Fire Protection

CANADIAN STEEL CONSTRUCTION COUNCIL

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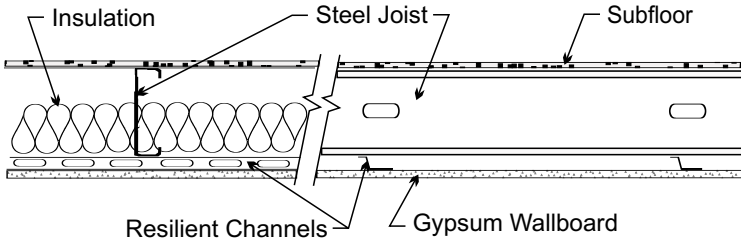
FIRE-RESISTANCE AND ACOUSTIC RATINGS FOR COLD-FORMED STEEL FRAMED FLOOR ASSEMBLIES

Introduction

The National Building Code of Canada (NBCC) is the model code for the construction and renovation of all buildings in Canada, regardless of occupancy or size. This code specifies the structural and fire protection requirements that enable prescribed minimum levels of occupant safety to be achieved. All provinces either adopt the NBCC without change, or use it as the basis for their provincial code.

The steel industry has a long history of establishing standards and conducting tests to meet these codes. The latest series of tests that form the subject of this Bulletin were conducted by the National Research Council of Canada (NRCC) and describe new generic fire-resistance ratings and acoustic ratings for steel framed floor assemblies using cold-formed C-section steel joists, suitable for all types of small building construction up to six stories, including residential.



Section of typical floor assembly using cold-formed steel joist

The advantages of cold-formed steel construction are numerous, and include:

- dimensional stability (no warping or twisting);
- resistance to termites and other insect infestation;
- light weight;
- ease of construction;
- the use of predominantly recycled materials;
- excellent economics.

However, this type of construction has often been perceived as offering reduced fire safety and increased noise transmission, important factors in residential construction. The tests described in this Bulletin show that cold-formed steel floor construction meet or exceed all relevant Code requirements for both fire and noise resistance.

Residential Construction

Buildings intended for residential (Group C) occupancy are designed using either Parts 3, 4, 5 and 6 of the NBCC or Part 9 of the NBCC depending on the size of the building. Part 9 - Housing and Small Buildings - contains detailed prescriptive requirements for such topics as fire protection and structural safety that are based on Part 3 - Fire Protection, Occupant Safety and Accessibility - and Part 4 - Structural Design – but useable without the services of an architect or engineer. Part 9 only applies to buildings which are 3 storeys or less, do not exceed 600 m^2 in area and contain Group C, D, E, F2 or F3 occupancies. Buildings of greater size or containing occupancies not permitted in Part 9 require the services of a design professional and must comply with Parts 3, 4, 5 and 6.

Most of the design criteria in Part 9 is based on long-standing historical practice in (predominantly) wood framed residential and small building construction. The program described in this Bulletin helps to expand the concept of Part 9 to include light steel framing.

CSCC

Algoma Steel Inc. Dofasco Inc. Ispat Sidbec Inc. Stelco Inc.
Canadian Fasteners Institute Canadian Institute of Steel Construction Canadian Sheet Steel Building Institute
Canadian Steel Service Centre Institute Corrugated Steel Pipe Institute Canadian Welding Bureau (Associate Member)

When fire and acoustic ratings are required

To limit the spread of fire and the likelihood of structural collapse during a fire emergency, both Parts 3 and 9 require certain walls and floors to have a fire-resistance (FR) rating based upon the size, occupancy and type of construction. Both Parts also prescribe minimum sound transmission class (STC) ratings in buildings with multiple dwelling units. The following summarizes the fire safety and acoustic requirements relating to non-high rise residential (Group C occupancy) buildings:

FR Rating	Design	Group C Construction Elements	Fire Separation[2]	NBCC Reference
2 h	Part 3	Floors[1] and walls separating Group C from Groups B1, B2, E, F2 Occupancies	Yes	Table 3.1.3.1.
	Part 9	Floors[1] and walls separating Group C from Groups E, F2 Occupancies	Yes	9.10.9.11.(2)
1 h	Part 3	Floors[1] and walls separating Group C from all other permitted Occupancies	Yes	Table 3.1.3.1.
	Part 9		Yes	9.10.9.11.(1)
	Part 3	Floors[1] in Buildings up to 6 storeys, except wholly within dwelling units	Yes	3.2.2.43. to 3.2.2.46.
	Part 3	Floors[1] in Buildings up to 6 storeys, wholly within dwelling units	No	3.2.2.43.(3) to 3.2.2.46.(3)
	Part 3	Floors[1] and walls separating suites from each other and remainder of building	Yes	3.3.4.2.(1)
45 min	Part 3	Floors[1] in Buildings up to 3 storeys, except floors wholly within dwelling units	Yes	3.2.2.47., 3.2.2.48.
	Part 9		Yes	9.10.8.1.
	Part 3	Floors[1] in Buildings up to 3 storeys, wholly within dwelling units	No	3.2.2.47.(3), 3.2.2.48.(3)
	Part 9		No	9.10.9.4.(2)
	Part 3	Floors[1] and walls separating suites from each other and remainder of building	Yes	3.3.4.2.(2)
	Part 9		Yes	9.10.9.14.(1)

Notes: 1) Supporting construction (walls, columns, arches) must have same FR rating. 2) No unprotected openings.

STC Rating	Design	Acoustic Separation of Dwelling Unit	NBCC Reference
50	Part 3	From any part of building where noise generated	3.3.4.6.(2)
	Part 9		9.11.2.1.(1)
55	Part 3	From elevator shaft or refuse chute	3.3.4.6.(3)
	Part 9		9.11.2.1.(2)

Goal of Program

The steel industry, through the Canadian Sheet Steel Building Institute (CSSBI), has already developed a large series of non-loadbearing cold-formed steel framed wall assemblies that achieve the required FR and STC ratings for a very wide range of design situations for Part 9 buildings. These are listed in Table A-9.10.3.1.A. Table A-9.10.3.1.B. gives FR and STC ratings for a limited selection of floor assemblies, including an assembly using open web steel joists. The goal of the program described in this Bulletin is to eventually extend this Table to encompass a wide range of cold-formed steel framed floor constructions.

The intent of NBCC Part 9 has always been to prescribe construction materials and assemblies that are as generic as possible - i.e. any materials, manufacturer's products or methods of construction that meet Part 9's minimum prescriptive requirements may be used (unlike Listed Designs, which often specify the products used by name). With the inclusion of a sufficiently large number of variations in construction details, virtually any design situation can be accommodated while still meeting all fire and acoustic rating requirements.

Fire ratings

Outline of tests

The full details of the fire-resistance tests conducted at NRCC are contained in the report entitled "Results of Fire Resistance Tests on Full-Scale Floor Assemblies", by Sultan, Seguin and Leroux. Eighteen companies and organizations contributed to or participated in this program, including the CSSBI. Thirty-two tests were conducted, of which five involved cold-formed steel C-section joists with a plywood subfloor, and one was a composite steel deck/concrete floor assembly without any joists. The remaining tests used solid wood joists or wood I-beams.

Description of steel joist assemblies

All the cold-formed steel joist floor structural details used in the fire tests were essentially identical. The main differences within these assemblies occurred in the construction of the finished ceiling, where various combinations of drywall thicknesses, as well as the types of insulation, were tested. All tests used resilient channels for installing the drywall ceiling. (Resilient channels are actually Z-sections attached to the structure by one flange only, leaving the other flange freely suspended.)

Other variations between the individual assemblies included joist spacing, with and without cavity insulation, the placement of the insulation in the cavity, and variations in subfloor installation procedures. One test consisted of a steel deck with a concrete topping, with no joists.

Testing procedures

All 32 fire tests were conducted in accordance with the standard testing procedures laid out in CAN/ULC-S101-M89, Standard Methods of Fire Endurance Tests of Building Construction and Materials. This means that the standard time-temperature curve was adhered to in all tests, even though this results in the testing furnace having to be turned down during the wood framed tests to compensate for the contribution to the fuel load from the combustible wood joists. In a real fire, such compensation of course does not exist.

The test standard also calls for the test assemblies to be loaded to their full design capacity, and this was achieved by means of a hydraulically-operated distributed pad system.

Results

An analysis of the results of all 32 tests shows that cold-formed steel joist floors generally either equal or outperform their wood joist counterparts in terms of fire-resistance. Table 1 of the NRCC report details the fire-resistance ratings achieved. The modes of failure were listed as being either structural, or by flame penetration through the sub-floor, which was usually plywood. No steel framed assemblies failed due to flame penetration through the sub-floor.

The ceiling finish consisted of either one or two layers of gypsum board fastened to resilient channels.

The following table summarizes the steel test results:

Test No.	Steel Joist		Layers of	Sub-Floor		Cavity Insulation		Fire Resistance
	Size (mm)	Spacing (mm)	Type X Drywall	Type	Thickness	Type	Thick-ness	(minutes)
FF-22	203 x 1.22	406	2 x 12.7 mm	Plywood	15.9 mm	—	—	74
FF-23	203 x 1.22	406	2 x 12.7 mm	Plywood	15.9 mm	G1	90 mm	68
FF-24	203 x 1.22	610	2 x 12.7 mm	Plywood	15.9 mm	G1	90 mm	69
FF-25	203 x 1.22	406	1 x 12.7 mm	Plywood	15.9 mm	R1	90 mm	46
FF-27	203 x 1.22	406	2 x 12.7 mm	Plywood Concrete	15.9 mm 38 mm	G1	90 mm	60
FF-26	76 mm Composite Steel Deck		2 x 12.7 mm	76 mm Concrete cover		—	—	105

Notes: 1) G1 = Glass fibre insulation batts. 2) R1 = Rock fibre insulation batts. 3) Resilient channels were used to support the gypsum wallboard in all assemblies and were installed at 406 mm on centre perpendicular to the joist span. 4) Insulation, when installed, was located in the bottom of the floor cavity.

The above results show that the steel joist assembly tested with one layer of drywall to the ceiling achieved a 46 min fire-resistance rating - enough for a 3 storey Group C building. The steel joist assemblies with two layers of drywall achieved an endurance of 60 min or more - enough for a 6 storey Group C building.

The NRCC report lists a number of conclusions drawn from the tests that illustrate the effect, if any, that specific variables would have on the fire endurance of floor assemblies in real buildings. The most important of these variations are:

- The type of subfloor (oriented strand board or plywood) had no effect on fire endurance.
- Fire-resistance can be improved by locating drywall ceiling screws no closer than 38 mm from the board edge (all steel assembles used 38 mm). The type of screw had some effect on fire-resistance (Type G screws helped to hold the face layer to the base layer at the butt ends).
- Glass fibre batt insulation in the floor cavity generally reduced the fire-resistance, while rock fibre insulation generally (but not always) increased it. For assemblies with two layers of drywall, all types of insulation generally (but not always) reduced fire-resistance.
- A second layer of drywall significantly increased fire-resistance.
- In certain wood I-beam assemblies, joist spacing affected fire-resistance, while joist spacing had no effect with steel joist assemblies.
- The addition of a concrete topping over the plywood subfloor reduced fire-resistance.

Acoustic ratings

Outline of tests

The acoustic tests were conducted using the same assemblies that were later used for the fire tests. The results of this part of the program are contained in the NRCC report entitled "Summary Report For Consortium On Fire Resistance And Sound Insulation Of Floors: Sound Transmission Class And Impact Insulation Class Results", by A.C.C. Warnock and J.A. Birta.

Two distinct acoustic tests were conducted for each assembly, the first being a sound transmission class (STC) rating, and the second being an impact insulation class (IIC) rating. Although the NBCC currently requires STC ratings in buildings with multiple dwelling units, at this point in time IIC ratings are not used. The STC and IIC ratings were determined in accordance with appropriate ASTM standards.

Results

As the acoustic tests were non-destructive, many more of them (113) were conducted than for the fire tests, and the results obtained were much more complex and varied. In fact, the report by Warnock and

Birta cautions that there are still a number of unanswered questions to be resolved when generating tables for building codes, especially in respect of wood I-joist floors, where large anomalies in STC and IIC results were encountered.

The majority of the tests (99) were conducted on wood framed assemblies, The large number of variables in these wood framed assemblies precludes summarizing their results in this Bulletin, except to note that over 20% achieved STC ratings of less than 50.

The results obtained for the 14 tested steel joist assemblies show that 13 achieved an STC rating of 50 or more, the exception being one uninsulated assembly, which achieved an STC rating of 44. All assemblies used cold formed C-channel joists 203 mm deep, of 1.22, 1.52 or 2.05 mm thickness, with an oriented strand board subfloor of various thicknesses. All had a single layer of 15.9 mm drywall forming the ceiling, attached to resilient channels, and with glass fibre batt insulation in the cavity. Two tests incorporated a 25mm concrete topping, which improved the STC rating, but had a negative effect on the IIC rating.

Again, cold-formed steel framed floor assemblies were shown to perform equally as well as or better than their wood framed counterparts, in both STC and IIC ratings. In particular, all the insulated steel joist assemblies tested met or exceeded the 50 STC rating required in multi-unit residential occupancies.

As with the fire tests, various conclusions are drawn from the testing program that will affect STC and IIC ratings. The most important of these are:

- The sum of the masses of the floor/ceiling construction is the major factor controlling sound insulation.
- Resilient metal channels are required in all floors (wood or steel framed) to achieve STC 50. Steel U-channels or wood furring were tested and found to be markedly inferior. Without resilient channels, adding insulation to the cavity has very little effect.
- Increasing joist spacing, resilient channel spacing, and thickness and density of the sound absorption material, all improve sound insulation.
- Joist length, and tightness and number of screws attaching the subfloor to the joists, has no effect on sound transmission.
- Adding extra resilient channels (for example, at bay edges) increases fire-resistance, but reduces sound insulation.
- Over-filling the cavity with glass fibre batts makes no difference to the sound insulation.
- Very poor IIC ratings are encountered with floors with a concrete topping but no resilient surfacing.
- Steel joist thickness (gauge) has no significant effect on either STC or IIC ratings.

Some areas require further work. These include:

- Tests conducted with one layer of 12.7 mm gypsum wallboard show less variation than expected compared with one layer of 15.9 mm wallboard.
- The large variability with wood trusses and I-joists needs to be resolved.
- The influence of the effect of the resilience of the floor covering needs further study.

Practical Application of Results
Cold formed steel residential floor construction

Because the tests described in this Bulletin involve generic (non-proprietary) assemblies, variations can be made to the construction details in real practice, as long as these variations do not reduce the overall fire or acoustic performance of the total assembly (NBCC A-9.10.3.1.). To aid designers in ensuring that these minimum performance criteria are maintained when variations are made, for a number of years now the NBCC in Part 9 has included tables that have a sufficient number of assembly variations to satisfy most conditions likely to be encountered.

Table A-9.10.3.1.B. in the 1995 NBCC includes fire and sound resistance ratings of floors, ceilings and roofs for around 20 generic assemblies, including solid wood joist, wood truss, and open web steel joist constructions. Proposals for future editions of the NBCC will expand this number to over 200, based on the testing program described in this Bulletin. Of these, a large proportion will consist of cold-formed steel joists, with either a wood subfloor, or with steel pans and a 50 mm concrete topping, and with fire-resistance ratings of 45 min, 1 h or more. The NBCC Part 9 committees responsible for promulgating this section of the Code are currently working on such an expanded list encompassing a wide range of fire- and acoustic-rated steel framed assemblies.

Today's homebuilder does not, however, have to wait for a future edition of the NBCC (or its Provincial equivalent) to make use of these test results. NBCC Article 2.5.1.3. Equivalence Demonstrated by Past Performance, Test or Evaluation can be invoked to enable cold formed steel joist floor assemblies, based on those described in this test program, to be used today in the design of efficient and environmentally friendly steel framed housing and small buildings that meet all required fire and acoustic ratings.