FLANKING IN WAREHOUSE TO RESIDENTIAL CONVERSIONS

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1. Introduction

Brown Strachan Associates have been working on an increasing number of warehouse conversion projects over the past few years. In these projects, warehouses built in the early 1900's are being converted to artist live/work studios or condominiums. The units range from rental units for low-income tenants to luxury condominiums.

The warehouse original construction typically has floors of full cut wood studs on edge (2 x 4 or 2 x 6). Hardwood or fir floor finishes are common. Heavy wood beams and columns form the basic supporting structure. Exterior walls are generally brick. Developers generally wish to retain the wood floor and to expose the wood ceilings.

Structural cross-bracing is required for seismic upgrading in most of the buildings. Both square hollow structural sections and steel cable tension elements have been used for this purpose. These often run continuously between dwelling units.

Several flanking paths have been identified in these projects. The most significant path has been through the continuous wood floors where the wood studs are oriented perpendicular to party walls. This path is particularly noticeable in top floors with a continuous wood roof where the studs are lighter. Flanking through structural cross-bracing and air leaks between studs and at structural penetrations have severely limited the isolation.

The wood stud roofs provide limited isolation from roof decks to top floor suites. Both impact noise and airborne transmission are concerns.

Treatment recommendations have included a concrete topping and isolated drywall ceiling. Partial cuts in the continuous wood floors were investigated where existing wood floor were required for architectural reasons. Generally, drywall ceilings are required to meet the STC 50 Code requirement between spaces in buildings. The Code Section 9.11 "Sound Control" does not cover roof decks.

2. Preliminary Measurements

2.1 Site #1

This project was a conversion to artist live/work studios. The floor construction was full cut 2 x 6 wood studs on edge running perpendicular to the party wall, with maple decking and plaster on the underside. The proposed wall construction was 3 1/2", 25 ga. steel studs, with two layers of 1/2" drywall on each side and 3 1/2" Fiberglas insulation in the cavity. Test data indicated STC 51 and STC 54 for this construction. A test suite was constructed to evaluate the floor and other flanking transmission paths.

Testing indicated that the floor isolation was NIC 30 with low frequency deficiencies between 160 Hz and 250 Hz. The measured wall isolation was NIC 35. Mid frequency deficiencies between 250 Hz and 1000 Hz were attributed to air leaks between the wall and adjacent columns.Vibration measurements indicated that flanking in the continuous floor and roof accounted for the low frequency deficiencies.

Later tests between rooms with an exposed wood roof of full cut 2 x 4's on edge perpendicular to the party wall indicated NIC 35. The isolation at 250 Hz to 300 Hz was only 25 decibels, which is characteristic of coincidence in 2 x 4's. Where the wood studs were parallel to the party wall, NIC 39 was measured, with 32 decibels at 250 Hz to 300 Hz. While these tests were affected at high frequencies by air leaks, they indicate the severe limitation of continuity in 2 x 4's oriented perpendicular to a wall.

2.2 Site #2

Flanking in a continuous wood roof constructed of 2 x 3's on edge was measured in a condominium conversion project. Double stud party walls were used and floors had 2" (nominal) concrete topping. The measured isolation between adjacent suites was NIC 43. High frequency isolation was limited by air leaks while reduced low and mid-frequency performance was attributed to continuity in the roof. Flanking was also present in structural cross-bracing which penetrated the party wall.

A further limitation of the lightweight wood roof was poor isolation from a common roof deck above the suite. The measured noise reduction between the deck and the test suite was NIC 32. High frequency flanking was also present (through exhaust ductwork) but the major limitation was the lightweight construction.

Impact Isolation Class (IIC) tests were not carried out but footstep impacts were clearly audible in the suite below.

2.3 Site #3

Site #3 had a floor construction of full cut 2 x 6's on edge (parallel to the party wall) with a fir finish. The wall plates were supported directly by the 2 x 6's. The party wall construction was a double row of 2 1/2" steel studs separated by a 1" airspace, batt insulation and two layers of 1/2" drywall on each side. Tests indicated that the isolation through the party wall with floor joists oriented parallel to the wall was FSTC 50 and 52. The isolation through the floor was FSTC 34, with deficiencies from 250 Hz to 2000 Hz.

3. Treatment Options

Air leaks were typically sealed with silicone caulking and careful attention to detail.

The transmission loss of the floors was improved to meet the Code STC 50 using a suspended drywall ceiling. The suspended ceiling construction at site #1 (without a concrete topping) was two layers of 1/2" drywall with a nominal 6" air gap. The metal framing was rigidly attached to the existing (12" deep) perimeter beams and the cavity was insulated with R12 home insulation. A central neoprene isolator support was provided on larger spans (15 ft.). The measured isolation was FSTC 52. A concrete topping alone generally increases the rating to about STC 46 and a concrete topping with a single drywall ceiling to about STC 54.

An initial treatment to reduce lateral flanking in the continuous floors was to use a concrete topping. Because of other flanking paths, the effect has not been determined. Provided the concrete is broken at the party wall line, the predicted isolation is about FSTC 50 with a separate stud wall (STC 55).

When a concrete floor topping was considered unacceptable at site #1, a 50% cut in the floor joists was recommended to reduce the bending stiffness to 1/8. A limitation in the cut depth was the (seismic) floor plate integrity. Allowing for a 3 decibel build-up in floor vibration resulting from changed boundary conditions, an improvement of 15 decibels was anticipated in the lateral floor transmission (NIC 35 to NIC 50). Beranek predicts a minimal reduction in reflection losses for a 50% cut based on considerations of the transversal forces, the transversal velocities, the moments and angular velocities on both sides of the junction. After minimizing airborne flanking, NIC 47 was eventually achieved. The difference between theory and measured results is attributed to the support beam minimizing vertical (shear) motion at the cut but more work is required in this area.

A 100% cut in the floor joists has been recommended at site #3 where the joists run perpendicular to party walls. To maintain the integrity of the floor as a horizontal shear plate, the structural consultant has accepted steel angles between the underside of the floor and the heavy timber beams. This detail has not been tested but experience indicates STC 50 should be achieved.

At site #2, a suspended ceiling in the top floor units was not an acceptable treatment to control footstep noise from the rooftop patios. As an original attempt to control impact noise into the roof, the patios had been built as a 2 x 6 frame spanning between shims located above the existing structural beams, about 15' o.c. The finish was 2 x 4's on the flat. The roof had 3" of styrofoam insulation and the shims were resting on 24" x 24" pavers to spread the load over the insulation. The calculated resonant frequency of the assembly was about 500 Hz due to the very light dead load and high insulation stiffness.

Concrete pavers (24" x 24" x 1 1/2") were investigated as a means of lowering the resonance. Tests were conducted with the blocks directly on the existing deck and isolated from the deck by SCE 41 neoprene strips. The concrete blocks alone reduced footstep peaks above 315 Hz by 3-5 dB. Isolating the pavers with neoprene reduced peak levels by about 10 dB (approximately to background levels), including low frequencies. Eventually, this treatment was considered impracticable.

Airborne flanking through the structural cross-bracing was attenuated by sealing the open ends of the hollow structural sections with drywall and caulking. This treatment also controlled dust migration from the basement. It was suggested that the cross-bracing be filled with sand to provide damping of structure-borne noise. This treatment was not evaluated (because of the volume of sand required in the top floor suite).

4. Conclusions

The most difficult flanking path to treat is lateral flanking through continuous wood joists, where the joists are oriented perpendicular to party walls. Isolation is reduced to about NIC 35 in some cases. A 1 1/2" concrete topping appears to be an effective treatment. Where it is necessary to preserve the existing wood finish, a significant floor cut is necessary acoustically but may not be acceptable structurally. A 100% cut with steel angles attaching the floor to the beams may be an option. This treatment is relatively expensive and requires testing but is justified when considered against the cost of a downtown condominium in a heritage building.

Suspended drywall ceilings have proven very effective to meet STC 50 and may be applied between the existing wood beams to minimize the impact on the heritage look. However, a concrete topping is considered the best fundamental treatment to minimize impact noise and floor "squeaks" in an old building.

Careful attention must be paid to sealing air leaks, particularly where partitions meet structural elements. Flanking paths should be identified and corrected before occupancy to minimize negative reaction from residents.

5. References

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United States Gypsum Company (1984), *Design Data for Acousticians*

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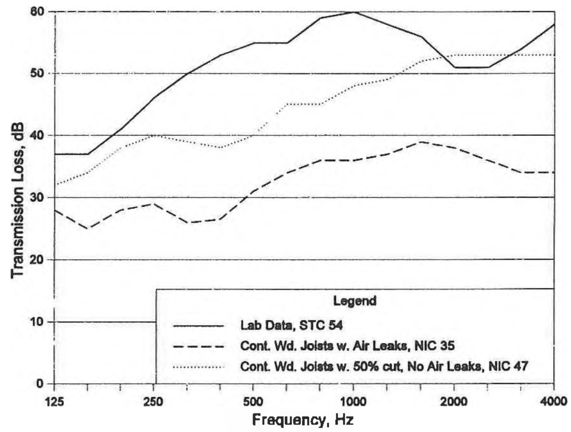

Figure 1: Effect of Flanking on Party Wall Performance

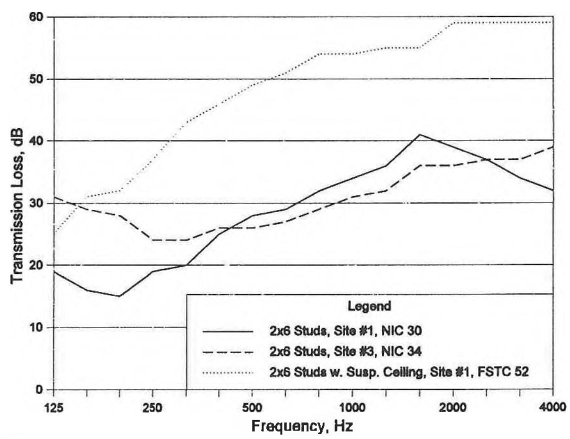

Figure 2: Effect of Suspended Ceiling Treatment