Breadth Study: Economy of Construction

To make a valid comparison between both alternate lateral and gravity systems, and to determine if they are indeed feasible alternatives, a cost analysis was necessary. In order to perform this analysis, I calculated material, fabrication, erection, and delivery costs for both the existing and alternate systems.

Lateral System

After designing each alternate lateral system, I used RAM Frame to perform a detailed take-off of all included material. I then used R.S. Means Construction Cost data to determine material and labor of each alternate. The following dollar values include shop fabrication and delivery costs.

Lateral System Cost Comparison (not including O+P)			
Lateral System	Material/Fabrication	Labor	Totals
Existing Frames	$313,054.75	$13,660.18	$326,714.93
Alt.#1: Concentric	$324,612.25	$13,710.44	$338,322.69
Alt #2: Chevron	$282,774.40	$12,160.28	$294,934.68
Alt #3: "K" Bracing	$347,034.25	$10,364.08	$357,398.33

As shown above, the chevron system is, overall, the most inexpensive system. This is largely due to the reduced size of the lateral frame beams, and the lack of extremely large bracing members. The most expensive system is the “K” bracing scheme, due in part to diagonal braces that are twice as large as those used in any of the previous designs. When considering that the price per pound of HSS members is higher than their wide flange counterparts, this increase in cost is justified.

When looking only at labor costs, “K” bracing is the most inexpensive system by almost $2000 dollars. This design offers the least amount of bracing to column connections as well as the least amount of bracing members to set into place. The erection schedule associated with this, and all of the alternatives (according to R.S. Means daily output figures), is approximately 4-6 days.

Gravity System

Improving the vibration characteristics of a floor system generally translates into an increase in cost. With that said, in certain cases different structural framing configurations or members can be used to ensure a consistent or even diminishing dollar value. For the Duquesne University Multipurpose Facility, the upper stories provided an opportunity to increase vibrational quality while maintaining a reasonable price tag.

Existing Gravity Framing per Floor (not including O+P)			
Floor No.	Material/Fabrication	Labor	Totals
2	$148,817.05	$10,943.67	$159,760.72
3	$143,289.60	$11,070.40	$154,360.00
4	$453,475.10	$10,612.77	$464,087.87
5	$452,528.50	$9,665.95	$462,194.45
			$1,240,403.04

Alternate Gravity Framing per Floor (not including O+P)			
Floor No.	Material/Fabrication	Labor	Totals
2	$173,202.95	$11,216.79	$184,419.74
3	$183,722.60	$11,112.59	$194,835.19
4	$357,415.10	$28,596.20	$386,011.30
5	$458,540.10	$36,454.99	$494,995.09
			$1,260,261.32

The above cost analysis (completed using R.S. Means 2007) shows that the redesign of the gravity system, for the four floors analyzed, is a feasible undertaking. First, the 2nd and 3rd floor levels saw a sizeable increase in material costs due to larger framing members in the designated fitness and aerobic areas. This increase in cost, however, is offset by the configuration, and intended use of the 4th and 5th floor.

At the 4th floor gymnasium level, a less strict vibration criterion was imposed due to the type of activity associated with that floor. Since total beam depth was not a critical issue, a lighter, stiffer, and deeper castellated beam member was used. The decrease in total weight resulted in an $80000 cost savings for this floor.

The 5th floor ballroom level demanded more strict vibration criterion than any of the previous areas. Again, castellated beams were used to address the long span condition without dramatically increasing the weight, and overall cost of the floor. As can be seen in the figures above, the raw material costs associated with the alternate framing were almost identical to that of the existing system. However, the labor costs related to castellated beams increase more than three times that of regular wide flange sections.

One factor affecting the overall cost of the alternate systems 4th and 5th floors are delivery charges for the castellated sections. In speaking with CMC Steel Products, a fabricator of castellated beams, I learned that the nearest location that 80’ members could be manufactured is Hope, Arkansas. Due to the length of the members, the highway driving restrictions associated with such a shipment, and the distance traveled, material delivery is a prime contributor to increased cost.

Breadth Study: Acoustic Performance

Acoustical performance of floor and wall assemblies is considered in most every building design. In this particular case, the intermixing of facilities lends itself to having several different activities going on at each floor level. Offices, aerobic rooms, weight lifting areas, gymnasiums, classrooms, and other spaces are all located in close proximity to each other. This proximity can lead to unwanted noises and disturbances at inopportune times. Improving upon the existing acoustic qualities throughout the structure will benefit everyone inside.

More specifically I will focus on the acoustical properties at five different areas; two floor assemblies and three wall assemblies. Because the floors are all the same (4.5" concrete on 2" metal deck), I will look at the most critical and least critical areas. They are:

- 2nd floor aerobic/office (wall)
- 2nd floor MEP/fitness (wall)
- 4th floor gymnasium/studio (wall)
- Watson bookstore/Forbes bookstore (floor)
- 3rd floor gym/2nd floor classroom (floor)

Rating Criteria

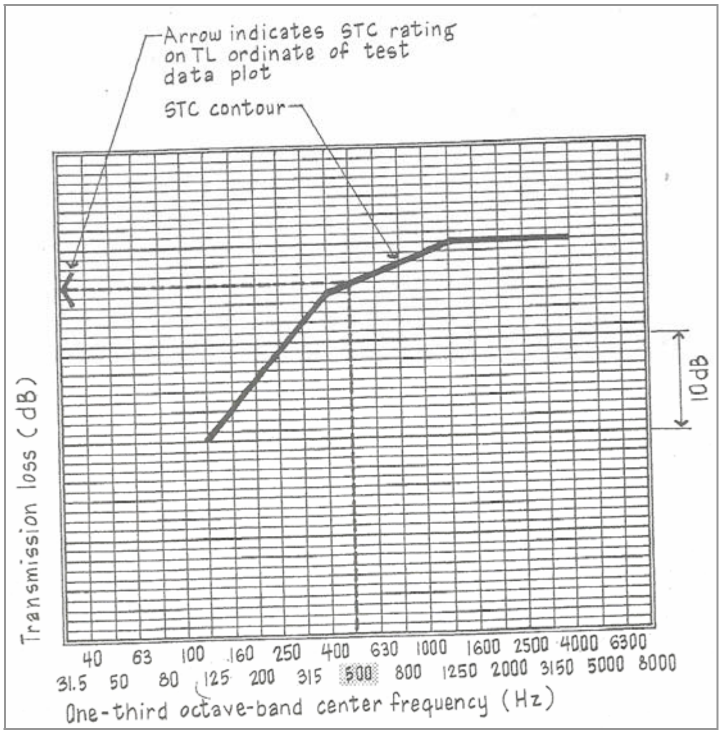
In analyzing the appropriateness of each separating assembly, I will be using STC and IIC rating criteria.

STC Rating Criteria

STC, or sound transmission class, is a single number rating of the airborne sound transmission loss (TL) performance of a construction measured at standard one-third octave band frequencies (Egan 201). A higher number STC rating is indicative of a barrier that is efficient at blocking sound transmitted within the given range of frequencies.

The STC rating contour, as shown on the next page, is used to determine STC ratings based on an ASTM procedure. The contour is shifted to fit the TL data of a particular construction, consistent with the following criteria:

- The maximum deviation of the test curve below the contour at any single test frequency shall not exceed 8 dB
- The sum of the deviations below the contour at all frequencies of the test curve shall not exceed 32 dB (on average, 2 dB per frequency)



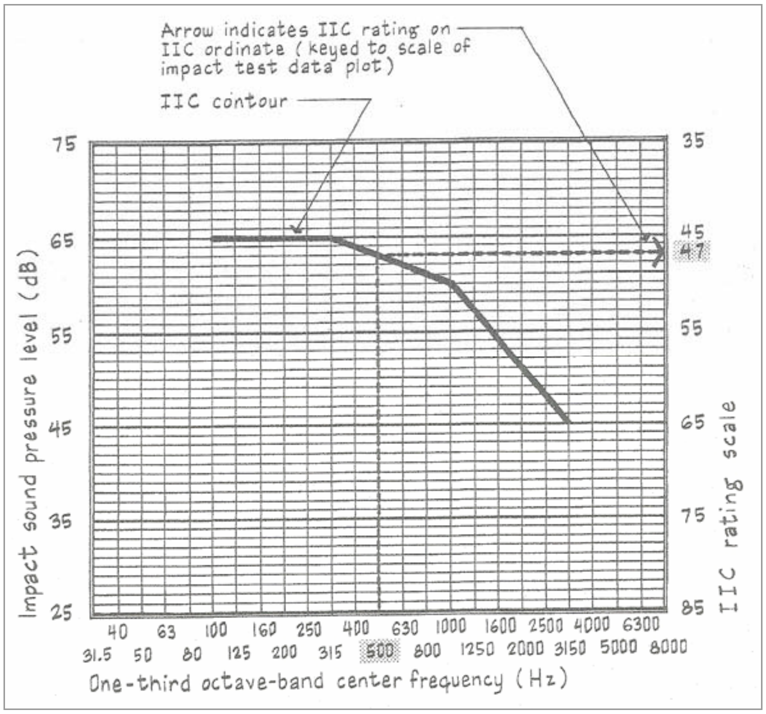
After fitting the STC contour to the TL data for the give wall system, the STC rating number is read as the TL number corresponding to the 500 Hz coordinate. For the purposes of my acoustical analysis, I will be using the TL data and STC ratings from the Egan text, as well as cross referencing (or if the construction is not available, using) the *Catalog of STC and IIC Ratings for Wall and Floor/Ceiling Assemblies*, issued by the California Department of Health Services.

IIC Rating Criteria

IIC, or impact isolation class, is a single number rating of the impact sound transmission loss performance of a floor-ceiling construction measured at standard one third octave band frequencies (Egan 250). As with the STC rating, the higher IIC rating is indicative of a barrier that is efficient at blocking impact sound transmitted within the given range of frequencies. The rating method is based on sound pressure levels produced in a room directly below the test floor.

The IIC rating contour, as shown on the next page, is used to determine IIC ratings based on an ASTM procedure. Obtaining an IIC rating from the chart is done in a similar fashion to the STC rating by using the following limitations:

- The maximum deviation of the test curve above the contour at any single test frequency shall not exceed 8 dB
- The sum of the deviations above the contour at all frequencies of the test curve shall not exceed 32 dB (on average, 2 dB per frequency)



After the IIC contour is adjusted to meet the above listed limitations the IIC rating is read as the vertical number on the right that corresponds with the 500 Hz coordinate. For the purposes of my acoustical analysis, I will be using the IIC ratings the *Catalog of STC and IIC Ratings for Wall and Floor/Ceiling Assemblies*, issued by the California Department of Health Services.

Existing Assemblies

Floor Assemblies

As stated earlier, each floor system in the structure consists of W-shape steel members supporting 4.5” of concrete on 2” metal deck (6.5” total). The only variant anywhere in the building is the floor covering. In the bookstore areas, the floor covering is not specified. In this case the bookstore, from my perspective, can be assumed to have either a low carpet or wood flooring. Thus, both possibilities will be considered.

Wall Assemblies

For the three walls in question, there are two different wall types in use. The aerobic/office wall and the MEP/fitness wall are both type 1 walls which consist of:

- 3-5/8" x 25 gage metal studs @ 16" o.c.
- 5/8" gypsum board, each side
- 3" minimum sound attenuation blanket

The wall separating 4th floor gymnasium and studio is type 1A which consists of:

- 6" x 20 gage metal studs @ 16" o.c.
- 5/8" gypsum board, each side
- 3" minimum sound attenuation blanket

Required/Existing STC and IIC ratings

Required STC Wall Ratings

In researching minimum requirements for wall assemblies, many sources of differing reliability surfaced. Of the many I have found, two presented themselves as both reliable and accurate. First, Egan's Architectural Acoustics text contains a table for STC ratings in schools. The table is a good starting place and a reliable source if no more specific information could be found. Another reference that will be used to judge the appropriateness of the wall systems herein will be ANSI S12.60-2002, the *American National Standard for Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools.* This standard provides guidelines and minimum STC ratings for new school classrooms and other secondary learning spaces. A third source of STC requirements for spaces is the *U.S. Army Physical Fitness Facilities Criteria*, issued by the Corps of Engineers.

Table 2 — Minimum STC ratings required for single or composite wall, floor-ceiling, and roof-ceiling assemblies that separate an enclosed core learning space from an adjacent space

Adjacent space			
Other enclosed or open plan core learning space, speech clinic, health care room and outdoors[c)]	Common use and public use toilet room and bathing room	Corridor,[a)] staircase, office or conference room[a,b)]	Music room, mechanical equipment room,[d)] cafeteria, gymnasium, and indoor swimming pool
50	53	45	60

Table 3 — Minimum STC ratings recommended for single or composite wall, floor-ceiling and roof-ceiling assemblies separating an ancillary space from an adjacent space

Receiving ancillary Learning space	Adjacent space Corridor,[a] staircase, common use and public use toilet and bathing room[b]	Music room	Office or conference room[a]	Outdoors[e]	Mechanical equipment room, [f] cafeteria, gymnasium or indoor swimming pool
Corridor	45	60[c]	45[d]	45[c]	55[c]
Music room	60	60	60	45	60
Office or conference room	45	60	45[d]	45	60

Required IIC Floor Ratings

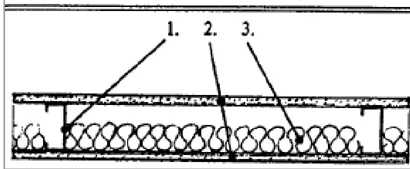
The IIC floor ratings will be taken from the Egan Architectural Acoustics text, IIC Ratings for Dwellings. For the purpose of this exercise, the highest rating in this chart will be assumed to be quite sufficient for each analysis. The ANSI standard used for the STC ratings will be consulted as well, as the recommended IIC rating for a receiving classroom is “at least 45 and preferably 50." (Below is the ANSI passage referring to IIC)

4.5.6 Impact Insulation Class (IIC) rating. The floor-ceiling assemblies of normally occupied rooms located above core learning spaces shall have IIC ratings of at least 45 and preferably 50. If a room below is an ancillary learning space, the floor-ceiling assembly shall have an IIC rating of at least 45. These IIC ratings shall apply without carpeting on the floor in the room above. In new construction, gymnasia, dance studios or other high floor impact activity, shall not be located above classrooms or other core learning spaces. For refurbishment of existing structures, if it is not possible to avoid such an incompatible condition, the IIC rating of the separating floor-ceiling assembly shall be at least 70 when located above a core learning space with an enclosed volume not greater than 566 m^3 (20 000 ft^3); 65 when located above a core learning space with an enclosed volume greater than 566 m^3 (20 000 ft^3); and 65 when located above an ancillary learning space.

Existing STC Wall Ratings

Wall #1: 2nd floor aerobic/office

- 3-5/8” x 25 gage metal studs @ 16” o.c.
- 5/8” gypsum board, each side
- 3” minimum sound attenuation blanket

Sketch	Brief Description	...	Laboratory Test Number Year Frequencies Tested Source of Data	STC	Section Number
	1. 3 5/8" metal studs, 24"o.c. 2. 5/8" gypsum board screwed to studs. 3. 2" thick sound attenuation blanket.	...	National Research Council of Canada NRC #66 1968 16f National Research Council of Canada	47	1.3.3.1.5.7

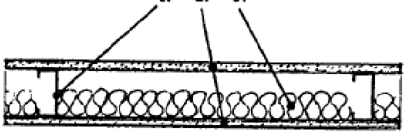
*Assume stud spacing does not affect STC

The criterion for the ANSI standard for secondary facilities (i.e. an office) is an STC rating of 60. However, the source room is not specified and is left open to 5 different sound producing possibilities. The U.S. Army criterion has an aerobic room STC requirement of 53. Similarly, the Army requirement for a private office is STC 50-53. Therefore, the wall construction shown here is inadequate. According to the Egan text, adding at least 2” of sound absorbing material could boost the STC value by 4-8 points. If that is not an option, adding an extra later of gypsum board will also increase the STC rating. Also, the above rating is for a 24” stud spacing and not 16”. This will affect the STC level by at least 1-2 rating points.

Existing STC:	**47-49**
Add 2” sound blanket:	**+ 4-8**
Total STC:	**51-57**
U.S. Army Required STC:	**53**

Wall #2: 2nd floor MEP/fitness

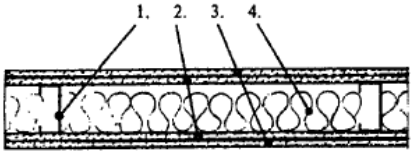
- 3-5/8" x 25 gage metal studs @ 16" o.c.
- 5/8" gypsum board, each side
- 3" minimum sound attenuation blanket

Sketch	Brief Description	...	Laboratory Test Number Year Frequencies Tested Source of Data	STC	Section Number
	1. 3 5/8" metal studs, 24"o.c. 2. 5/8" gypsum board screwed to studs. 3. 2" thick sound attenuation blanket.	...	National Research Council of Canada NRC #66 1968 16f National Research Council of Canada	47	1.3.3.1.5.7

*Assume stud spacing does not affect STC

Existing STC: 47-49

Proposed Construction:

	1. 3 5/8" metal studs, 24"o.c. 2. 1/2" type X gypsum board screwed 12"o.c. 3. 1/2" type X gypsum board screwed 24"o.c. 4. 3" thick sound attenuation blanket.	...	Owens/Corning Fiberglas OCF 539 1967 16f Owens/Corning Fiberglas	56	1.3.3.2.4.4

Upgrade to 5/8" gyp. Board: +2-3
ANSI Required STC: 55-60 (ancillary learning space)
U.S. Army Required STC: 55

Wall #3: 4th floor gymnasium/studio

- 6" x 20 gage metal studs @ 16" o.c.
- 5/8" gypsum board, each side
- 3" minimum sound attenuation blanket

Since the catalog at my disposal has only 1-5/8" through 3-5/8" metal studs, I cannot directly compare this construction to an available value. However, in seeing the last assembly being rated at STC 56, I believe this construction would be rated at an STC of over 60.

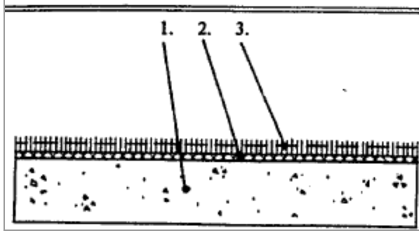
Estimated STC: > 60

ANSI Required STC: 60
U.S. Army Required STC: 53 office
55-60 fitness/gym

Existing IIC Floor Ratings

Floor #1: Watson bookstore/Forbes bookstore

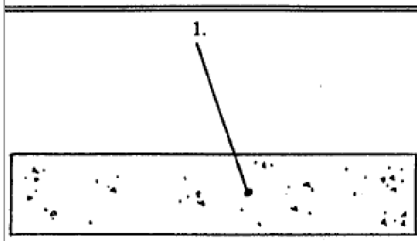
- W16 and W18 framing members
- 4.5" NWC on 2" composite metal deck
- Carpeting on rubber pad
- ACT ceiling in bookstore

Sketch	Brief Description	...	Laboratory Test Number Year Frequencies Tested Source of Data	STC IIC	Section Number
	1. 5" thick concrete slab. 2. 1/2" wood-fiber board glued to concrete. 3. 24 oz. carpet on 32 oz. hair pad.	...	Kodaras Acoustical Labs. L-188-1-64 1964 16f Homasote Co.	NA 70	2.3.1.1.2.1

IIC from chart: 70
ANSI Required IIC: 65

Floor #2: 3rd floor gym/2nd floor classroom

- W16 framing members
- 4.5" NWC on 2" composite metal deck
- Rubber athletic floor on rubber base
- ACT ceiling in classroom

Sketch	Brief Description	...	Laboratory Test Number Year Frequencies Tested Source of Data	STC IIC	Section Number
	1. 6" thick concrete slab, 75 psf.	...	Riverbank Acoustical Labs. NA NA 16f Prestressed Concrete Inst.	55 34	2.3.2.1.1.1