Embodied Energy Study

Lightweight Concrete in Steel Framed Buildings

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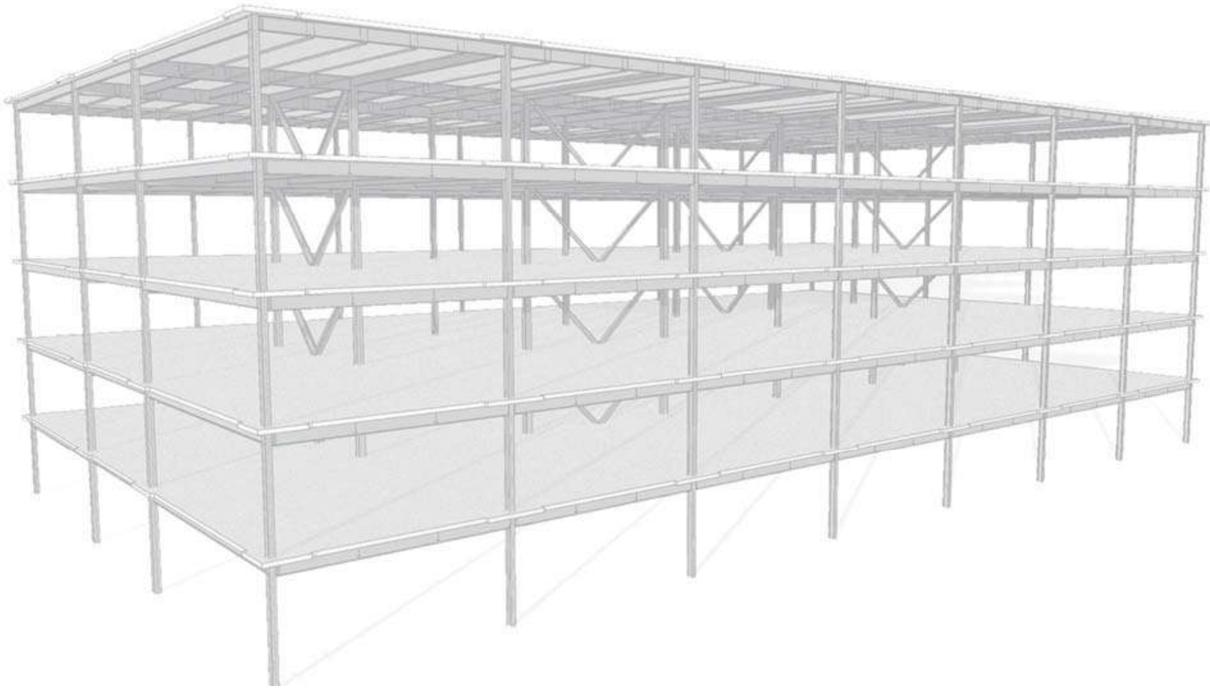


WALTER P MOORE

Introduction

This report presents the results of an embodied energy study performed by Walter P. Moore and Associates, Inc. for the Expanded Shale, Clay and Slate Institute (ESCSI). The purpose of the study was to compare the embodied energy in the structural system of a steel framed building with lightweight concrete floor slabs on composite steel deck to the same system utilizing normalweight concrete. The lightweight aggregate used in this study was rotary kiln expanded shale, clay, and slate lightweight aggregate and for simplicity is referred herein as “lightweight aggregate”.

Scope

A representative 5-story office building was designed in an area of moderate-seismicity in suburban Charlotte, North Carolina, as depicted in Figure 1. The building features approximately 115,000 SF of office space. Each floor has a footprint of 210’ x 110’ with seven 30 ft bays in the long direction and 3 bays in the short direction with 40 ft outer bays and a 30 ft inner bay. Floor to floor heights are 14 ft. Detailed structural framing plans are included Appendix A.

The main building structural system is structural steel framing supporting a composite metal deck. The lateral system is concentric braced frames. The foundations are spread footings and a 5” slab on grade. Roof construction consists of 1 ½” metal deck over steel joists.

Four schemes of the structure were designed. The first assumed a floor system of normalweight concrete (NWC) on composite beams. The second assumed a lightweight concrete (LWC) floor system on composite beams with the same beam spacing as the normalweight concrete system. The third version also assumed a lightweight concrete floor system on composite beams but with a larger spacing and thicker deck than the second version. Although it is not common engineering practice to space interior beams at 15’-0” in an office building, this system reduces the floor beam steel tonnage and the number of steel beams, both of which are common strategies to reduce the cost of floor framing. The fourth version assumed a lightweight concrete floor system with a 2” deck and beams spaced at 10’-0” OC. Although this system utilizes a thinner slab, the beam and girder sizes are driven by vibration requirements rather than strength requirements. The four systems are summarized on the facing page.

NWC Composite Steel Deck Floor Slab (NWC)

- 2" 18 ga. deck + 4 1/2" NWC slab (6 1/2" total)
- 10'-0" spacing of interior beams

LWC Composite Steel Deck Floor Slab (LWC A)

- 3" 22 ga. deck + 3 1/4" LWC slab (6 1/4" total)
- 10'-0" spacing of interior beams

LWC Composite Steel Deck Floor Slab (LWC B)

- 3" 18 ga. deck + 3 1/4" LWC slab (6 1/4" total)
- 15'-0" spacing of interior beams

LWC Composite Steel Deck Floor Slab (LWC C)

- 2" 20 ga. deck + 3 1/4" LWC slab (5 1/4" total)
- 10'-0" spacing of interior beams

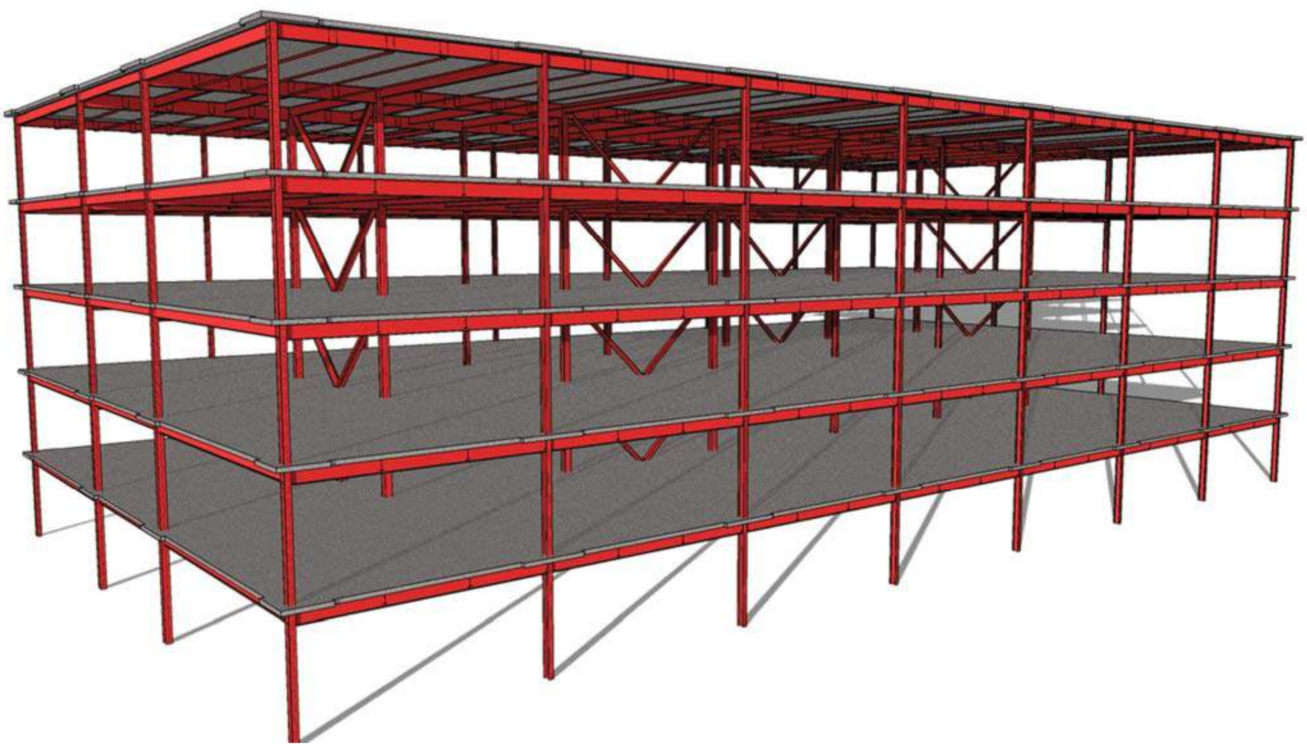


Figure 1. Representative Building

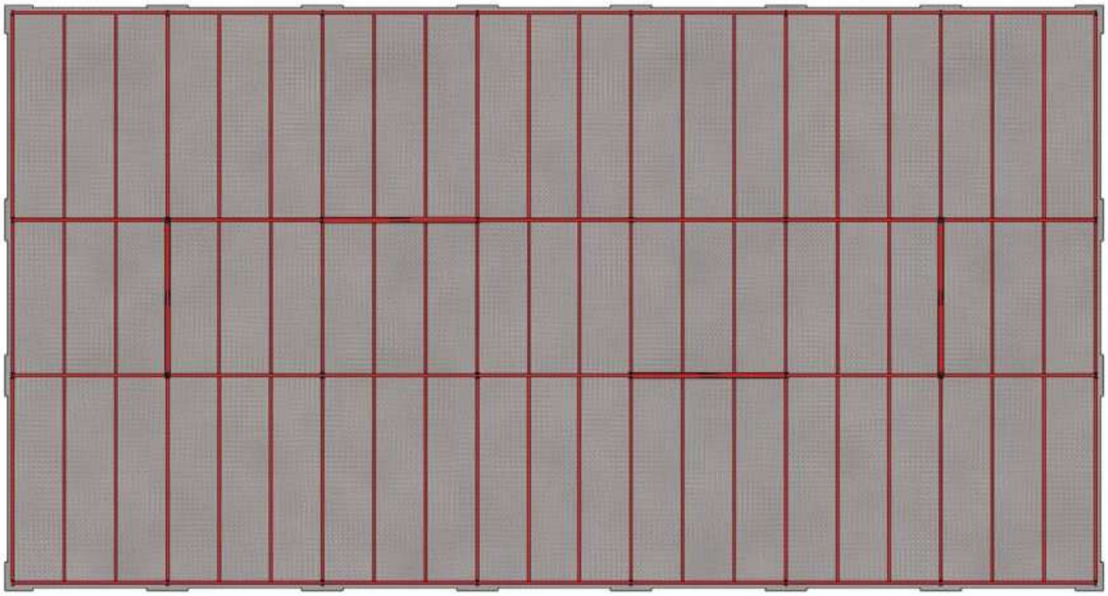


Figure 2. Schematic Plan View

Design Criteria

The design criteria for this study was established through the Basis of Design document issued to ESCSI in August 2011.

Codes and Standards

The design is based on the following Building Codes and Standards:

International Building Code 2006 .... IBC 2006
Minimum Design Loads for Buildings and Other Structures ....ASCE 7-05
AISC Specification for Structural Steel Buildings..AISC 360-05 LRFD
Building Code Requirements for Structural Concrete.. ACI 318-08

Floor Live Loads

Office Live Load .... 50 psf
Roof Live Load.. 20 psf
MEP, Ceilings, and Misc Loads .... 15 psf
Cladding Loads.. 15 psf

Wind Loads

Basic Wind Speed (3-sec gust).. 90 mph
Building Category ....II (ASCE 7-05 Table 1-1)
Importance Factor ....Iw = 1.0 (Table 6.1)

Directionality Factor .... Kd = 0.85 (MWFRS)
Gust Factor 0.85
Exposure Category .... B

Seismic Loads

Spectral Response Acceleration for Short Period: .... Ss = 0.35
Spectral Response Acceleration for 1-second Period: .... S1 = 0.12
Site Class Definition: .... D
Coefficient Fa .... Fa = 1.5
Coefficient Fv .... Fv = 2.3
Seismic Importance Factor: .... IE=1.0
Five Percent Damped SRA for Short Periods .... SDs = 0..36
Five Percent Damped SRS for 1 sec. Periods .... SD1 = 0.18
Seismic Design Category: C
Seismic Resisting System .... Structural steel system not specifically detailed for seismic resistance
Response Modification Coefficient .... R = 3
System Over strength Factor .... Ω = 3
Deflection Amplification Factor .... Cd = 3
Analysis Procedure .... Equivalent Lateral Force

Materials

Reinforcement

Reinforcing Steel .... ASTM A615, Grade 60
Headed stud anchors .... ASTM A108, Fu = 65 ksi

Normal-Weight Concrete

Slab on Metal Deck .... 3,500 psi
Foundation Elements .... 4,000 psi
Slab-on-Grade .... 4,000 psi

Light-Weight Concrete

Slab on Metal Deck .... 3,500 psi

Structural Steel

Wide flange shapes .... ASTM A992 Grade 50
Angles .... ASTM A992 Grade 50

Steel Roof and Floor Deck:

Floor Deck .... Varies - refer to plan (Fy = 50 ksi,)
Roof Deck .... 22ga. (Fy = 33 ksi,)

Boundaries and Performace Criteria

Structural System

The scope of this study includes only the embodied energy of the building's structural materials. This analysis does not include energy associated with the transportation of materials to the site, the transportation and operation of equipment at the site, or temporary materials such as concrete formwork. This analysis does not include embodied energy in the building envelope or other building systems.

The basic flowchart of this embodied energy study is shown in Figure 3.

Floor Acceleration

To ensure functional equivalence of compared systems, all systems compared in this study meet the maximum floor acceleration limit established by *AISC Design Guide 11 – Floor Vibrations Due to Human Activity*. Chapter 4 of the *AISC Design Guide 11* recommends 0.5%g as the limit for office, residence, and church/assembly area occupancy. The recommended damping ratio for paper offices with demountable partitions is 3%. For electronic offices with light workstations and demountable partitions, the recommended ratio is 2%. For the purpose of this study, the maximum acceptable acceleration for a floor system is 0.5%g and the assumed damping ratio is 2.5%

The floor schemes that are considered in this study are shown in Table 1. Due to the floor acceleration criteria, the composite beam size for system LWC C was increased beyond the sizes required when only strength is considered. Although LWC C is the lightest overall system considered in this study, this system is likely not economically feasible due to the increased steel weight and member depths.

Fire Rating

All floor systems were selected to provide a 2hr fire rating per UL Design D916 without fireproofing applied to the deck. Fireproofing applied to the beams was considered to be the same in both cases and therefore was not included in this study.

System	Beam Size	Beam Spacing	Interior Girder Size	Perimeter Girder Size	Steel Weight (psf)	Deck Weight (psf)	System Weight (psf)	Acceleration
NWC	W18x40	10'	W24x62	W21x44	4.5	71.5	76.0	0.33%
LWC A	W16x31	10'	W24x55	W21x44	3.9	47.4	51.3	0.52%
LWC B	W18x40	15'	W24x55	W24x55	3.4	48.5	51.9	0.51%
LWC C	W21x44	10’	W24x55	W24x55	5.0	42.6	47.6	0.50%

Table 1. Structural Scheme Comparison

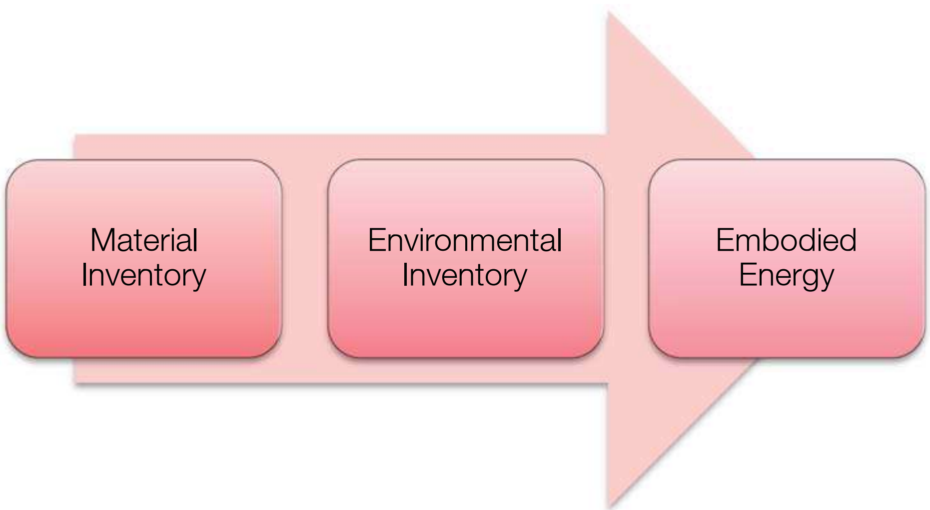


Figure 3. Embodied Energy Study

Inventory Analysis

Structural System

The structural systems were analyzed and designed using a linear elastic three-dimensional model using CSI's ETABS software. Gravity, wind, and seismic loads were considered in the analysis. Seismic loads governed the design of the lateral system in both directions. All designs were performed in accordance with AISC 360-05 LRFD. The design included the analysis and design following structural elements:

- Roof framing
- Floor slab and deck
- Composite floor beams
- Composite floor girders
- Steel columns
- Lateral load resisting system (bracing)
- Slab-on-grade
- Foundations

Floor Design

Composite beam design was performed in ETABS using the ETABS composite beam design post processor for both strength and serviceability design. All designs adhere to the criteria listed below.

Maximum % composite action 100%
Camber .... 75% of construction dead load
Minimum camber .... ¾"
Maximum camber .... L/180 or 3"
Camber increment .... ¼"
Live load deflection L/360
Total deflection L/240

Roof Design

Roof construction in the interior 30' bay uses the same composite floor construction methods as the lower floors. This provides a designated area for roof top mechanical units. The outer 40' bays consist of 1 ½" steel roof deck over steel joists spaced at 6'-0" on center. Steel joists were designed to SDI standards and are 20K10 joists for all schemes.

Column Design

Column were designed in ETABS using the steel design post processor using the effective length method. All columns are Grade 50 W12 shapes and range in size from W12x40 to W12x106. Column sizes were optimized in groups and are spliced between the 3rd and 4th levels.

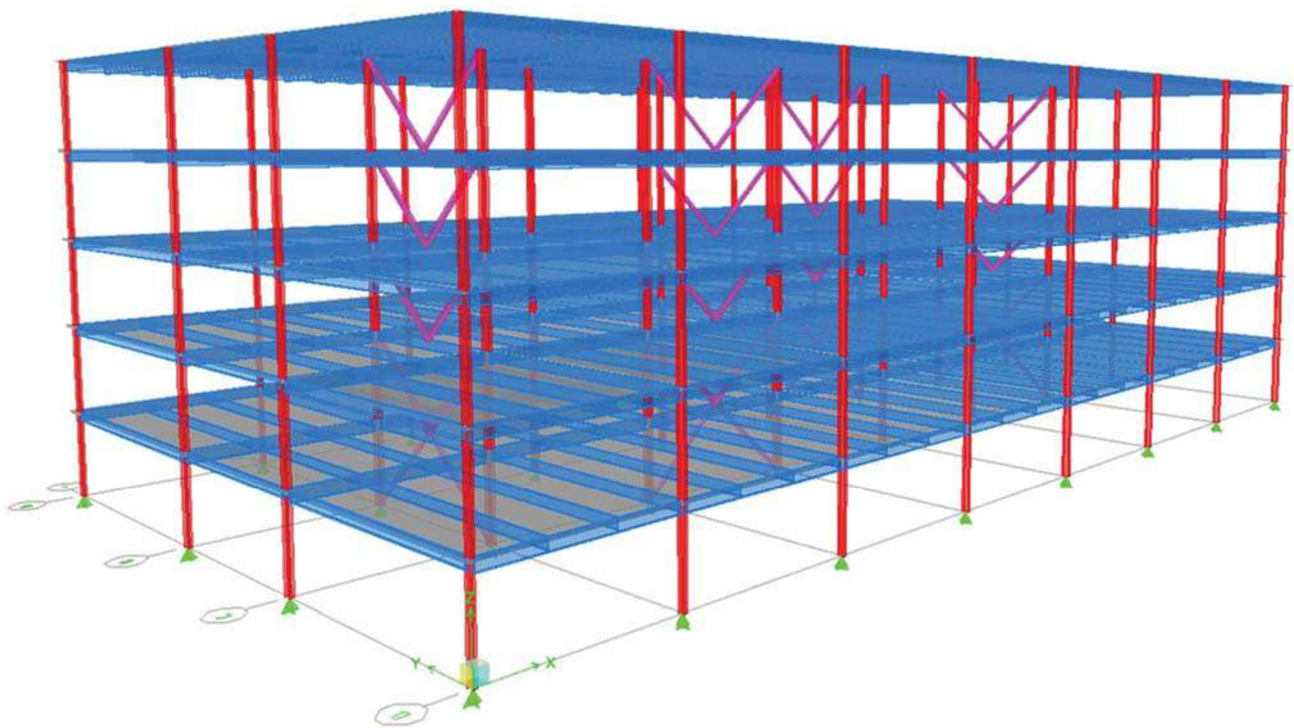


Figure 4. ETABS Model

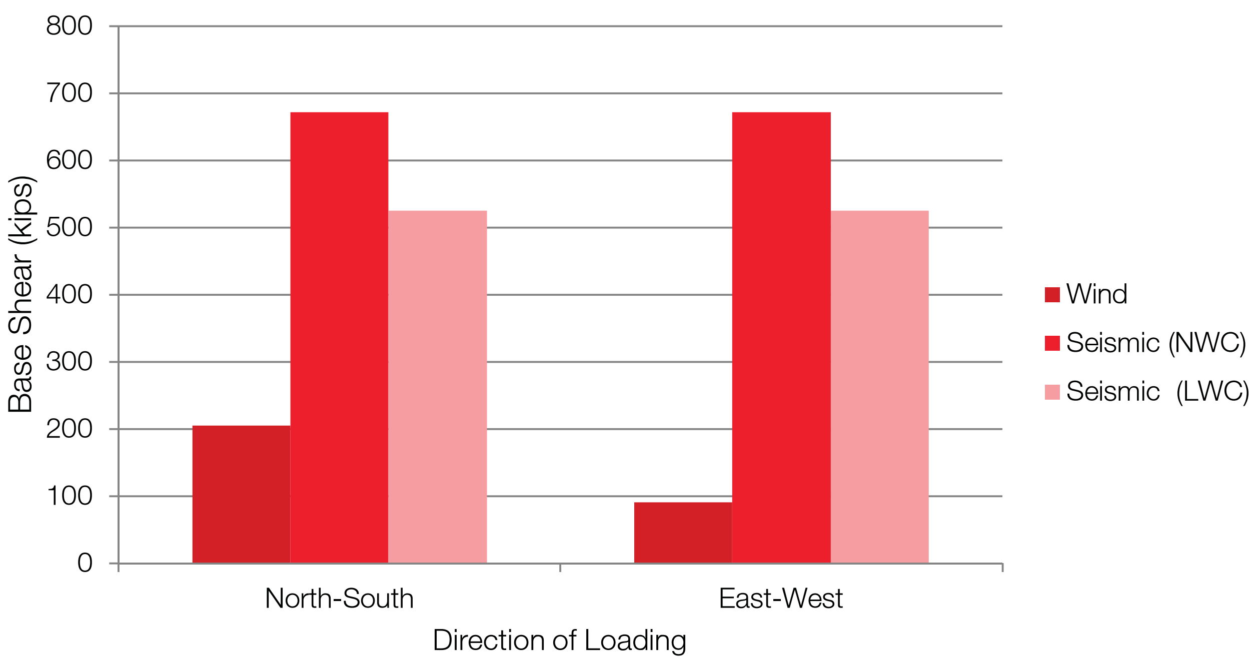


Figure 5. Comparison of Service Level Base Shear

Lateral System

Seismic loads govern the lateral system in both directions. The service level base shears in each direction for both wind and seismic loads are shown in Figure 5. The seismic design category was determined to be seismic design category C, which permitted the lateral system for all structural schemes to consist of steel concentric braced frames not specifically detailed for seismic resistance (R=3) as noted in the design criteria.

There are two lines of braced frames in each direction as shown in Figures 6 and 7. The braced frames are located on the interior center of the building adjacent to the corridors in the plan East-West direction and at the first interior column line in the North-South direction. The frames align vertically without interruption for the full height of the building. The braces for all schemes are grade 50 double angles. The braces were designed in ETABS using the steel design post processor. Brace sizes range from 2L6x6x5/16 to 2L8x8x1.

Brace sizes for the lightweight schemes are slightly smaller than the normalweight scheme due to the lower base shear of the lightweight system. This is because seismic load governs the design of lateral system.

Foundations

Service level reactions were exported for all schemes from the ETABS models to facilitate the design of the foundation elements. Foundations consist of square spread footings for the gravity columns and combined, rectangular footings for the braced frames. The allowable soil bearing pressure is assumed to be 3000 psf.

The typical slab on grade at the ground floor is a soil-supported 5" thick concrete slab with WWR 6x6 – W5.5xW5.5 reinforcing.

Structural Framing Plans

The results of the analysis and design of the structural components can be found in the structural plans and details, attached as an appendix to this report. The list of drawings is as follows:

S201.A .... NWC Scheme Foundation Plan
S201.B .... LWC Scheme Foundation Plan
S202.A .... NWC Scheme Typical Floor Plan
S202.B .... LWC A Scheme Typical Floor Plan
S202.C .... LWC B Scheme Typical Floor Plan
S202.D .... LWC C Scheme Typical Floor Plan
S203.A .... NWC Scheme Roof Plan
S203.B .... LWC Scheme Roof Plan
S301 .... Schedules and Elevations

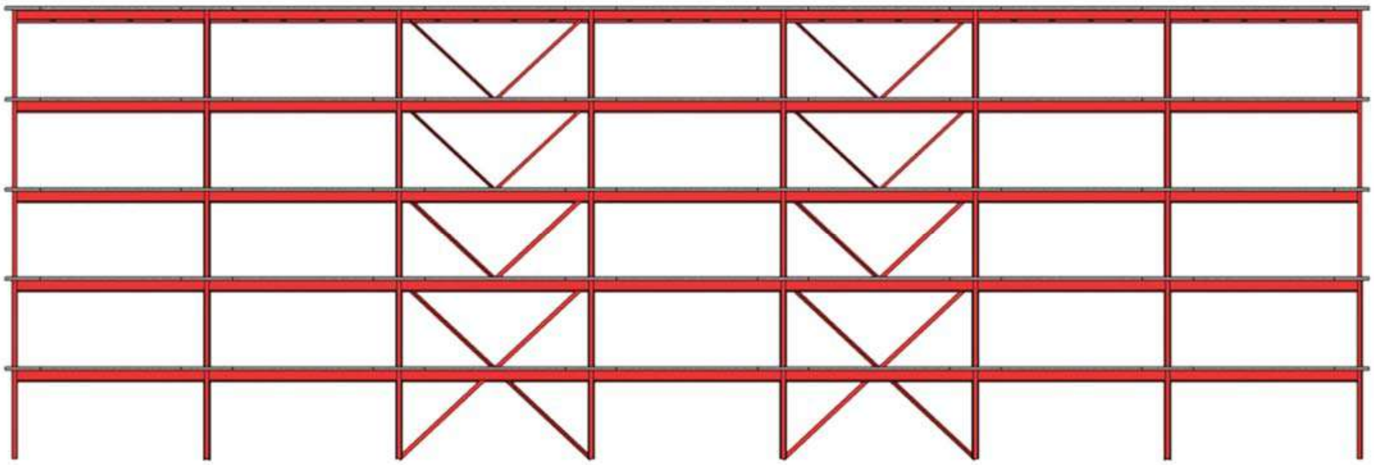


Figure 6. Braces in East-West Direction

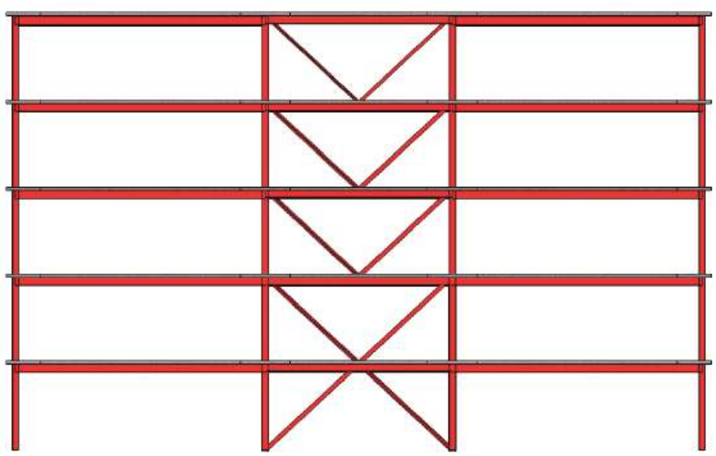


Figure 7. Braces in North-South Direction

Material Inventory

The material inventory is based on the results of the analysis and design of the structural schemes. The structural elements are broken out by material since each is associated with a unique energy intensity value. Reinforced concrete is separated into its individual components of cement, aggregate, and rebar.

The production of Portland cement is an extremely energy intensive process since it requires very high temperatures. Therefore, this study is sensitive to not only the volume of concrete, but also the proportions of the concrete mix design. For this reason, Walter P Moore aggregated data from historical concrete mix designs used in our practice across the United States to develop a representative average value for the concrete mixes. The values are presented in Table 2. In general, the cement content of a NWC mix contains approximately 85 lb/CY less cement than a similar LWC mix.

Mixture	Cement (lb/CY)	Fly Ash (lb/CY)	Coarse Aggregate (lb/CY)	Fine Aggregate (lb/CY)
3500 PSI NWC Slab on Metal Deck	425	140	1900	1275
3500 PSI LWC Slab on Metal Deck	510	130	875	1350
4000 PSI Foundation	450	125	1925	1200

Table 2. Concrete Mixture Designs

Using the concrete mix designs and the design results from the gravity and lateral analyses, the material inventory was generated for each structural component. The material inventory is shown in Table 3. The lateral system included the beams, braces, and braced frame columns. The gravity columns include all steel columns that are not part of the lateral load resisting system. The floor framing includes only the steel beams that comprise the floor system. The composite deck and slab includes the steel deck, the concrete slab and the rebar within the composite floor. The composite deck and slab also includes the interior bay of composite roof slab located at the roof level in the mechanical area. The roof deck and framing includes the steel roof deck and the steel beams and joists at the roof level. Lastly, the foundation includes the concrete and rebar used in the spread footings and the slab on grade.

		Material Inventory (lbs)			
	Material	NWC	LWC A	LWC B	LWC C
Lateral System	Recycled Engineering Steel	100,000	88,000	88,000	88,000
	Studs	220	130	130	130
Gravity Columns	Recycled Engineering Steel	76,000	71,000	71,000	71,000
Floor Framing	Recycled Engineering Steel	500,000	419,000	403,000	554,000
	Studs	3,990	2,790	2,160	2,790
Composite Deck + Slab	Steel Sheet	264,000	179,000	288,000	200,000
	Cement	732,000	760,000	760,000	677,000
	NWT Aggregate	3,273,000	-	-	-
	LWT Aggregate	-	1,303,000	1,303,000	1,162,000
	Sand	2,196,000	2,011,000	2,011,000	1,792,000
	Recycled Rebar	27,600	19,900	19,900	19,900
Roof Deck + Framing	Recycled Engineering Steel	101,000	96,000	94,000	104,000
	Studs	140	140	100	140
	Steel Sheet	31,000	31,000	31,000	31,000
Foundations	Cement	450,000	389,000	389,000	389,000
	NWT Aggregate	1,923,000	1,662,000	1,662,000	1,662,000
	Sand	1,199,000	1,036,000	1,036,000	1,036,000
	Recycled Rebar	46,000	42,000	42,000	42,000
Total Material Inventory (lbs)		10,922,950	8,109,960	8,200,290	7,830,960

Table 3. Material Inventory

Environmental Metrics

Material Energy Intensity

The energy intensity of all structural materials used within this study is from the Inventory of Carbon & Energy (ICE) Version 2.0 by G. Hammond and C. Jones of The University of Bath Department of Mechanical Engineering, published January 2011. This report contains cradle-to-gate estimates for embodied energy and embodied CO_2 of various building materials. "Cradle-to-gate" boundaries include only the embodied impacts up to the point where the material leaves the manufacturer. In this analysis the tabulated values are used for embodied energy estimates.

Recycled Engineering Steel, Rebar and Studs

Grade 50 engineering steel generally contains 93% recycled content. Values are tabulated for both virgin and recycled engineering steel and bar stock. In all cases we assumed structural steel shapes to be rolled from primarily recycled content and produced in an electric arc furnace.

Steel Sheet

The material intensity of steel sheet accounts for the galvanizing of the steel sheet. The intensity assumes an average recycled content of steel sheet to be 59%.

Cement

The material intensity of cement presented within this report assumes a composition of 94% clinker, 5% gypsum, and 1% minor additional constituents.

Normalweight Aggregate and Sand

The intensity of the coarse aggregate and sand presented here account for the extraction of virgin materials.

Lightweight Aggregate

The energy intensity of the lightweight aggregate is the only value used within this study that was not taken from the ICE report. This value is provided by the ESCSI from a report by Jan Consultants and Construction Technology Laboratories entitled *The Life Cycle inventory of the Lightweight Aggregate Manufacturing Process* published February 17, 2000. The ESCSI performed a subsequent survey of their members in 2006. While data from the second survey is not used in this report, it is discussed in more detail in the conclusions section.

Fly Ash

This study treats fly ash as a waste product and follows the common practice of the "polluter pays principle" where the energy intensity of the waste processing is assigned to the product that generated the waste. This methodology results in fly ash having a material energy intensity of zero.

Material Energy Intensity Table		
Material	EE (MJ/kg)	EE (BTU/lb)
Recycled Engineering Steel	13.10	5630
Steel Sheet	22.60	9720
NWT Aggregate	0.08	40
Cement	5.50	2370
LWT Aggregate	2.74	1180
Sand	0.08	40
Recycled Rebar	8.80	3780
Studs	13.10	5630

Table 4. Material Energy Intensities

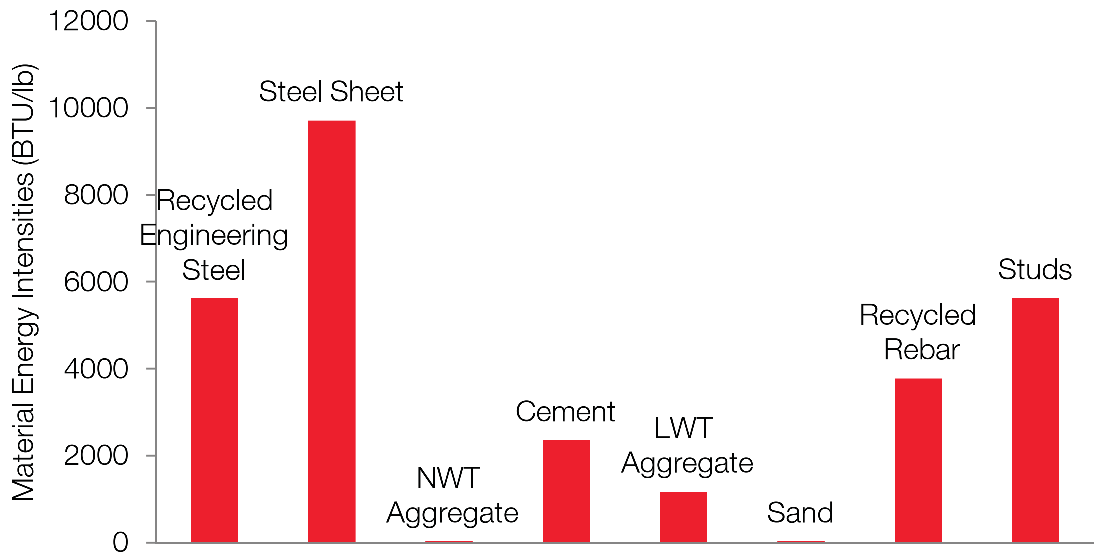


Figure 8. Relative Material Energy Intensities Per Unit Weight

Embodied Energy Study

Material intensities were used to determine the total embodied energy for each material. The table of total embodied energy shown is subdivided into several categories to facilitate comparison between the various systems. Embodied energy is shown in units of millions of British thermal units (MMBTU) rounded to the nearest 100,000.

Total Embodied Energy

The total embodied energy for each of the structural system is presented in Figure 9. The chart shows that the lightweight system, LWC A, has the lowest embodied energy, at just over 10,500 MMBTUs. The embodied energy of the normalweight concrete system, NWC, is just slightly larger than the lightweight system, LWC A. LWC B, has an embodied energy of close to 11.5 billion BTUs. Lastly, although the LWC C system has the lowest total weight, it does not have the lowest embodied energy due to the increased amount of structural steel required to meet the vibration criteria.

		Embodied Energy, MMBTU			
	Material	NWC	LWC A	LWC B	LWC C
Lateral System	Recycled Engineering Steel	560	500	500	500
	Studs	0.1	0.1	0.1	0.1
Gravity Columns	Recycled Engineering Steel	430	400	400	400
Floor Framing	Recycled Engineering Steel	2,820	2,360	2,270	3,120
	Studs	22	16	12	16
Composite Deck + Slab	Steel Sheet	2,570	1,740	2,800	1,940
	Cement	1,730	1,800	1,800	1,600
	NWT Aggregate	120	-	-	-
	LWT Aggregate	-	1,540	1,540	1,370
	Sand	80	70	70	60
	Recycled Rebar	104	75	75	75
Roof Deck + Framing	Recycled Engineering Steel	570	540	530	580
	Studs	0.8	0.8	0.6	0.8
	Steel Sheet	300	300	300	300
Foundations	Cement	1,060	920	920	920
	NWT Aggregate	70	60	60	60
	Sand	40	40	40	40
	Recycled Rebar	180	160	160	160
Total Embodied Energy, MMBTU		10,660	10,520	11,480	11,140

Table 5. Complete Table of Embodied Energy

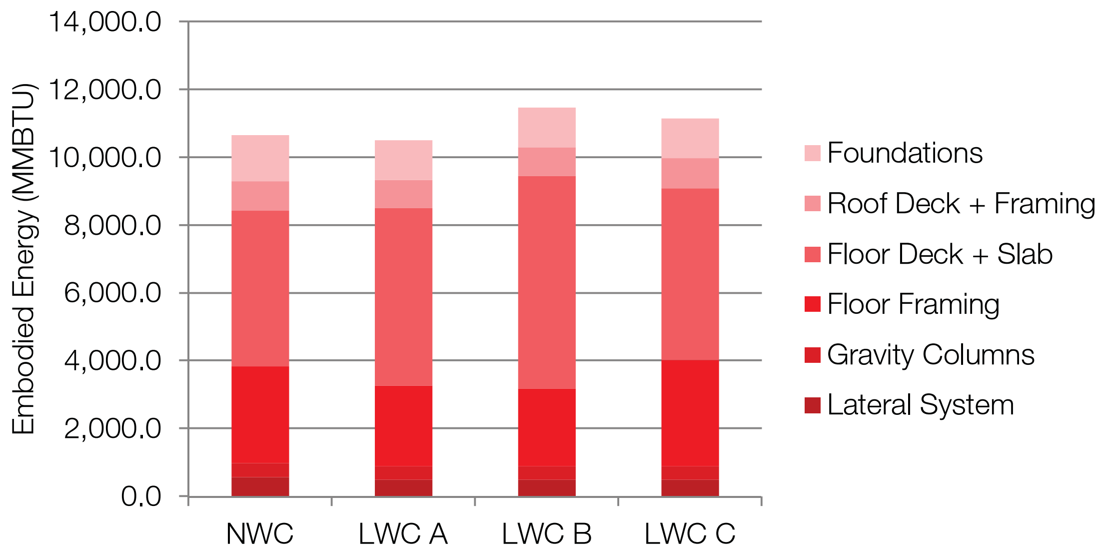


Figure 9. Total Embodied Energy

Structural Steel Embodied Energy

The structural steel accounts for just over a third of the total embodied energy. As shown in Figure 10, the majority of the embodied energy attributed to structural steel is from the floor framing. Therefore, although the lightweight concrete schemes realize some savings due to reduced seismic weight, the relative overall impact is small. Overall, there is approximately a 5% total embodied energy savings in the structural steel for the lightweight concrete system.

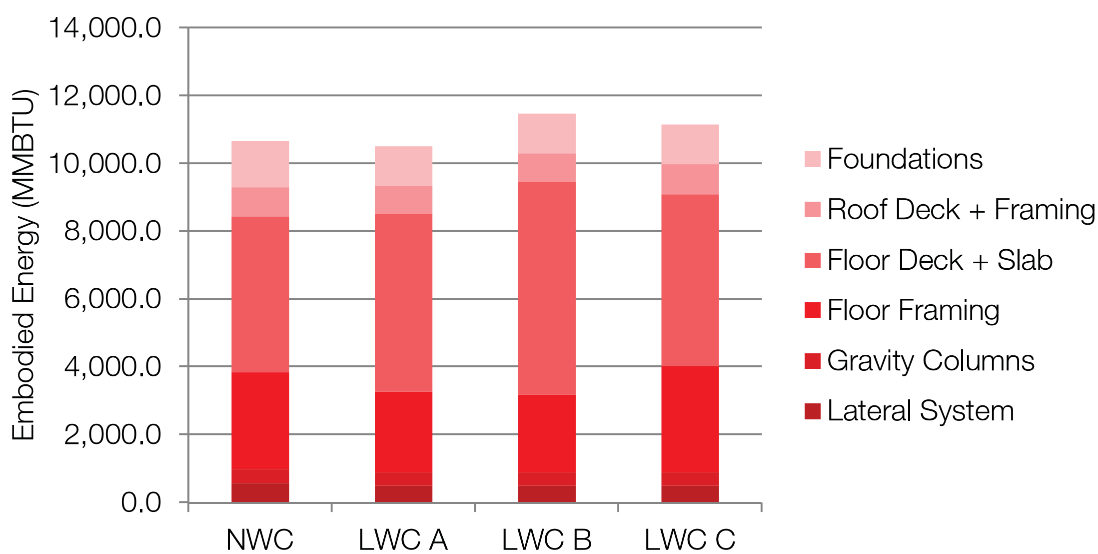


Figure 10. Structural Steel Embodied Energy

Composite Floor Deck and Slab Embodied Energy

The results of the embodied energy study show that, depending on the scheme, the composite deck and slab comprise almost half of the total embodied energy of the structure. The elements that comprise the composite deck and slab are: steel sheet, cement, aggregate, sand, and rebar. Figure 11 shows the relative impact of each of these elements in each structural system.

For the NWC scheme, the steel sheet is only 2% of the weight of the structure; but it accounts for roughly 25% of the embodied energy. For this study, the normalweight concrete scheme required a 2" 18ga deck to span 10'-0" and support the concrete required to achieve a 2-hour fire rating. However, the lightweight system only required a 22 ga deck to function equivalently. For this reason, the lightweight scheme, LWC A, has approximately 30% less embodied energy due to the steel sheet component of the composite deck. Although the LWC B scheme is able to reduce the floor framing structural steel tonnage by utilizing a larger beam spacing, the use of 18 ga deck for this scheme makes it much more energy intensive than LWC A. Likewise, although the LWC C scheme reduces the deck weight by using a thinner system, the increased structural steel tonnage required to satisfy vibration criteria makes it more energy intensive than LWC A.

The other major contributor to the energy intensity of the composite floor is the cement. The weight of the cement comprises only 5-10% of the total weight of the structure, yet contributes 15-20% of the total embodied energy. This can be reduced by using supplementary cementitious materials such as fly ash and GGBF slag which as byproduct materials carry considerably smaller embodied impacts.

As noted previously, the production of lightweight aggregate is considerably more energy intensive than that of normalweight aggregate. Figure 12 shows how the use of lightweight aggregate significantly changes the relative embodied energy contributions in a given volume of concrete. In a normalweight concrete mix, the cement accounts for 90% of the embodied energy and the coarse aggregates account for 5%. Conversely, for a lightweight concrete mix, the cement accounts for 60% while the lightweight aggregate accounts for over 30% of the embodied energy. Per unit volume of concrete a lightweight concrete will have a significantly greater embodied energy and therefore makes a much larger contribution to the overall embodied energy of a structure. In the normalweight scheme, the aggregate accounts for approximately 30% of the total weight of the structure but only 1% of the total embodied energy. However, for the lightweight schemes, the lightweight aggregate accounts for 15% of the total weight yet accounts for more than 10% of the total embodied energy.

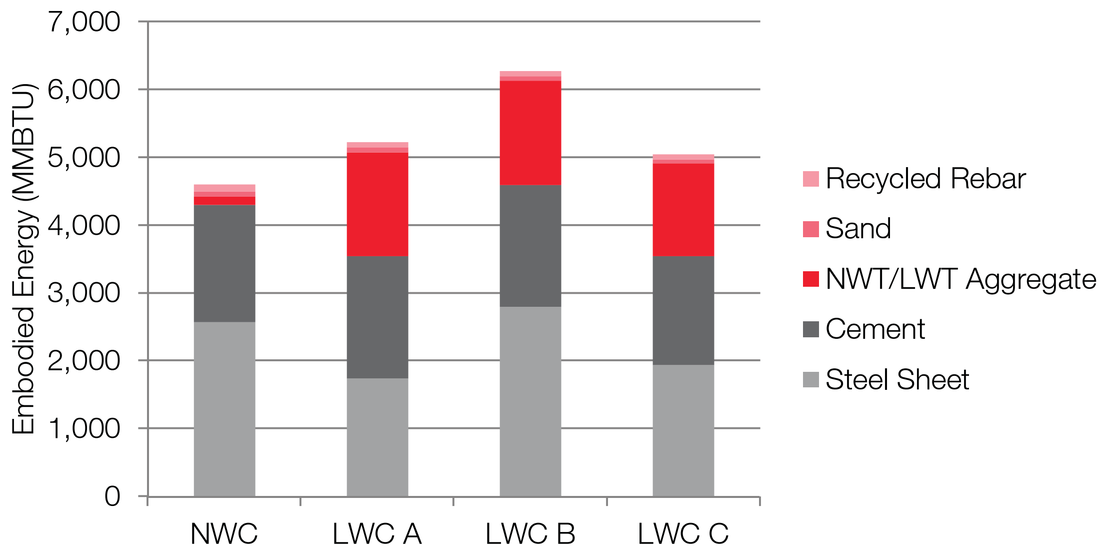


Figure 11. Composite Deck System Embodied Energy Breakdown

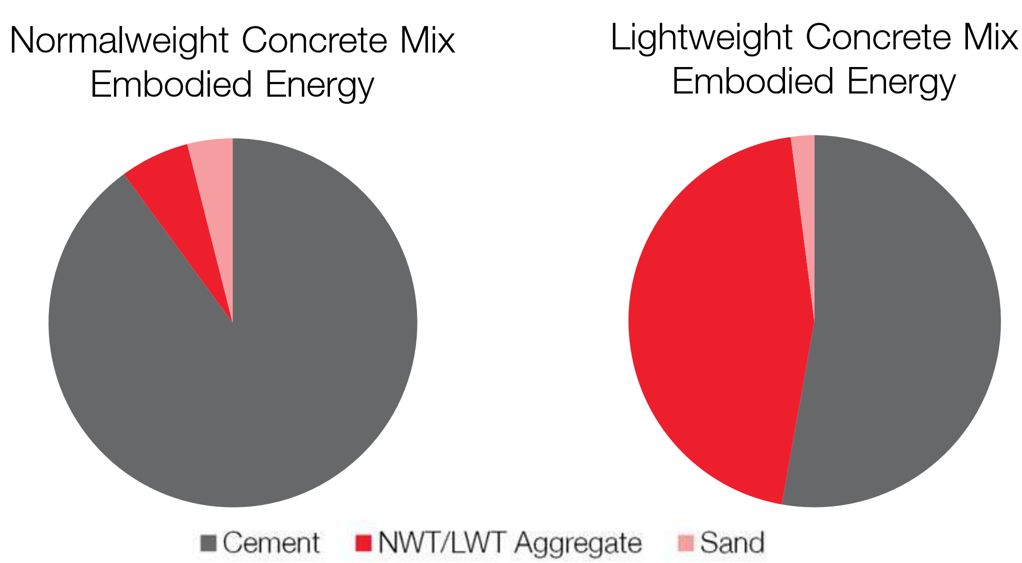


Figure 12. Embodied Energy Contribution Per Unit Volume of Concrete

Conclusions

This study found that although lightweight aggregates require more energy to produce than normalweight aggregates, a number of factors collectively offset the increased embodied energy of the lightweight aggregate. These factors include: reduced dead load of the lightweight system, reduced concrete volume due to better fire performance of lightweight concrete, and thinner steel decks for a given beam spacing due to the reduced wet weight of the concrete floor. These weight savings also decrease the material required to resist seismic loads as well as reduce foundation size.

The floor framing is the most significant contributor to the total embodied energy of the subject structures. This demonstrates that while the use of lightweight aggregate helps reduce the lateral system for buildings governed by seismic loads, that reduction is not as significant as potential reductions in the horizontal framing system. This also suggests that the results of this study are applicable to buildings in areas where non-seismic loads govern the design of the lateral system.

The lightweight concrete mixes collected for this study consistently contain more cement than the comparable normalweight concrete mixes. This is notable because cement makes the dominant contribution to the embodied energy of a concrete mix and hence the composite floor system. Any reductions in the cement content of lightweight mixes will further help to offset the increased embodied energy in the mix due to the lightweight aggregate. Common supplementary cementitious materials such as fly ash and ground granulated blast furnace slag can be used to replace cement.

Overall this study found that the reductions in material quantities due to the use of lightweight aggregate offset the increased embodied energy required to produce the lightweight aggregate. The lightweight aggregate building “LWC A” had a smaller total embodied energy than the functionally equivalent building using normalweight concrete. However, the difference was within a few percentage points, which is well within underlying range of uncertainty for the tabulated environmental data.

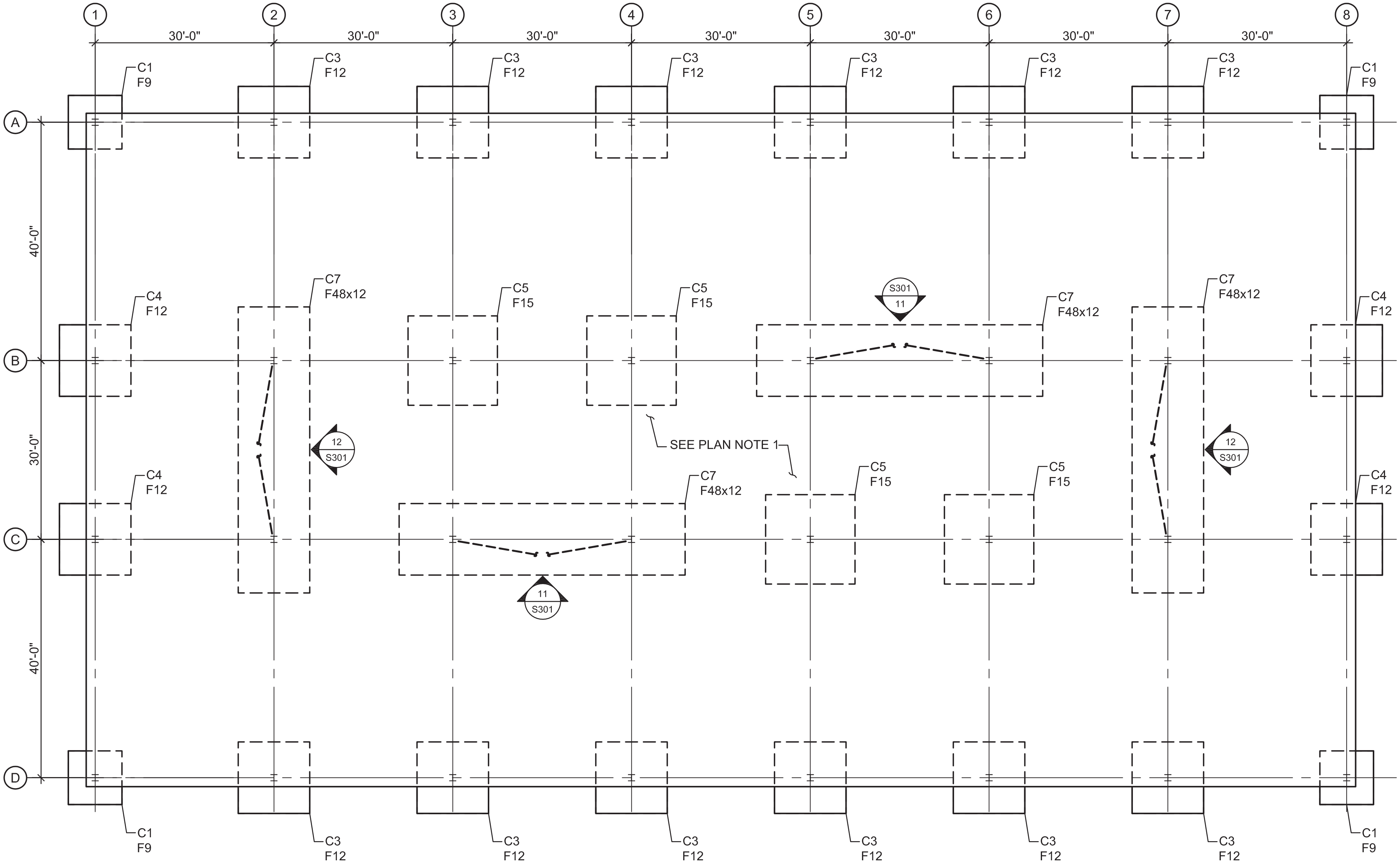
This study also included a building framed with 2” composite deck and a lightweight concrete floor “LWC C”. This framing system creates a very light floor that while structurally acceptable, is susceptible to excessive floor vibrations. To make this system functionally equivalent to other systems the floor beams and girders were stiffened to keep floor accelerations within the limits recommended by the American Institute of Steel Construction. This additional steel caused the embodied energy of this system to exceed that of LWC A.

It is also significant to note that the life cycle inventory of the lightweight aggregate indicated that, depending on the producer, the embodied energy of lightweight aggregate can vary significantly. This study assumed the average value for embodied energy of several materials. However, if a specific building is located in a region where the lightweight aggregate supplier provides an aggregate with a less than average embodied energy the impact increase of the floor will be smaller than reported within this study. In such cases the energy savings realized by the use of lightweight aggregate will become more significant.

The life cycle inventory data used for lightweight aggregate was based on a third party analysis performed in 2000. This survey included 11 producers of lightweight aggregate representing just over 2 million tons of capacity.

In 2006 the ESCSI performed an additional survey of their members. The results of this survey are contained in Publication #9153 “Embodied Energy to Manufacture Expanded Shale, Clay and Slate Lightweight Aggregate” published November 30th 2006. The 2006 report included 13 producers representing nearly 4 million tons of production capacity. The later survey indicated that the average embodied energy of lightweight aggregate is 1008 Btu/ lb. This represents a 15% reduction from the previous study. To evaluate the impact such a reduction would have on the overall embodied energy of the structural frame one can scale the LWT aggregate value in Table 5 by 0.85 and re sum the columns. This results in a roughly 2% decrease in total embodied energy for each of the lightweight framing schemes.

Appendix – Structural Framing Plans



PLAN NOTES:
1. FLOOR STRUCTURE IS A 5" SLAB ON GRADE REINFORCED WITH WWR 6x6-W5.5xW5.5

1 NWC Scheme Foundation Plan

1/16" = 1'-0"

WALTER P MOORE

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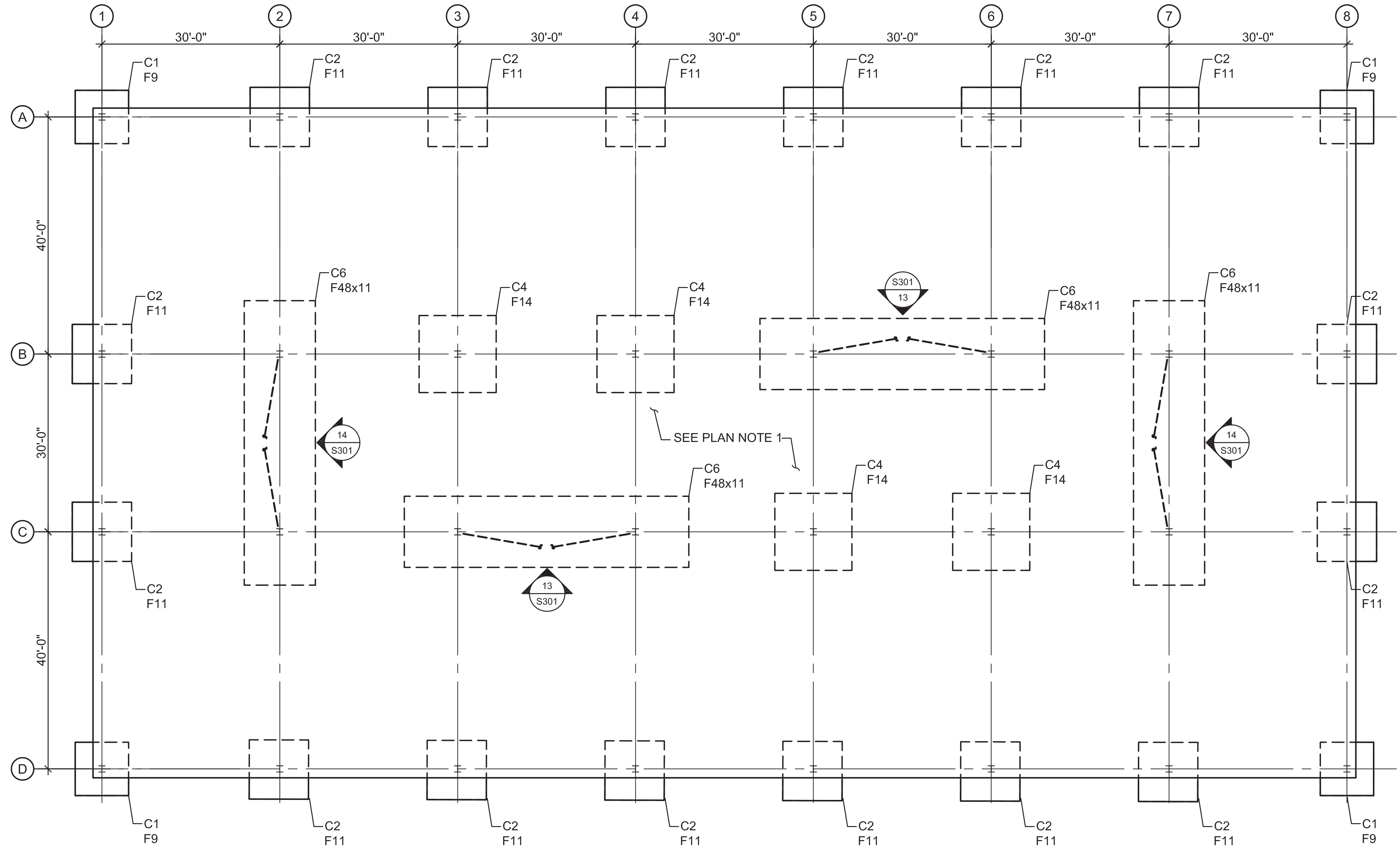
PHONE: 512.330.1270 FAX: 512.330.1295

Project Name: Embodied Energy Study of Lightweight Aggregate in Steel Framed Buildings

Client: Expanded Shale, Clay and Slate Institute

Project No.:	Date:	Scale:	Sheet No.:
R02.11001.00	09.21.2012	1/16" = 1'-0"	S201.A



PLAN NOTES:
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Project No.:	Date:	Scale:	Sheet No.:
R02.11001.00	09.21.2012	1/16" = 1'-0"	S201.B

PLAN NOTES:

1. FLOOR STRUCTURE IS 4 1/2" NWC ON 2" 18 GA. COMPOSITE DECK REINFORCED WITH WWR 6x6-W2.1xW2.1

1 NWC Scheme Typical Floor Plan

1/16" = 1'-0"

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Client: Expanded Shale, Clay and Slate Institute			
Project No.: R02.11001.00	Date: 09.21.2012	Scale: 1/16" = 1'-0"	Sheet No.: S202.A

PLAN NOTES:

1. FLOOR STRUCTURE IS 3 1/4" LWC ON 3" 22 GA. COMPOSITE DECK REINFORCED WITH WWR 6x6-W1.4xW1.4

1 LWC A Scheme Typical Floor Plan

1/16" = 1'-0"

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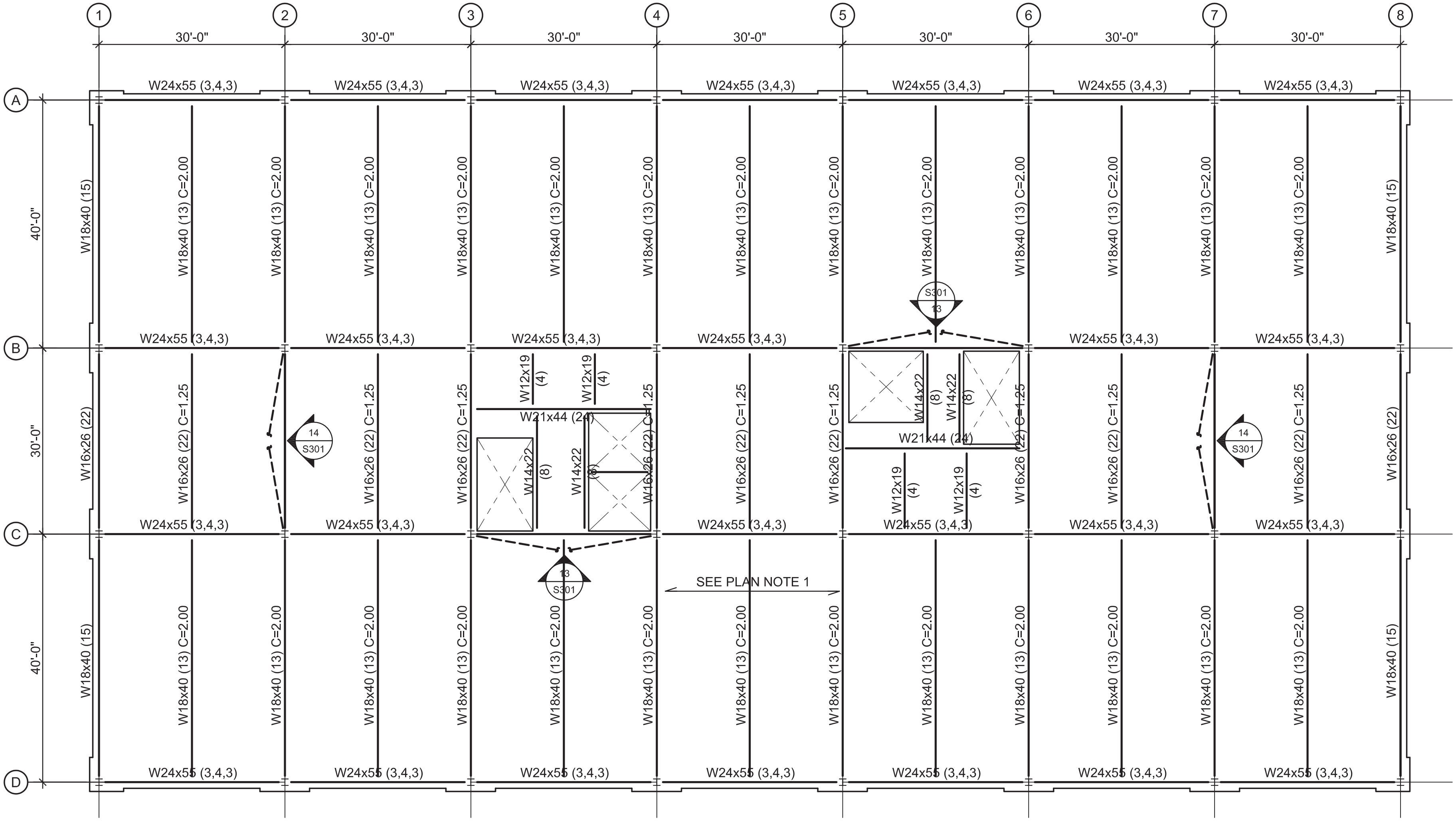
R02.11001.00	09.21.2012	1/16" = 1'-0"	S202.B



PLAN NOTES:

1. FLOOR STRUCTURE IS 3 1/4" LWC ON 3" 18 GA. COMPOSITE DECK REINFORCED WITH WWR 6x6-W1.4xW1.4

1 LWC B Scheme Typical Floor Plan

1/16" = 1'-0"

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Project No.:	Date:	Scale:	Sheet No.:
R02.11001.00	09.21.2012	1/16" = 1'-0"	S202.C

PLAN NOTES:

1. FLOOR STRUCTURE IS 3 1/4" LWC ON 2" 20 GA. COMPOSITE DECK REINFORCED WITH WWR 6x6-W1.4xW1.4

1 LWC C Scheme Typical Floor Plan

1/16" = 1'-0"

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Project No.:	Date:	Scale:	Sheet No.:
R02.11001.00	09.21.2012	1/16" = 1'-0"	S202.D

PLAN NOTES:

1. ROOF STRUCTURE IS 1 1/2" GALV. 22 GA ROOF DECK BETWEEN GRIDS A & B AND C & D AND 4 1/2" NWC ON 2" 22 GA COMPOSITE DECK REINFORCED WITH WWR 6x6-W2.1xW2.1 BETWEEN GRIDS B & C

1 NWC Scheme Roof Plan

1/16" = 1'-0"

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Client:	Expanded Shale, Clay and Slate Institute

Project No.:	Date:	Scale:	Sheet No.:
R02.11001.00	09.21.2012	1/16" = 1'-0"	S203.A

PLAN NOTES:
1. ROOF STRUCTURE IS 1 1/2" GALV. ROOF DECK BETWEEN GRIDS A & B AND C & D AND 3 1/4" LWC ON COMPOSITE DECK REINFORCED WITH WWR 6x6-W1.4xW1.4 BETWEEN GRIDS B & C

1 LWC Scheme Roof Plan

1/16" = 1'-0"

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Project No.: R02.11001.00	Date: 09.21.2012	Scale: 1/16" = 1'-0"	Sheet No.: S203.B

STEEL COLUMN SCHEDULE							
MARK / LEVEL	C1	C2	C3	C4	C5	C6	C7
ROOF LEVEL							
FOURTH FLOOR							
THIRD FLOOR		W12x40	W12x40	W12x40	W12x50	W12x65	W12x72
SECOND FLOOR							
FIRST FLOOR	W12x40	W12x45	W12x50	W12x53	W12x65	W12x87	W12x106
BASE PLATE	22"x22"x2"	22"x22"x2"	22"x22"x2"	22"x22"x2"	22"x22"x2"	22"x22"x2"	22"x22"x2"
ANCHOR RODS	(4)¾"Øx1'-0"	(4)¾"Øx1'-0"	(4)¾"Øx1'-0"	(4)¾"Øx1'-0"	(6)1¾"Øx3'-2"	(4)¾"Øx1'-0"	(4)¾"Øx1'-0"

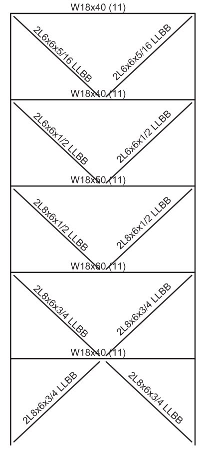
STEEL COLUMN SCHEDULE

(4) SCHEDULE

SPREAD FOOTING SCHEDULE				
MARK	PLAN SIZE	THICKNESS	REINFORCEMENT	
			SHORT WAY	LONG WAY
F9	9'-0"x9'-0"	22"	(10) #6	(10) #6
F11	11'-0"x11'-0"	25"	(10) #7	(10) #7
F12	12'-0"x12'-0"	28"	(10) #8	(10) #8
F14	14'-0"x14'-0"	31"	(12) #8	(12) #8
F15	15'-0"x15'-0"	34"	(14) #8	(14) #8
F48x11	48'-0"x11'-0"	40"	#5@12" T #9@12"B	#5@12" T #9@12"B
F48x12	48'-0"x12'-0"	46"	#5@12" T #9@12"B	#5@12" T #9@12"B

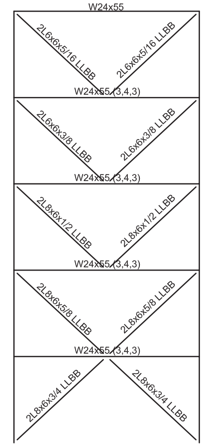
SPREAD FOOTING SCHEDULE

(2) SCHEDULE



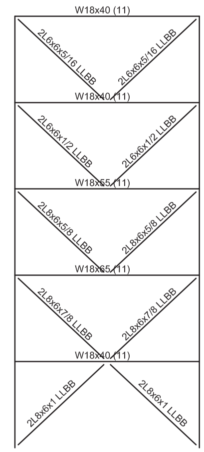
LWC BRACED FRAME GRIDS 2 & 7

(14) ELEVATION



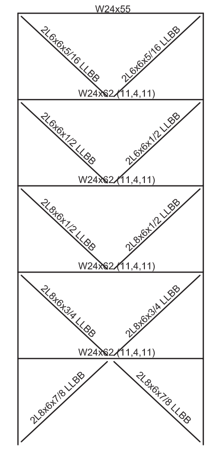
LWC BRACED FRAME GRIDS B & C

(13) ELEVATION



NWC BRACED FRAME GRIDS 2 & 7

(12) ELEVATION



NWC BRACED FRAME GRIDS B & C

(11) ELEVATION

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Project No.:	Date:	Scale:	Sheet No.:
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