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NOISE CONTROL THROUGH ROOFS

by Noral D. Stewart, Ph.D., FASA, FASTM, INCE

Stewart Acoustical Consultants

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Forward

Sound can be soothing, relaxing, invigorating and informative but it can also be disturbing, annoying, disruptive and even damaging if it's too loud, intrusive and unwanted. At that point, we call it noise, and try to control it. Between rooms, we can control intrusive noise by building barriers, usually with massive walls or multi-layered construction. Within spaces, we control noise with absorptive surfaces to keep the sound energy from reverberating.

When the noise source is from the exterior in the form of airplane, traffic or construction equipment, we can block it with monolithic, heavy construction. However, most commercial and residential construction is light weight steel or wood framing, and relatively transparent to sound. Around airports, there are numerous low sloped roof buildings, such as schools, hotels, apartments and assisted living facilities, which are greatly affected by the intrusion of unwanted noise.

Georgia-Pacific Gypsum recognized the need to isolate noise and conducted a series of sound isolation tests on roofing assemblies incorporating DensDeck® Roof Boards, at independent acoustic labs to document the performance of the assemblies. The results were impressive and can provide building owners several solutions to help control the problem of noise intrusion in their buildings.

We asked Noral Stewart, Ph.D., FASA, FASTM, INCE, Stewart Acoustical Consultants, to review the findings and put them in context with an overview of acoustic challenges in buildings.

Reinhard Schneider, AIA
Technical Manager
Georgia-Pacific Gypsum


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Today we see increasing trends to locate buildings in noisy areas near airports, highways, railroads, industrial areas, or entertainment and sports venues. Even in a quieter area, noisy equipment on a roof can cause problems within the building. Sometimes there is a need to contain sound such as loud music within a building. Recognizing these problems, regulations addressing outdoor to indoor sound transmission are becoming more common. For many years HUD (Housing and Urban Development) has had requirements for new multifamily residential structures in noisy areas. Special requirements have been established by local governments around many airports. The ANSI S12.60 standard for schools requires control of sound reaching classrooms from the outside where it is applied. The 2010 Facilities Guide Institute (FGI) requirements for health care facilities care address noise reaching facilities from the outside. With the growth of emphasis on sustainable design many of the LEED® (Leadership in Energy and Environmental Design, a U.S. Green Building Council Program) and other programs have recognized acoustical problems in early projects and now require that control of sound entering buildings be addressed or provide credits for doing so. Thus, it is becoming increasingly important that noise entering buildings through walls and roofs be addressed.

When considering outdoor noise intrusion or sound containment, the first thoughts of many usually involve windows. Windows are often the weak link especially when considered on the basis of sound transmission per unit area or when the room is not on a top floor. However, a factor often overlooked is the important contribution of the roof. Roofs are often very light weight and can be as weak as the windows. Once their large area is considered, they become the major path of sound intrusion or escape. This becomes especially important around airports; when noisy equipment is on the roof; or when there is a need to contain sound within a building.

This important contribution of the roof is often overlooked. It results in rooms on the top floor of a building being noisier than those on lower floors. This is a problem in itself because both regulations and users expect these top floor rooms to be as quiet as others. Actually in many cases the occupants of the top-floor spaces expect them to be quieter than spaces on other floors. For example, executive offices or the most expensive condominiums are often on the top floor. In normal building design, the windows and walls are no better on the top floor than on other floors, thus if the sound coming through the roof is even significant compared to that through the walls, these rooms will be louder. As a practical matter, the roof needs to be much better than the walls for blocking sound if the sound impinging on the roof is as great as that reaching the walls. This is the case for aircraft noise. Even if the roof is shielded from the primary outdoor noise sources as is often the case, the shielding may not be enough to allow it to be weaker than the walls without significantly increasing sound in the top-floor spaces. Spaces built to contain sound such as entertainment venues are often built with heavy walls. Unfortunately, the roof is sometimes overlooked, resulting in significant sound escaping to neighboring buildings.

A major concern in the design of roofs and roof-ceiling assemblies for sound blockage is the lack of test data to verify expected performance. Historically, there has been demand for test data on interior partition and floor-ceiling assemblies generated by regulatory requirements. Manufacturers of products used in these interior assemblies have sponsored tests at acoustical laboratories by ASTM E90. However, there has been less demand for such data on exterior walls and roofs from regulatory agencies and fewer tests have been conducted.

As interest in control of sound from the outdoors has increased for HUD projects and projects near airports, so has the demand for test data on façade elements. The strongest initial demand was for window data since the performance of seals must be verified. Window data are now widely available. Acoustical consultants assisting with the design of buildings in noisy areas have continued in most cases to estimate the expected performance of walls and roofs without verifying test data.

Recently, Georgia-Pacific Gypsum, manufacturer of DensDeck® Roof Boards, has sponsored a series of ASTM E90 tests of steel-deck roof and roof-ceiling assemblies with DensDeck roof boards added to the roofs under or over the thermal insulation material or both. Some of these assemblies included different absorptive materials between the roof and ceiling, and some had mineral fiber board rather than foam board above the roof. Two roof assemblies were tested without ceilings and the others had gypsum ceilings, in some cases with resilient sound isolation clips (RSIC). Acoustical consultants have been using these methods to improve roofs based on basic theoretical analysis, but without data to verify performance. While these tests provide important data for the tested assemblies, the information is also useful in estimating the performance of untested similar assemblies.

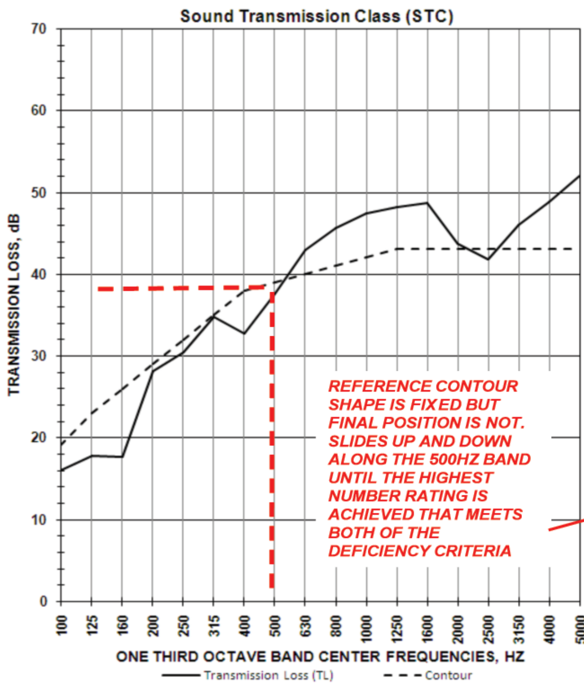
Upon request, acoustical consultants can obtain a copy of the test reports prepared by Riverbank Acoustical Laboratories for details of the assemblies and the detailed data for sound transmission as a function of sound frequency (contact techservices@gapac.com). Frequency is the characteristic of sound related to the perceived pitch. Low frequency sounds are in the bass range and have long wavelengths that are difficult to block. Thus, the blockage of sound generally increases with frequency, but this variation with frequency can be very different for different structures. The most accurate analysis of the noise reduction provided by a structure considers the frequency spectrum of the sound source and the blockage of sound at each frequency.

Methods have been developed to assign a single-number rating to the sound blockage of an assembly based on certain assumptions regarding characteristics of the source sound. These ratings allow comparison of assemblies as an initial screen to select candidates for further evaluation. However, just because two assemblies have the same rating does not mean they are equivalent in all regards. Two assemblies with the same rating can produce very different results when exposed to different sounds.

The most well-known of these ratings is the Sound Transmission Class (STC) which was originally developed for rating interior partitions. Due to the way the STC is determined, two assemblies with the same rating exposed to the same sound can produce very different overall A-weighted sound levels in adjacent spaces.

STC Calculation Background

Notice that increases in Transmission Loss (TL) above the final reference contour position does not improve the STC rating.



ASTM E413 - Classification for Rating Sound Insulation

1/3 Octave Band, Hz	STC Ref Contour	Deficiencies
100	19	3
125	23	5
160	26	8
200	29	1
250	32	2
315	35	0
400	38	5
500	39	1
630	40	0
800	41	0
1000	42	0
1250	43	0
1600	43	0
2000	43	0
2500	43	1
3150	43	0
4000	43	0
5000	43	0

Maximum Deficiency: 8 << 8 or less
Total Deficiency: 26 << 32 or less

STC 39

In the 1980's it became apparent to members of the ASTM committee that prepares the standards that the STC rating was very misleading when it came to rating exterior façade or roof assemblies for performance in the presence of typical outdoor noises. Transportation noises, outdoor mechanical systems, and music all have strong low-frequency components. It was observed that in the presence of such sources, assemblies with lower STC ratings sometimes provided more noise reduction than assemblies with higher STC ratings. There was no correlation between the STC and the ability of an assembly to block sound as measured by the overall A-weighted level. Criteria for reduction of outdoor sound reaching the inside are usually based on the A-weighted sound level.

Thus, in 1990, ASTM introduced the Outdoor-Indoor Transmission Class (OITC.) This rating is based on data from the same laboratory test used to establish the STC. However, the rating uses data at lower frequencies, and is based directly on reduction of A-weighted sound level. Thus, while two structures as always will perform differently when exposed to different sounds, two that have the same OITC will always give the same reduction in A-weighted sound level when exposed

to the same sound. The OITC rating is never greater than the STC and can be as much as 17 points less than the STC for some assemblies.

The OITC is the preferred method of comparison of façade elements including roofs for blockage of exterior sounds. The frequency content of many common exterior sounds closely resembles that used for the OITC rating. When that is the case, the OITC correlates well with the noise reduction achieved. This occurs for most road noise but an exception is high-speed freeway sound dominated by tire noise. While STC is specified in some regulations and guidelines, there is no direct correlation between STC and the noise reduction achieved with most exterior sources.

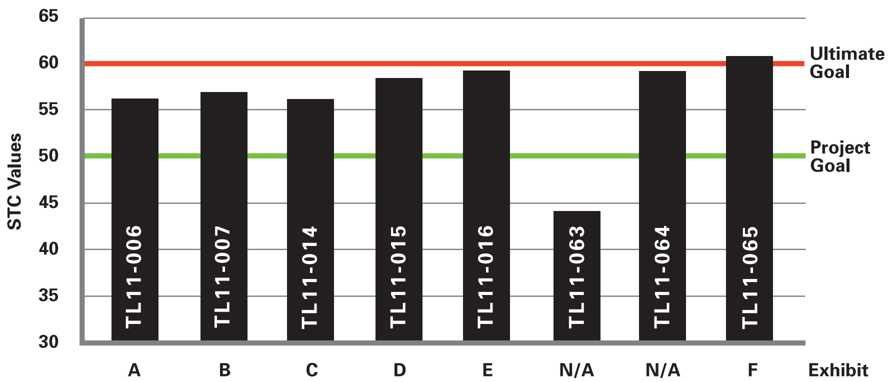
While the OITC is very useful in comparing constructions, the outdoor to indoor noise reduction also depends on the relationship between the area of structure exposed to the outside sound and sound absorption within the space. Further, when going from outdoors to indoors there is a factor of 6 dB that is lost in the noise reduction that does not occur between two interior rooms. Assume a simple case of a roof only exposed to aircraft noise (similar to the OITC spectrum) with no wall exposure, and interior space furnished similar to a typical residence or office. Then the outdoor to indoor noise reduction will be approximately 6 dB less than the roof OITC. When the roof and walls of multistory buildings are equally exposed, it is useful to make the roof much better than the walls so it does not add sound to the top floor.

Exhibits A-F are schematics of each roof assembly tested. Some assemblies have no ceiling, but most have gypsum ceilings, and in most cases the gypsum ceilings are isolated from the structure. Recognize that each assembly has only been built and tested once. It is common in repeated constructions and testing for results to vary +/- 2 points from the average value, and on more rare occasions the variation can be greater. Thus, some of these initial results could easily be 1 or 2 points better or worse than the average of many constructions and tests. Table 1 below shows the STC and OITC for each of the assemblies. Table 2 shows the results in chart form.

TABLE 1 RAL Testing on Sounds Assemblies with DensDeck® Roof Boards

TL11-	Exhibit	STC Rating	OITC Rating
006	A	56	42
007	B	57	43
014	C	56	41
015	D	58	43
016	E	59	44
063	TL11-065 with no ceiling or fireproofing (Control Test) NOT ILLUSTRATED	44	33
064	TL11-065 with one layer 5/8″ gypsum ceiling (Control Test) NOT ILLUSTRATED	59	46
065	F	61	49

TABLE 2 **DensDeck® Sound Testing Results**



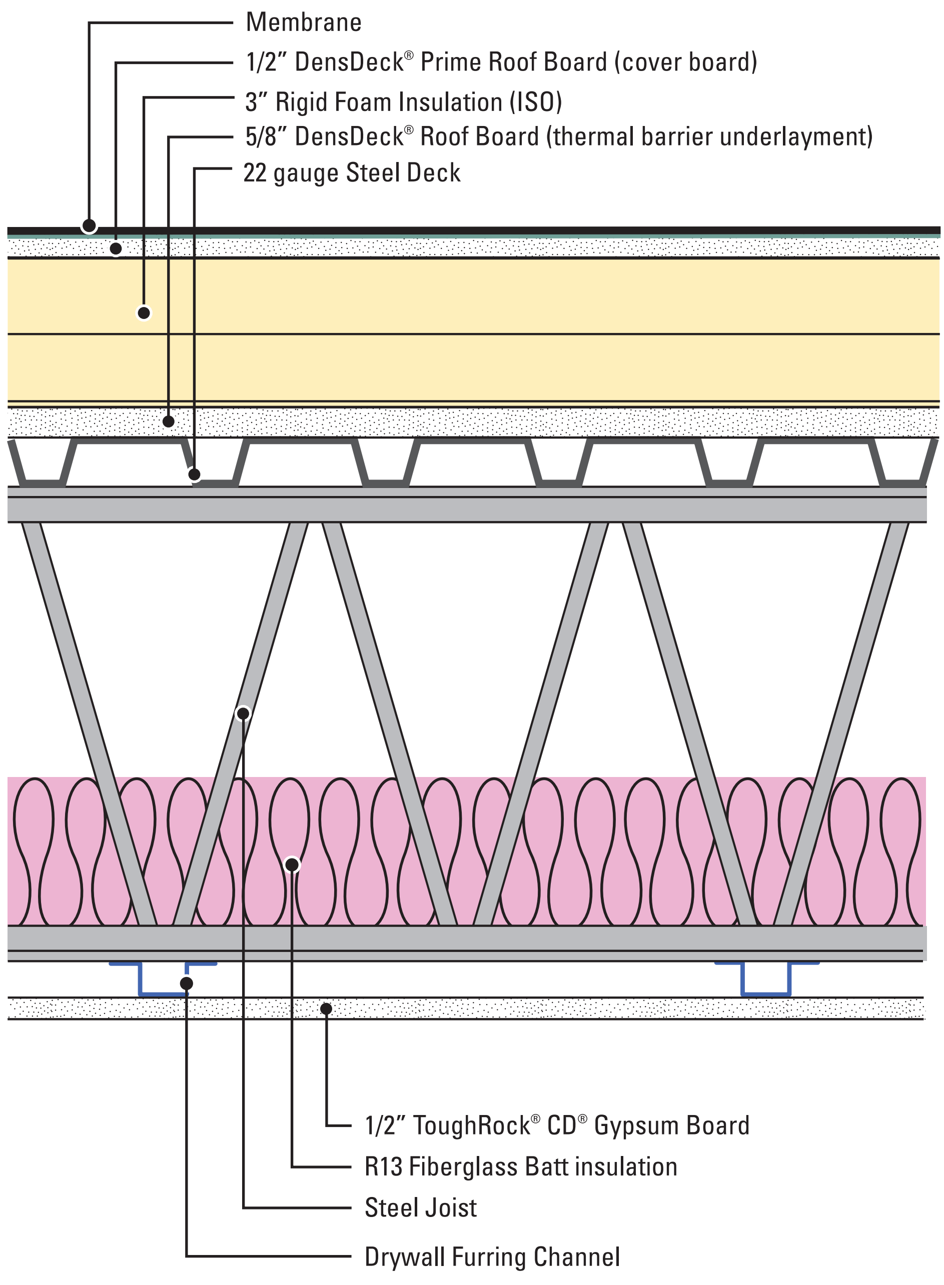
While these tests show a wide variety of conditions they do not illustrate all possible combinations. For assemblies without ceilings, mass is the primary factor influencing results and adding the DensDeck® panels to roof significantly increases mass and sound blockage. However, in theory a doubling of mass is needed for each 6 dB improvement. For much greater blockage than achieved with two layers of DensDeck boards, without a ceiling, a concrete roof is the common alternative. For greater blockage without much greater mass, a ceiling with a cavity can be very helpful. Performance is improved with deeper cavities and fewer connections between the ceiling and roof. Sound absorption in the cavity helps strongly when the cavity is small, and resilient attachment devices help strongly when there are many connection points or closely spaced joists. A lighter mass acoustical ceiling will not block as much sound as gypsum, but it has the advantage of adding absorption to the room which may compensate for the difference. In some situations a combination of a solid gypsum ceiling for blockage with an additional acoustical ceiling for absorption may be necessary.

With careful design, much improved sound isolation can be achieved using DensDeck boards on a roof. The results achieved in these tests are adequate for most buildings in most high-noise environments.

Exhibit A

STC=56

RAL#TL11-006



Tests per ASTM E 90 and ASTM E 413 were conducted in 2011 at Riverbank Acoustical Laboratories. Results are based on characteristics, properties and performance of materials and systems obtained under controlled test conditions. Actual results may vary. Assemblies are presented for illustration only. It is important that you consult a design professional for assembly information. Georgia-Pacific Gypsum does not provide architectural or engineering services.

Exhibit B

STC=57

RAL#TL11-007

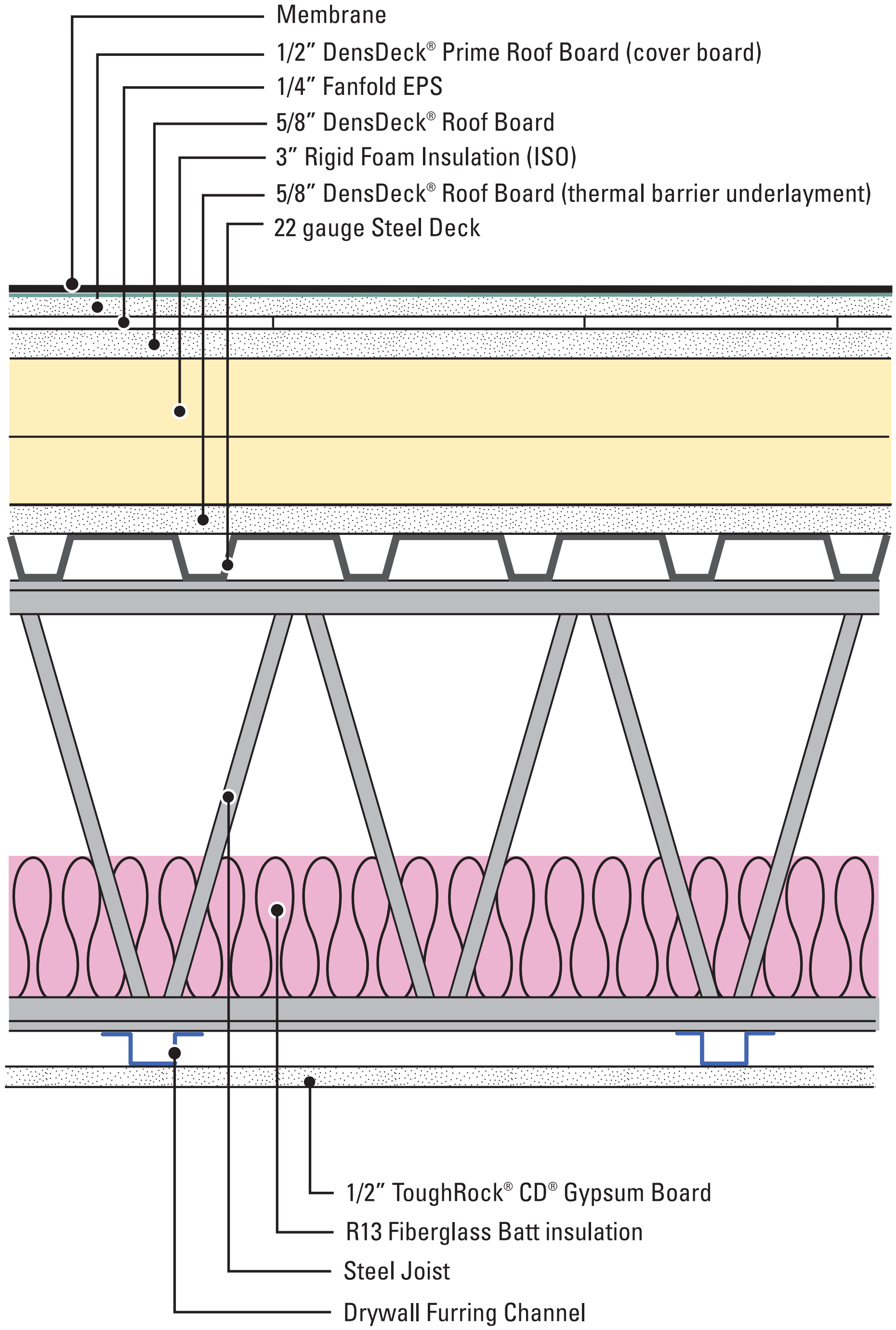


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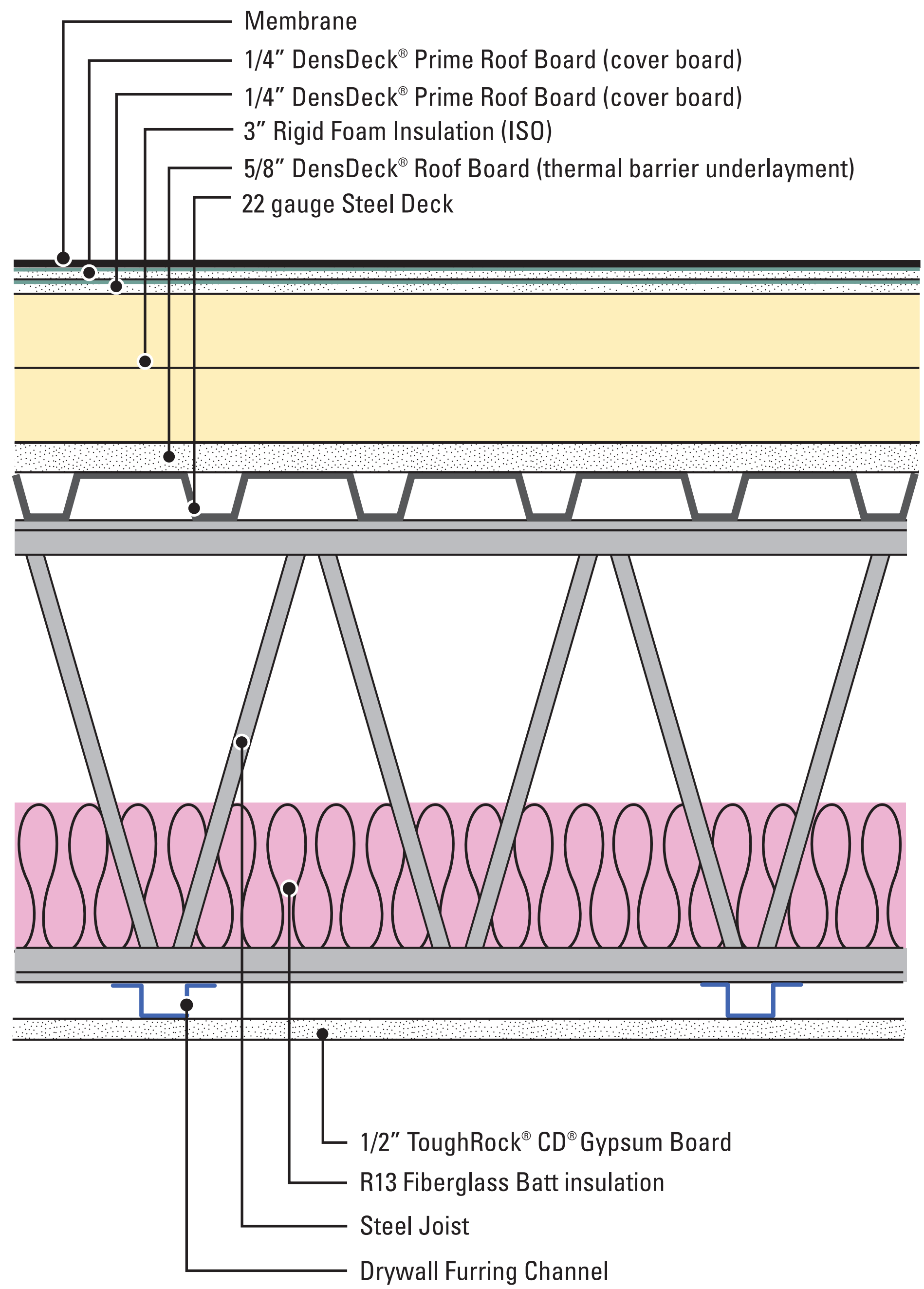
Exhibit C

STC=56

RAL#TL11-014



Tests per ASTM E 90 and ASTM E 413 were conducted in 2011 at Riverbank Acoustical Laboratories. Results are based on characteristics, properties and performance of materials and systems obtained under controlled test conditions. Actual results may vary. Assemblies are presented for illustration only. It is important that you consult a design professional for assembly information. Georgia-Pacific Gypsum does not provide architectural or engineering services.

Exhibit D

STC=58

RAL#TL11-015

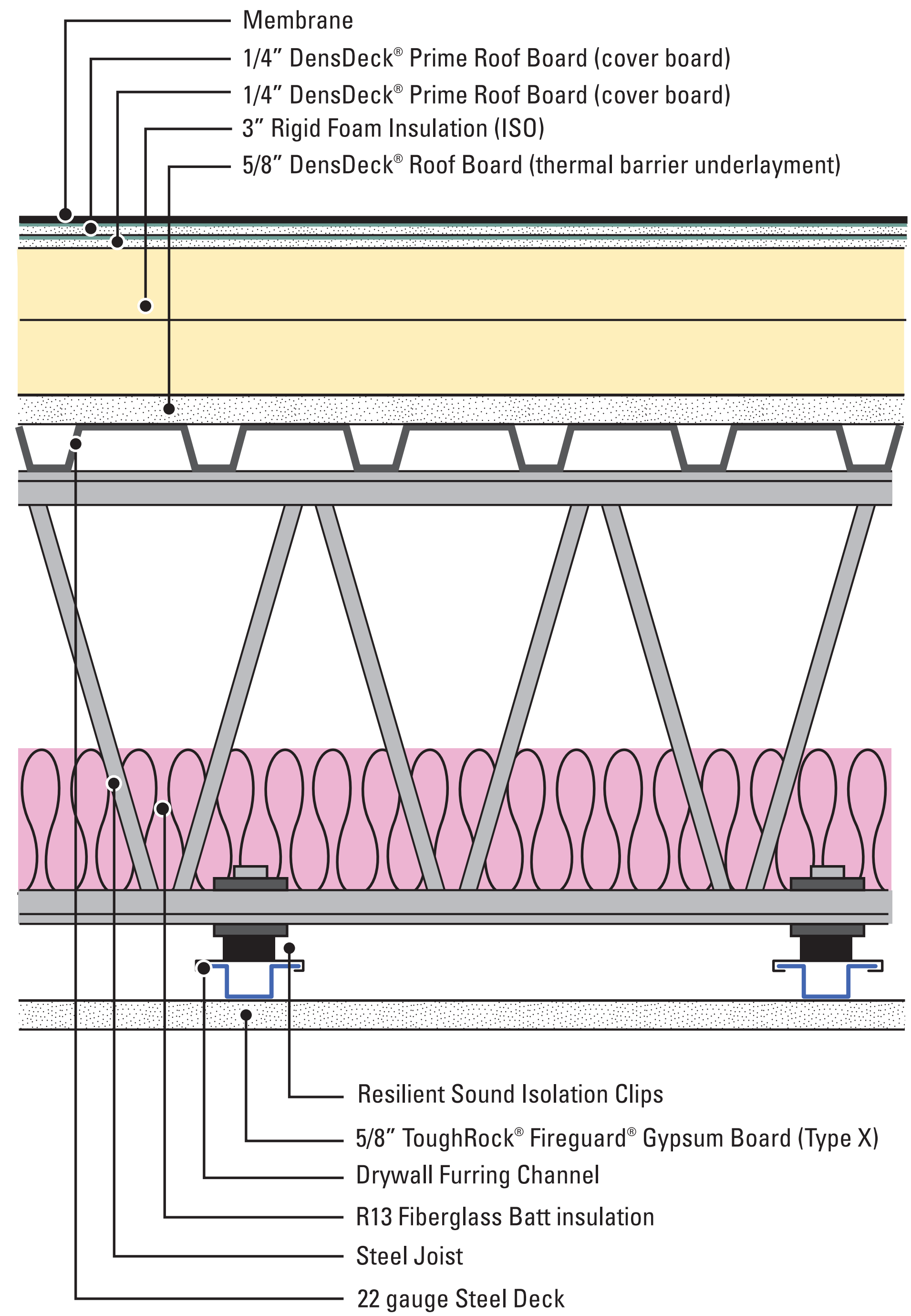


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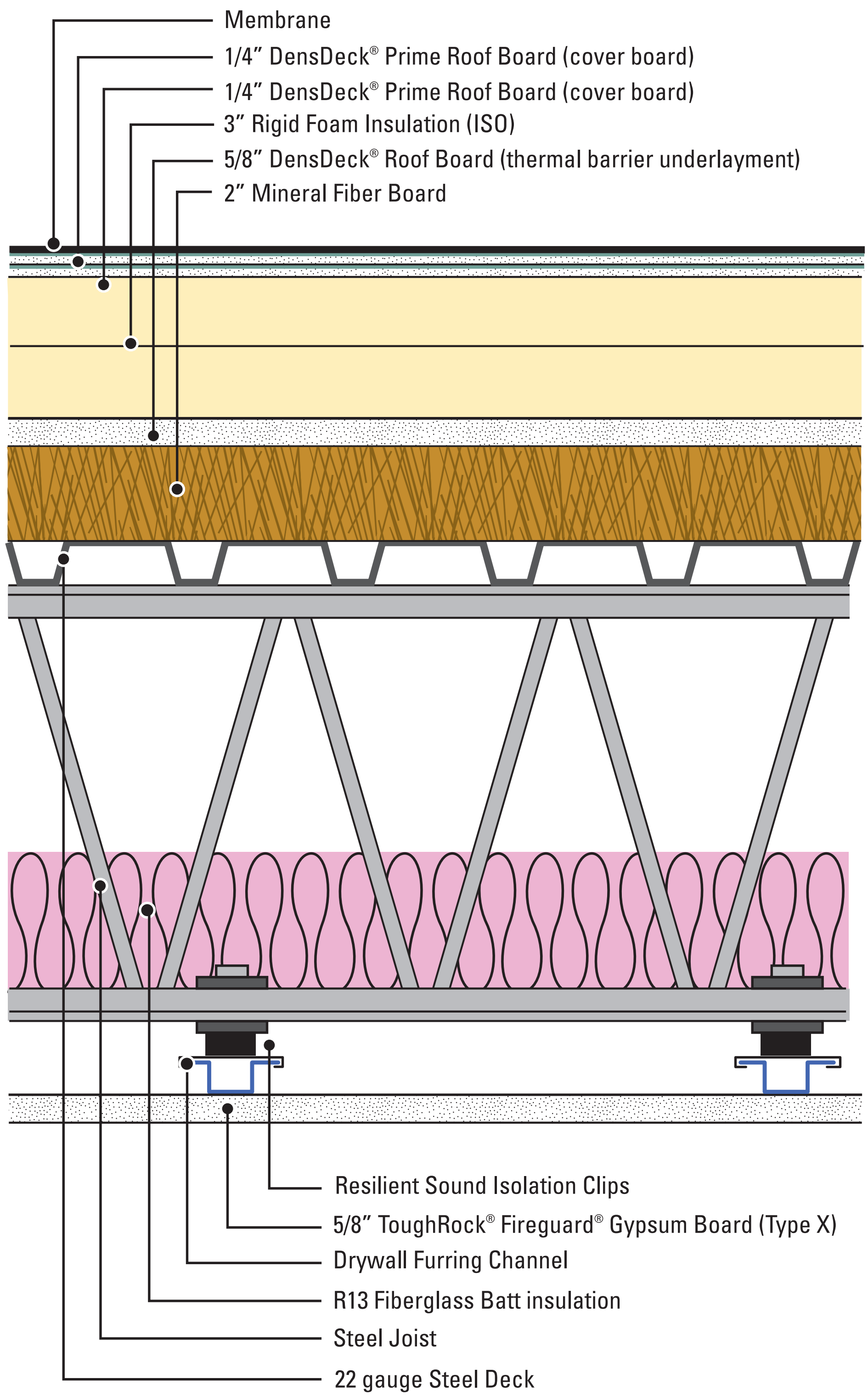
Exhibit E

STC=59

RAL#TL11-016

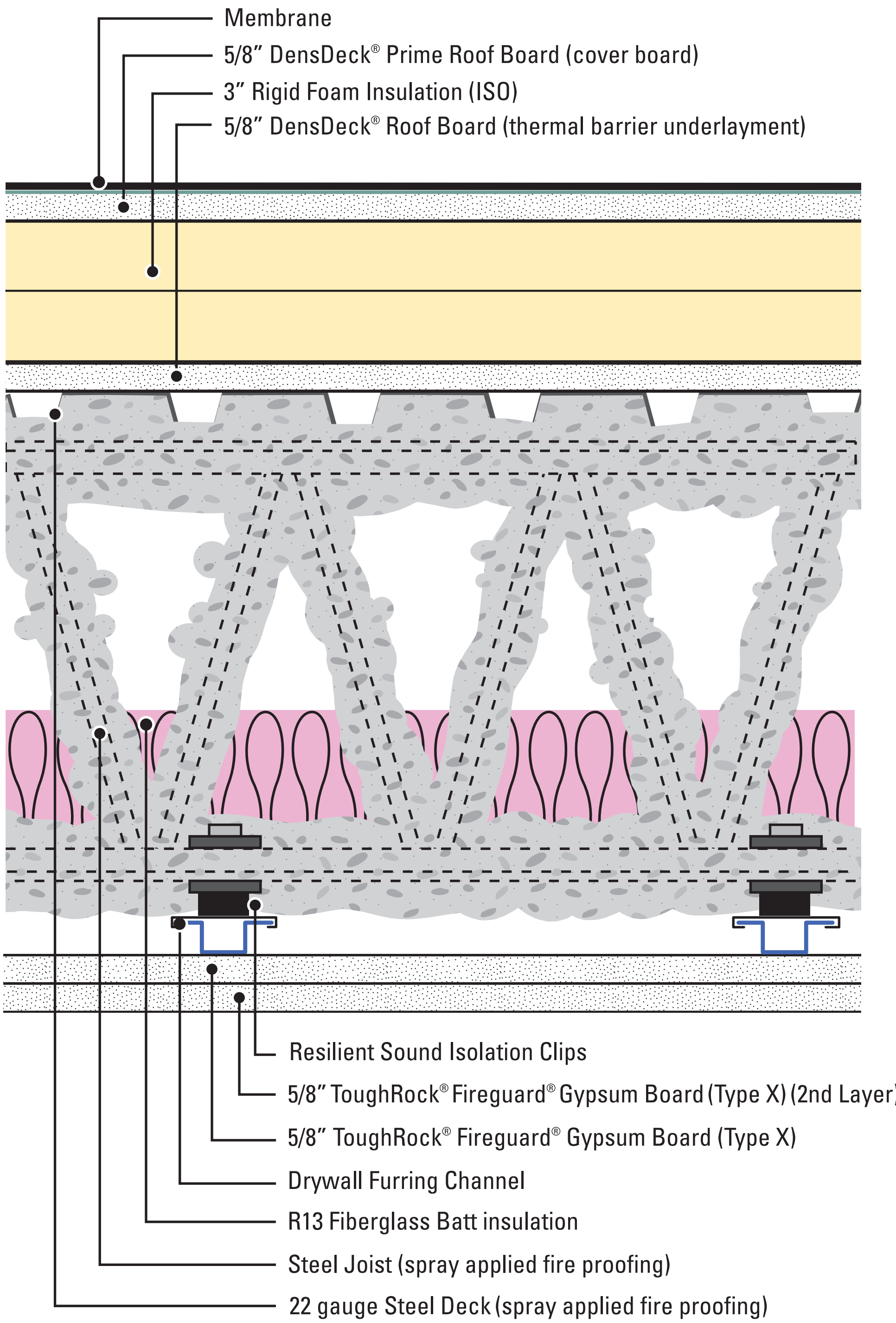


Tests per ASTM E 90 and ASTM E 413 were conducted in 2011 at Riverbank Acoustical Laboratories. Results are based on characteristics, properties and performance of materials and systems obtained under controlled test conditions. Actual results may vary. Assemblies are presented for illustration only. It is important that you consult a design professional for assembly information. Georgia-Pacific Gypsum does not provide architectural or engineering services.

Exhibit F

STC=61

RAL#TL11-065



Tests per ASTM E 90 and ASTM E 413 were conducted in 2011 at Riverbank Acoustical Laboratories. Results are based on characteristics, properties and performance of materials and systems obtained under controlled test conditions. Actual results may vary. Assemblies are presented for illustration only. It is important that you consult a design professional for assembly information. Georgia-Pacific Gypsum does not provide architectural or engineering services.

Decibels
A measure of the intensity of a sound, or simply how loud a sound is.

Outdoor Indoor Transmission Class (OITC)
A single number rating calculated in accordance with standard ASTM E-1332 using the Transmission Loss measured at 18 one-third octave bands from 80 Hz to 4000 Hz. The rating is most appropriate for comparing the performance of exterior facade elements including roofs exposed to typical transportation noise sources.

Sound
1. The sensation produced by stimulation of the organs of hearing by vibrations transmitted through the air or other medium.
2. Mechanical vibrations transmitted through an elastic medium, traveling in air at a speed of approximately 1087 feet (331 meters) per second at sea level.
3. The particular auditory effect produced by a given cause: the sound of music.
4. Any auditory effect; any audible vibrational disturbance: all kinds of sounds.
5. A noise, vocal utterance, musical tone, or the like: the sounds from the next room.

Sound Transmission Class (STC)
A single number rating calculated in accordance with standard ASTM E-413 using the transmission Loss measured at 16 one-third octave bands from 125 Hz to 4000 Hz. This rating is typically used to measure performance between spaces.

Transmission Loss (TL)
A measure in decibels (dB) of the sound energy per unit area transmitted through a partition or barrier measured in one-third octave bands in a laboratory in accordance with the standard ASTM E-90.