Analysis 3: Interior Structure Redesign (Breadth Study)

Problem

Wood is a cheap and workable material. However, it is a material that is not durable. Metal is a more durable and resistant material that would benefit the building in the long run. Moreover, metal studs come with pre-punched holes for plumbing and electrical conduits to run through. With wood, you need to drill those holes, which cost money and time.

Goal

In this project, all the interior framing, as well as the floor system was done with wood. I believe that wood was used in this project due to its low cost. However, I think that it is worth studying how the project would be affected if metal studs had been used instead. Metal studs, and metal joist would certainly increase the cost of the project, but they would also increase the value of the building. Metal studs, and metal joist are more resistant, more durable, and they have pre-punched holes for the plumbing and electrical conduits already. Therefore, replacing wood framing for metal framing would increase the value of the building and reduce the schedule as well. This analysis will explore how the project would benefit from switching to metal framing in terms of cost, schedule and method of construction.

Background

The Apartment Complex has a combination of structural systems. Concrete is only used up to the second floor slab. Cast in place concrete is used in this project for the foundations, perimeter wall up to the second floor, and beams and columns that extent from G2 level until the first floor slab. From the second floor to the fifth floor is all wood and metal studs. All the exterior and interior framing is load bearing. The metal studs are used on the exterior of the building, while the wood studs are used on the interior framing. The floor joist system was also done with wood. The problem of having many different components in one system is that many trades have to work on the same structure. When many trades work together, most likely there will be conflicts. With many trades, there is the need of extra coordination to avoid conflicts. Maybe by simplifying the structure, conflicts could be avoided, and the schedule could be reduced.

Steps for the Analysis

- Perform a Quantity Take-Off of the Existing Structure
- Perform a load analysis of the building
- Compare the current system with the proposed new system.
- Perform a Quantity Take-Off and Cost analysis of the Proposed Structure
- Perform a Cost & Schedule Comparison of both Systems
- Conclusion: Advantages and Disadvantages of new system

Quantity Take-Off of the Existing Structure

For the sake of this analysis, I decided to study only one part of the building since the interior structure is very repetitive. From the quantity take-off of this analysis I will estimate the cost of the entire interior wood structure. The quantity take-off will be done to the 4th floor east wing, which is located on the east side of Festival Street. The size of this area is 18,000 SF. This section of the building contains seventeen units. There are six different types of units in this area that will be analyzed later in this section. The total cost of this section is shown on the table below.

Unit	# of Units	# of wood studs	Total Studs	Cost per Stud	Total Cost
1F	2	66	132	$2.55	$336.60
2LCU	1	134	134	$2.55	$341.70
2LAU	1	135	135	$2.55	$344.25
2LDU	14	129	1806	$2.55	$4,605.30
1+DAMPDU	1	159	159	$2.55	$405.45
ILBU	3	110	330	$2.55	$841.50
				Total Cost	**$6,874.80**

Unit	# of Units	# of wood joists	Total Joists	Cost per Joist	Total Cost
1F	2	15	30	$40.00	$1,200.00
2LCU	1	18	18	$40.00	$720.00
2LAU	1	15	15	$40.00	$600.00
2LDU	14	19	266	$40.00	$10,640.00
1+DAMPDU	1	15	15	$40.00	$600.00
ILBU	3	25	75	$40.00	$3,000.00
				Total Cost	**$16,760.00**

Unit	# of Units	# of wood Trusses	Total Trusses	Cost per Truss	Total Cost
1F	2	1	2	$90.00	$180.00
2LCU	1	0	0	$0.00	$0.00
2LAU	1	0	0	$0.00	$0.00
2LDU	14	2	28	$120.00	$3,360.00
1+DAMPDU	1	2	2	$110.00	$220.00
ILBU	3	2	6	$120.00	$720.00
				Total Cost	**$4,480.00**

The cost shown on the tables only reflects the east wing of the forth floor, which is 18,000SF. To calculate the entire cost of the wood structure I calculated the cost per square feet and then multiply it by the complete area of the wood structure.

($6,874.80 + $16,760.00 + $4,480.00) / 18,000 SF = 1.56 $/SF

Floor	Area (SF)
2	54,650
3	49,893
4	56,050
5	51,263
total	**211,856**

211,856 SF x 1.56 $/SF = $330,905

Total Cost of interior wood structure is $330,905

Load Analysis

The load calculations shown below are the load on the interior structural system of the 4th floor east wing. The load is transferred from the slab to the floor joist system. The load from the floor joist system is then transferred to the wood trusses that are acting as girders. The load is then transferred from the wood trusses to the exterior metal frame studs, which transfer the load from the fifth floor to the first floor, where the concrete structure begins. The concrete beams and columns transfer the load from the first floor all the way to the foundations, which are below the second garage level.

Since I am replacing the interior framing from wood studs to metal studs, I am also replacing the wood floor joist system to a metal floor joist system. I am also replacing the wood trusses for metal joist girder. The load calculations shown below were done to determine the loads on the current wood joist system so that I can replace it for a metal joist system. In order to design the new system, I used the Standard Load tables for Open Web Steel Joist Systems from "Load tables and weight tables for steel joist and joist girders". Each type of unit had a different floor joist system, so a load analysis was done for each unit type.

Unit IF

S = 4.38 ft

Live load = 40psf x (4.38 ft) = 175.2plf

Dead load = 4.38 ft x [(1.6) x (40psf) + (1.2) x (4in / 12) x (150psf)] = 543.12plf

Then use an Open Web steel joist k-series 16K6 (dead load = 576plf / live load = 238plf)

P = (543.12plf) x (25ft) = 13.58Kips   Use 15.0 Kips

Then, based on the Joist Girder Design Guide use a 35G8N13.6K (42plf)

Unit ILBU

S = 4.17 ft

Live load = 40psf x (4.17 ft) = 166.8plf

Dead load = 4.17 ft x [(1.6) x (40psf) + (1.2) x (4in / 12) x (150psf)] = 517.08plf

Then use an Open Web steel joist k-series 12K5 (dead load = 555plf / live load = 198plf)

P = (517.08plf) x (21ft) = 10.86Kips   Use 12.0 Kips

Then, based on the Joist Girder Design Guide use a 50G12N10.9K (65plf)

Unit 1+DAMPDU

S = 4 ft

Live load = 40psf x (4 ft) = 160plf

Dead load = 4 ft x [(1.6) x (40psf) + (1.2) x (4in / 12) x (150psf)] = 496plf

Then use an Open Web steel joist k-series 12K5 (dead load = 555plf / live load = 198plf)

P = (496plf) x (21ft) = 10.42Kips   Use 12.0 Kips

Then, based on the Joist Girder Design Guide use a 32G8N10.4K (32plf)

Unit 2LDU

S = 4.17 ft

Live load = 40psf x (4.17 ft) = 166.8plf

Dead load = 4.17 ft x [(1.6) x (40psf) + (1.2) x (4in / 12) x (150psf)] = 517.08plf

Then use an Open Web steel joist k-series 12K5 (dead load = 555plf / live load = 198plf)

P = (517.08plf) x (21ft) = 10.86Kips   Use 12.0 Kips

Then, based on the Joist Girder Design Guide use a 50G12N10.9K (65plf)

Unit IF

S = 4.38 ft

Live load = 40psf x (4.38 ft) = 175.2plf

Dead load = 4.38 ft x [(1.6) x (40psf) + (1.2) x (4in / 12) x (150psf)] = 543.12plf

Then use an Open Web steel joist k-series 16K6 (dead load = 576plf / live load = 238plf)

Unit IF

S = 4.38 ft

Live load = 40psf x (4.38 ft) = 175.2plf

Dead load = 4.38 ft x [(1.6) x (40psf) + (1.2) x (4in / 12) x (150psf)] = 543.12plf

Then use an Open Web steel joist k-series 16K6 (dead load = 576plf / live load = 238plf)

Current system Vs New proposed system

There is no overall plan of the interior wood framing. The framing for each unit type was detailed individually. The individual unit framing plans shows the type, spacing, and quantity of woods studs used on each wall. Moreover, wherever there is an opening, there is the need of extra studs. The individual unit framing plans also shows the extra studs needed on openings, which are called posts. Depending on the dimensions of the opening, the Jack/King stud schedule will determine how many extra studs are needed. The legends of the marks on the plans are shown below.

Wood Wall Schedule	
MARK	Wall Construction
W12	2x4 @ 16" O.C.
W13	2x4 @ 12" O.C.
W14	2x4 @ 12" O.C. +1
W15	(2) 2x4 @ 16" O.C.
W16	(2) 2x4 @ 12" O.C.
W17	(3) 2x4 @ 12" O.C.
W22	2x6 @ 16" O.C.
W23	2x6 @ 12" O.C.
W24	2x6 @ 12" O.C. +1

Wood/Steel Post Schedule	
MARK	Post Construction
P12	(2) 2x4
P13	(3) 2x4
P14	(4) 2x4
P15	(5) 2x4
P16	(6) 2x4
P17	(7) 2x4
P18	(8) 2x4
P19	(9) 2x4
P110	(10) 2x4

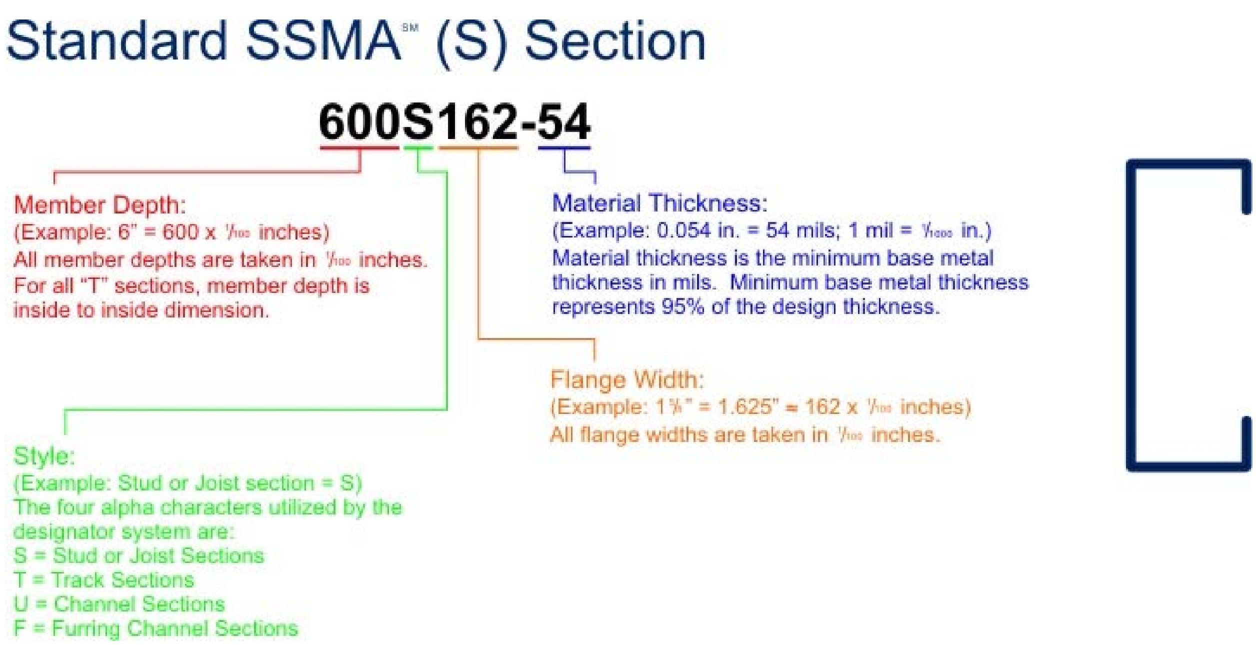
Lightgage Post Schedule	
MARK	Post Construction
MP1	(2)-400S162-54
MP2	(2)-400S162-54 (1)-400T125-54
MP3	(2)-400S162-54 (2)-400T125-54
MP4	(3)-400S162-54 (2)-400T125-54
MP5	(3)-400S162-54 (3)-400T125-54
MP6	(4)-400S162-54 (3)-400T125-54

Lightgage Wall Schedule	
Mark	Wall Construction
M12	600S162-43 @ 16" O.C.
M13	600S162-43 @ 12" O.C.
M14	600S162-54 @ 16" O.C.
M15	600S162-54 @ 12" O.C.
M16	600S162-97 @ 16" O.C.
M17	(2)600S162-54 @ 16" O.C.
M18	(2)600S162-68 @ 16" O.C.
M19	(2)600S162-97 @ 16" O.C.
M20	(3)600S162-54 @ 16" O.C.
M24	800S250-54 @ 16" O.C.
M25	800S250-54 @ 12" O.C.

Jack/King Stud Schedule		
MARK	0'-0" - 4'-0"	4'-1" - 7'-0"
W12	1k + 2j	2k + 2j
W13	1k + 2j	2k + 2j
W14	2k + 2j	3k + 2j
W15	2k + 2j	4k + 2j
W16	3k + 2j	5k + 2j
W17	5k + 2j	7k + 2j

Simple Mils to Gauge Conversion Chart	
Minimum Thickness (mils)	Reference Gauge Number
33	20
43	18
54	16
68	14
97	12
118	10

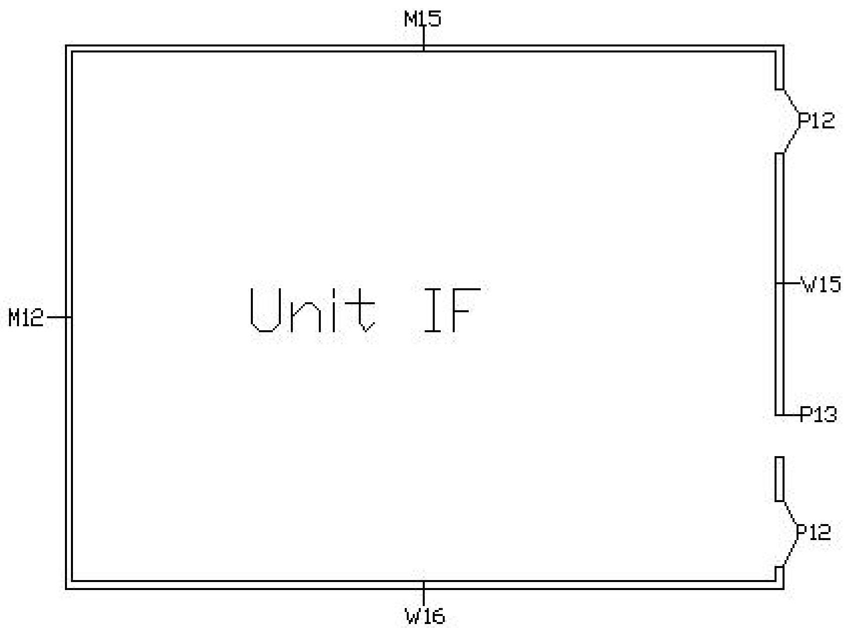
Load	Metal Stud
4k	400S162-54
8k	400S162-97
12k	(2) 400S162-54
16k	(2) 400S162-68
20k	(2) 400S162-97
24k	(2) 400S162-97
30k	(3) 400S162-54



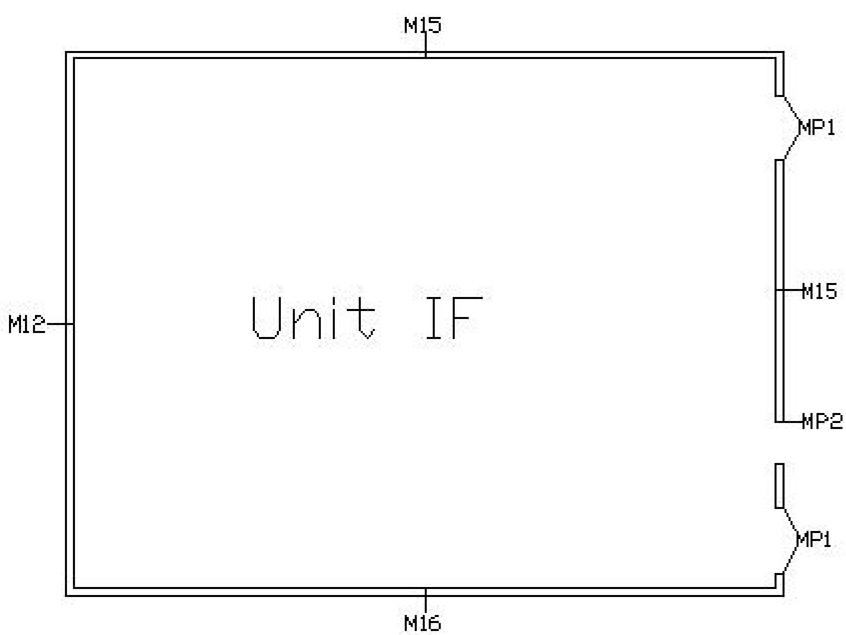
After proposing a new floor joist system, and a new joist girder system, the only wood members remaining are the wood studs used on the interior framing. Based on the load analysis and the wood framing analysis, I proposed a new system that will replace all the wood studs for metal studs. Each unit was analyzed and a new framing system with metal studs was proposed. The unit comparison plans are shown below. Use the legend tables above to read the plans.

Unit IF

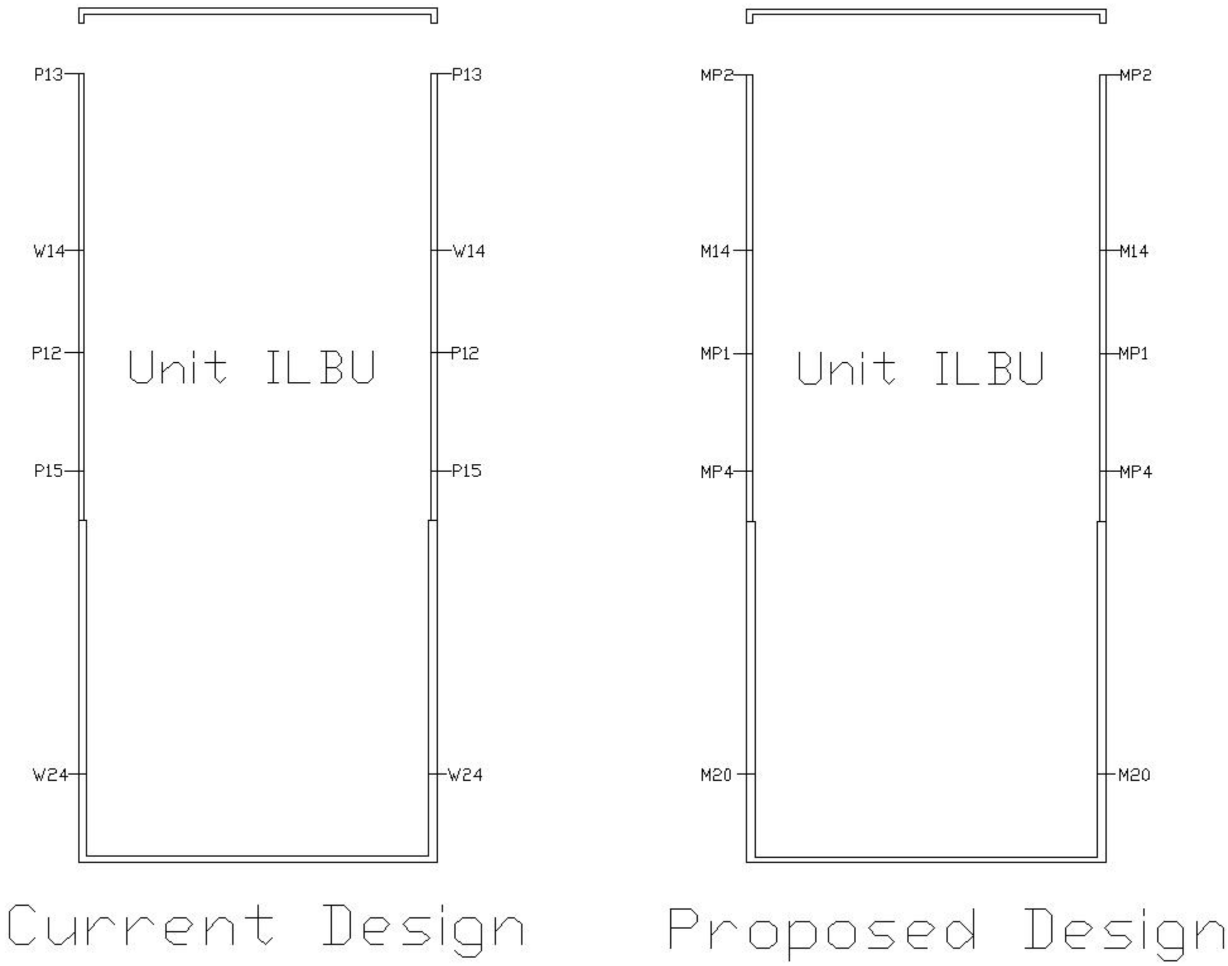
Current Design



Proposed Design

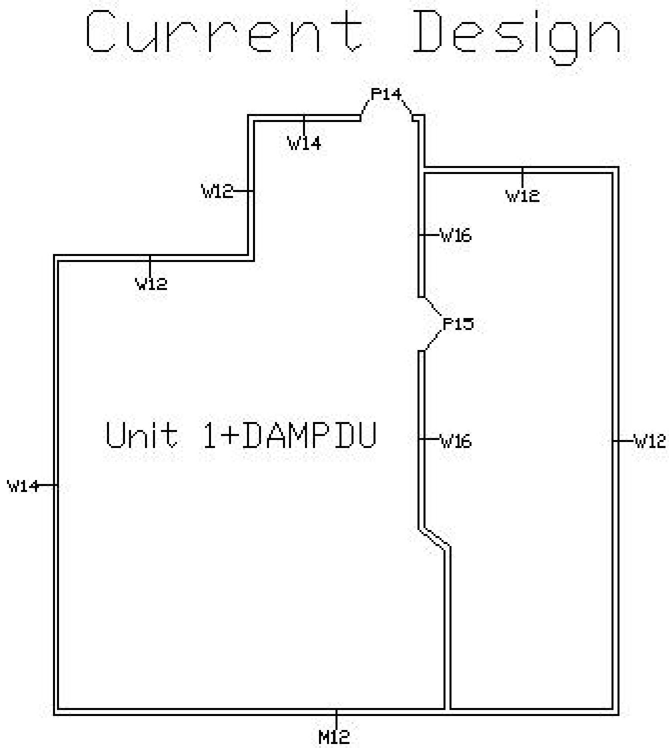


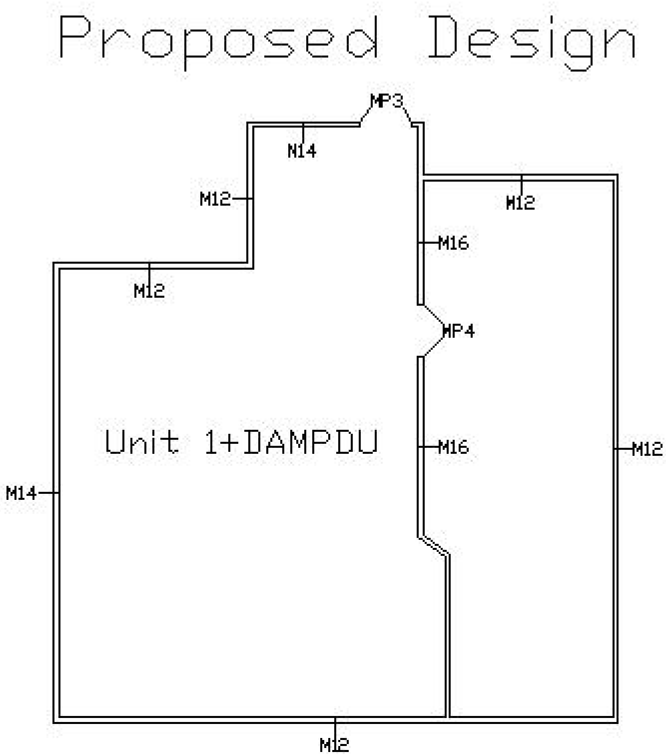
Unit ILBU



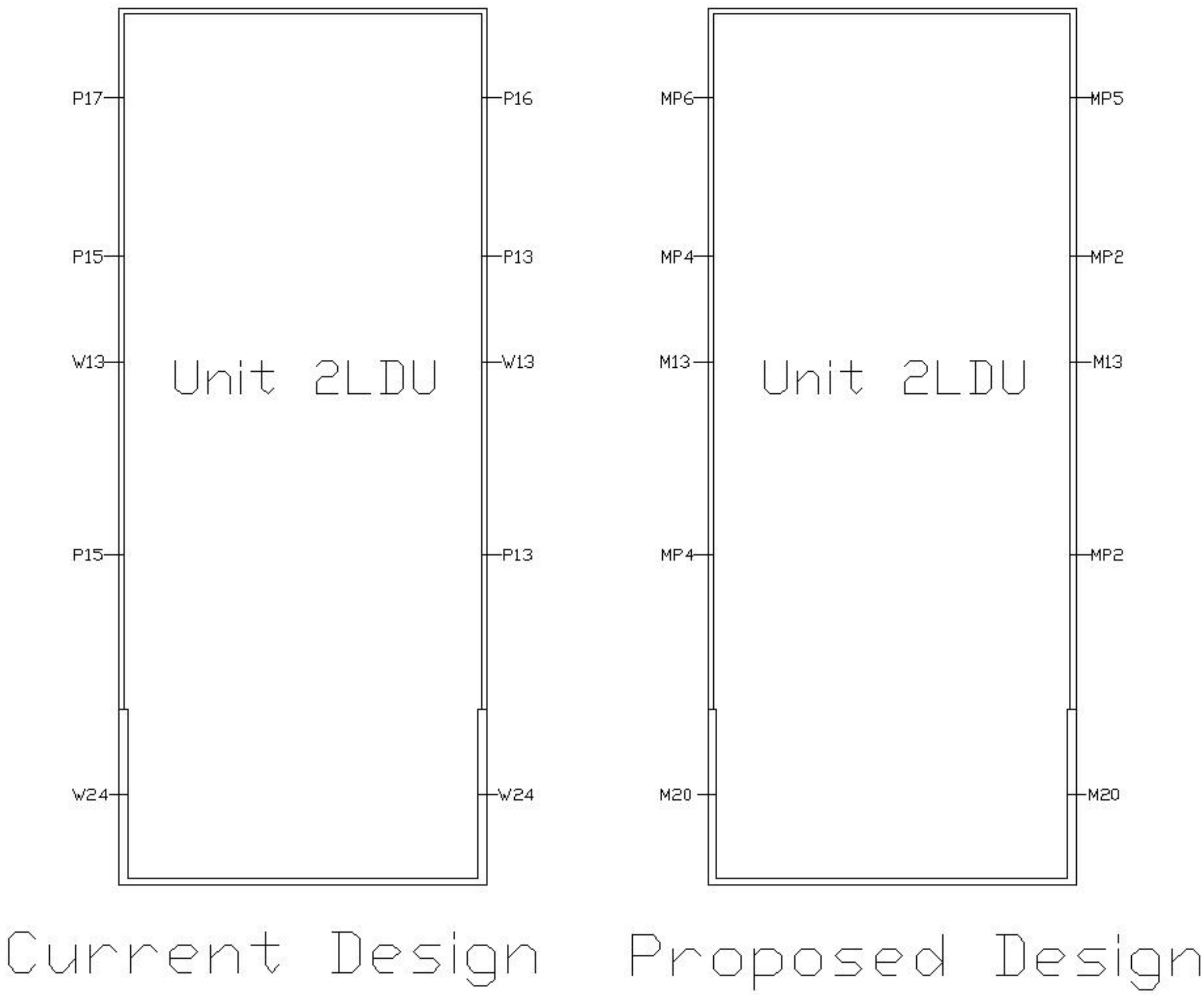
P13
P13
W14
W14
P12
P12
Unit ILBU
P15
P15
W24
W24
MP2
MP2
M14
M14
MP1
MP1
Unit ILBU
MP4
MP4
M20
M20
Current Design
Proposed Design

Unit 1+DAMPDU





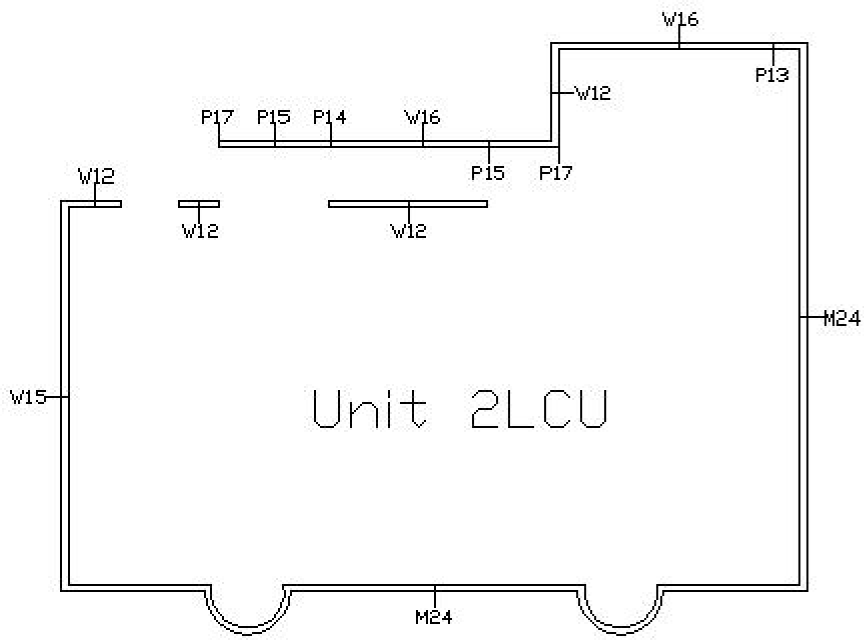
Unit 2LDU



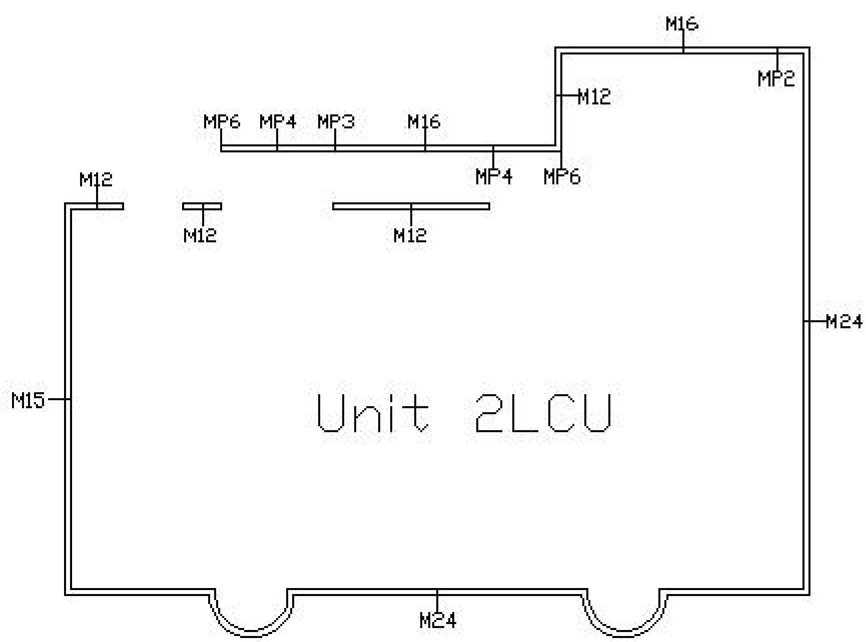
P17
P16
P15
P13
W13
Unit 2LDU
W13
P15
P13
W24
W24
MP6
MP5
MP4
MP2
M13
Unit 2LDU
M13
MP4
MP2
M20
M20
Current Design
Proposed Design

Unit 2LCU

Current Design

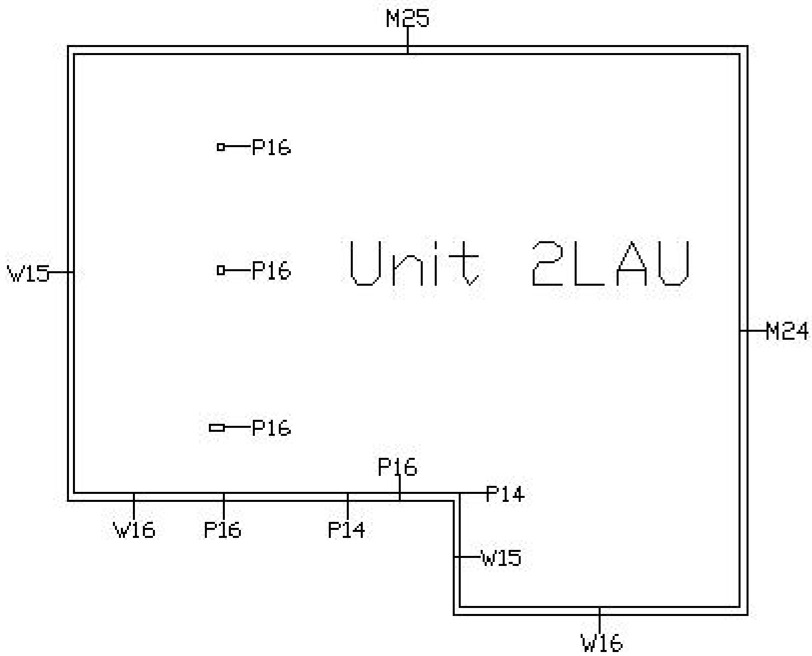


Proposed Design

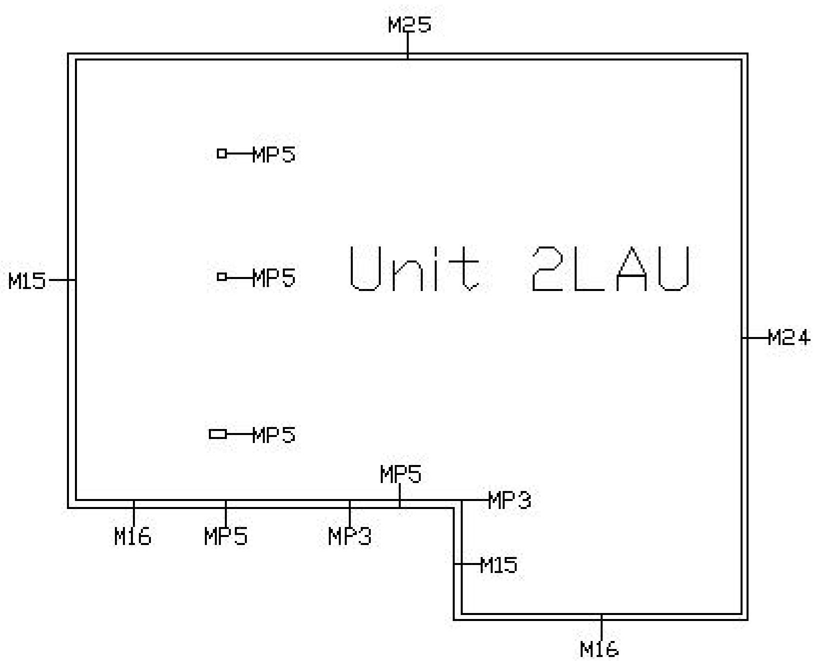


Unit 2LAU

Current Design



Proposed Design



Cost of New proposed system

The cost analysis will focus on the same section as before, which was the 4th floor east wing. This way I can compare the cost of both systems.

Unit	# of Units	# of Metal studs	Total Studs	Cost per Stud	Total Cost
1F	2	51	102	$3.45	$351.9
2LCU	1	102	102	$3.45	$351.9
2LAU	1	105	105	$3.45	$362.25
2LDU	14	129	1806	$3.45	$6,230.7
1+DAMPDU	1	110	110	$3.45	$379.5
ILBU	3	110	330	$3.45	$1,138.5
				Total Cost	**$8,814.75**

Unit	# of Units	Metal joists weight	Total Weight	Cost per Ton	Total Cost
1F	2	.433	.867	$1,500	$1,300
2LCU	1	.433	.433	$1,500	$650
2LAU	1	.433	.433	$1,500	$650
2LDU	14	.607	8.49	$1,500	$12,740
1+DAMPDU	1	.433	.433	$1,500	$650
ILBU	3	.607	1.82	$1,500	$2,730
				Total Cost	**$18,720**

Unit	# of Units	Metal joists weight	Total Weight	Cost per Ton	Total Cost
1F	2	.108	.216	$1,300	$280
2LCU	1	0	0	$1,300	$0.00
2LAU	1	0	0	$1,300	$0.00
2LDU	14	.308	4.31	$1,300	$5,600
1+DAMPDU	1	.231	.231	$1,300	$300
ILBU	3	.308	.923	$1,300	$1,200
				Total Cost	**$7,380**

($8,814.75 + $18,720.00 + $7,348.00) / 18,000 SF = 1.94 $/SF

211,856 SF x 1.94 $/SF = $411,000

Total Cost of new proposed structure is $411,000

Cost Comparison

Since metal is a better quality material than wood in so many aspects, the cost was expected to be greater. The new proposed system costs 24% more than the previous structural system. 24% increase may sound a lot but compared to the entire cost of the building is not much. The new proposed system increases the overall cost of the building by 0.2%. Maintenance cost of wood is much greater that maintenance cost of metal, so even thought the initial cost of metal is greater, the initial cost savings of wood is lost due to a higher maintenance cost. Considering the advantages that metal brings to the projects, a 0.2% cost increase is not much.

Schedule Comparison

Before doing this analysis, I had the impression that wood construction took longer. However, after talking to industry professionals, I realize that the duration of the installation of metal and wood studs is the same. However, due to the fact that metal studs have already pre-punched holes, they do save some time. Wood studs need to be punched before installation in order to be able to install all the conduits that go through the wall. However, even though metal studs save time due to the pre-punched holes, the schedule does not really change much. The truth is that the schedule is really not impacted much by the new proposed system.

Conclusion

As we can see from the analysis above, the new system increases the cost and it really does not change the schedule much. However, even thought the cost of the building increases, the value of the building also increases. The main reason why I think that the new system should replace the current system is because metal will add so much value to the building that it will overcome the additional cost in the long run. Metal has many advantages over wood. Some of those advantages are shown below:

- Steel is stronger, lighter and more dimensionally stable than wood.
- Steel stud interior walls provide an uncommonly straight and stable wall. This reduces call backs for sheet rock separation, nail pop-outs, molding separation and warping.
- Pre-punched service holes in studs for electrical wiring, plumbing or other utility lines save time and money.
- Steel framed homes are safer in fires – they will not add fuel to a fire nor collapse as easily as wood.
- Stronger: steel framed homes greatly exceed all wind and seismic codes without adding any additional cost.
- Lightning protection: steel gives electricity a pathway to ground resulting in less secondary fires and explosions.
- No mold, mildew or rotting
- Super Insulated – no air infiltration if insulated with foam.
- Avoid termite problems
- Less repairs and maintenance
- No wasted scrap – all extra material can be recycled.