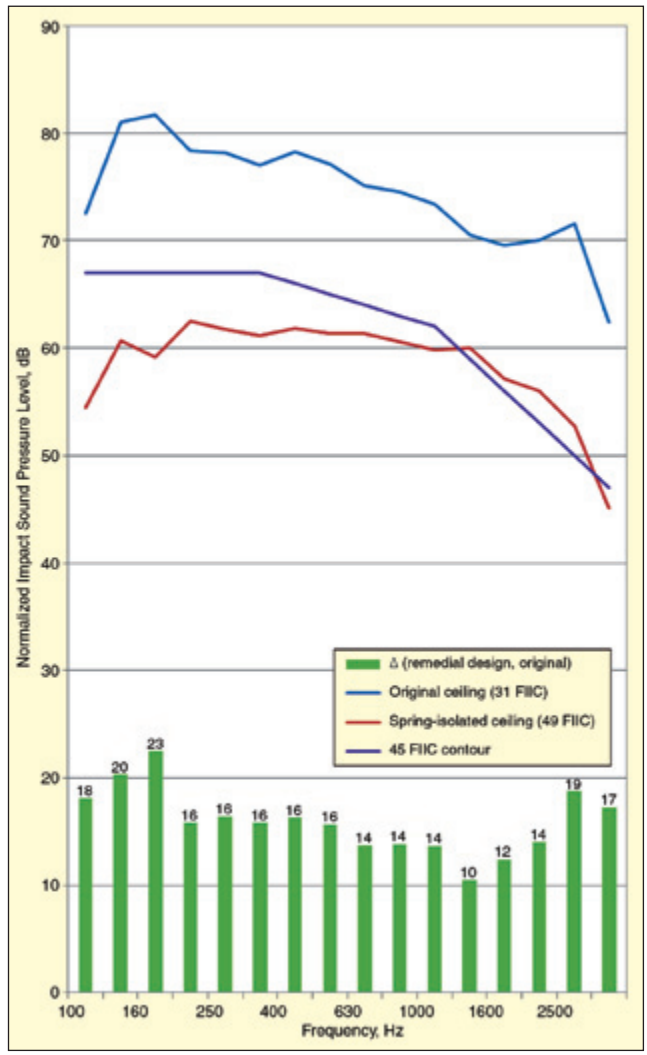

Figure 6. Pre- and post-mitigation test results (Unit D).

now met the building's 45 FIIC requirement.

When conducting FIIC testing on the existing ceiling, tapping machine noise sounded as though it was radiating from the entire ceiling. Following the installation of the spring isolated ceiling, residual tapping machine noise clearly sounded as though it was being radiated from the walls in the receive room and not through the ceiling, indicating that the ceiling was no longer the primary noise transmission path between condo units on different floors.

Full-Scale Production

Following the favorable test results, and more importantly test results in compliance with the building's FIIC requirement, the decision was made to install the spring-isolated ceiling system in all 100+ condo units. This decision was supported by the positive testimony received from the owners of the three prototype condos.

Scheduling. A schedule was devised by the ceiling contractor to install the grid system in a certain number of condo units per week, ranging from one to eight units. All condo units were completely furnished, therefore possessions had to be moved from each unit, stored, and then moved back in following the ceiling completion.

The entire process, from the move out to the move in date, was typically one month for each unit. All moving in and out of condo units was coordinated by the ceiling contractor and done in the presence of the condo owner to verify that all possessions, walls, floors, etc., had not been damaged.

Demolition and Installation. After removing all condo possessions, all remaining condo surfaces and fixtures were protected. Walls were coved in plastic, plywood sheets were laid over all flooring, and cabinets, and sinks, toilets, etc. were boxed in with plywood (see Figure 8). The existing ceiling was then removed and the springs and spring grid were installed. Following the installation of the grid system, ceiling gypsum board was installed and the entire ceiling was painted.

Crown molding was also installed and painted in all condo rooms to hide the gap (necessary for the ceiling to remain isolated from the walls) from the suspended ceiling gypsum board. All ceiling fixtures were then reinstalled and possessions were moved back into the unit.

Grid Inspections. All condo units were inspected by Phoenix Noise & Vibration prior to installing ceiling gypsum board. These inspections were requested to verify that each spring-isolated grid was properly installed and would function as intended (providing a minimum 45 FIIC rated floor/ceiling system). The units were inspected once to identify any installation errors, the errors were corrected by the contractor, and the grids then reinspected on the same visit so that each unit could be certified ready for gypsum board installation.

Additional field testing was not conducted after the three prototype units were tested and found to comply with the FIIC requirement. Since the prototype testing proved the acoustical integrity of the remedial ceiling design, grid inspections were conducted in lieu of full pre- and post-mitigation testing. As long as each grid was inspected and found to be properly installed, testing was not required to verify that each grid system was capable of providing the necessary structure borne noise isolation.

During the inspection of the first four grid systems, many installation errors were found, and much time was spent educating installers of the grid system during the first inspections on correct and incorrect installation procedures. The number of errors found in each unit gradually decreased as the grid installers became more experienced installing the grid system and more aware of the critical aspects of the design.

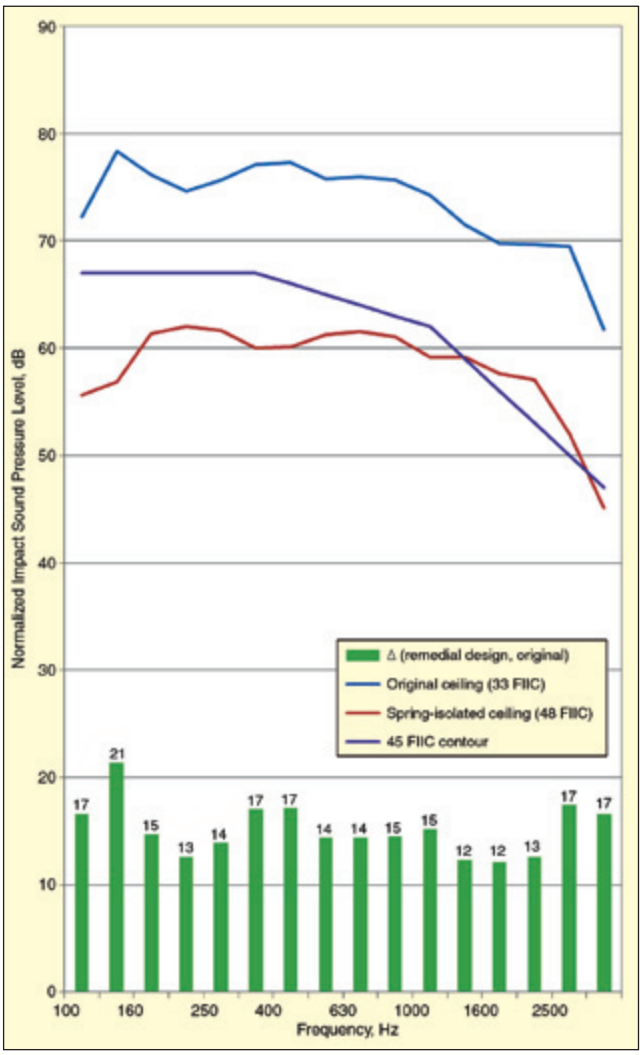

Figure 7. Pre- and post-mitigation test results (Unit E).

Inspection time also gradually decreased as inspection methods became more efficient. Several tools were used during the inspection process; these included:

- Color-coded floor plan to verify spring colors and record errors.
- Spray paint to indicate errors to the contractor.
- Flash light and telescopic mirror to check hard-to-reach springs above kitchen cabinets.
- Custom-designed pole with a hook to pull springs when checking for compressibility.

Conclusions

The last condo unit was recently completed, and the occupants' belongings were moved back in. This project was a valuable experience for Phoenix Noise & Vibration and ended with some resolution for all those involved. The project was completed ahead of schedule and met with mostly positive testimony from condo owners who expressed satisfaction with their quieter condos in which the isolation from their neighbors was much improved, and much appreciation for correcting a problem that had once so negatively impacted their living environment.

Figure 8. Existing ceiling demolition and spring isolated ceiling installation.

The decision to develop a mitigation solution by modifying the ceiling rather than the floor proved to be the most practical design method for this particular incident; however, this may not be the feasible option for all projects. Many factors were considered before selecting the design approach, which was ultimately influenced and limited by the impact that the overall remedial process would have on the building's nonacoustic characteristics.

Much was learned from this project, primarily how to successfully develop and implement a remedial design, when limited by strict constraints, that satisfies the requirements and demands of multiple conflicting groups. This project was rewarding professionally and serves as a prime example of how costly ignoring acoustics during the design phase of development can be long after the product is completed and delivered.

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The author can be reached at: sharvey@phoenixnv.com.