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Structural Option
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Boyds Bear Country
Pigeon Forge, TN

Thesis Proposal
Structural Redesign / Cost, Schedule and Coordination Analysis / Architectural Impact

Executive Summary:

Boyds Bear Country, located in Pigeon Forge, Tennessee, is designed as a multi-functional space and tourist attraction for Boyds Collections Ltd. The 112,620 square foot building houses three floors of retail space with multiple cashier and information desks, warehouse storage, a loading dock, a full sized restaurant, food court, ice cream parlor, special events areas, and offices.

In analyzing structural systems of Boyds Bear Country it is quickly apparent that special considerations will have to be made to accommodate the use of multiple materials and unique applied loads in the structure. It implements structural steel, cold rolled steel, concrete slabs, cast-in-place concrete walls and foundations, reinforced concrete block, wooden trusses, and wooden members.

The existing structural system of the building is composed of a steel grid supporting composite slabs. Wooden trusses support the roof, covered in plywood sheathing. Lateral resistance is provided by concentric braced frames, masonry shear walls, and masonry piers. Foundations consist of shallow footings and piers, built as a mixture of cast-in-place concrete and masonry.

In order to lessen the downfalls created by the application of multiple materials, options will be considered to transform the building into primarily a single material. The first option to be studied in depth will be the application of structural pre-cast concrete system. As initially identified in Technical Report 2, a wholly pre-cast system will focus on double-tees supported by pre-cast beams, girders, and columns. The second option to simplify the use of materials in the structure comes in the use of wooden framing, as studied briefly in Technical Report 2. Primary members of the structure will be engineered wood products as opposed to large scale timbers.

Breadth topics in construction management and architecture will be considered in following work. As in with the introduction of any changes to a building, cost will be a consideration in the viability of the new systems. Schedule and coordination adjustments will be rather large in the proposed adjustments. In accomplishing the goal of minimizing the number of materials used in the building, it is inevitable that these will be simplified. Both redesign options will have an impact on the architectural design of the building as its materials will be changing. Considerations will be made to balance the performance of the system as a structural frame and the appearance of the system within required design architectural goals.

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Introduction to the Existing Structural System:

Framing Layouts

The structural framing at Boyds Bear Country is primarily a steel grid with wooden roof trusses. The main structural grid is made of standard steel shapes, a typical floor plan of which can be seen as figure 1, and the yield strengths of applicable steel members are listed below:

Structural Steel Shapes	Type	[ksi]
Wide Flanges and WTs	ASTM A992	50
Pipe – Type S, Grade B	ASTM A53	35
Tube – Grade B	ASTM A500	46
Plates	ASTM A36	36
Other Shapes	ASTM A36	36
¾" Diameter High Strength Bolts	ASTM A325	n/a

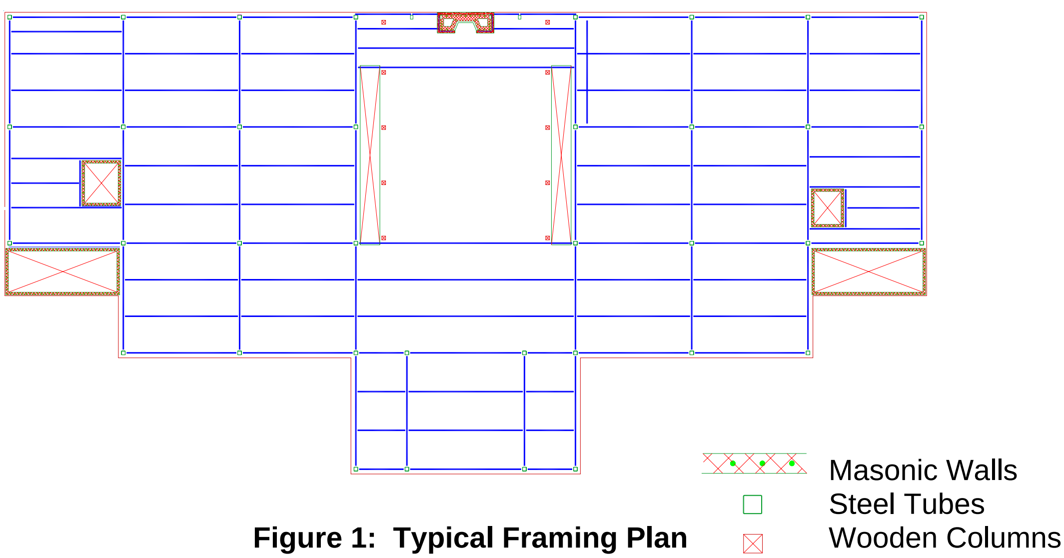

Figure 1: Typical Framing Plan

Typical bays measure ~30'x30' square with W16 beams, framing to W24 girders, which connect to steel tube columns. This framing grid varies around stairwells, elevators, and the front façade projection of the building.

Deeper members are located within the center bay, which features spans of up to 60'. On the central floors, this center bay becomes and atrium flanked on either side by large escalators with primarily decorative wooden framing.

Wooden framing is located in other areas of the building as structural support, primarily in exterior seating areas. Structural joists, girders, and posts are typically specified as No. 2 Southern Pine. All roof framing consists of wooden trusses spaced 2' on center and were manufactured off site of primarily 2x4 No. 2 Southern Pine. These can be seen in construction in figure 3.

Exterior walls on the ground floor are primarily concrete block, ranging from 8" to 16" thick; both common concrete blocks (1500 psi) and high strength Ivany blocks (2800 psi) are used. These blocks are also used in the construction of walls surrounding stairwells, mechanical rooms, and elevator shafts, some of which act as shear walls in the building. Interior walls throughout, and exterior walls on the upper floors, are cold-formed steel framing sheathed in plywood and gypsum board, as shown in figure 2.

Figure 2: Light gauge steel framing with plywood sheathing[1]

Figure 3: Roof trusses of 2x4 No.2 Southern Pine spaced at 2' OC.[1]

Structural Slabs

Elevated slabs in the building are composite construction. All elevated slabs are supported on 3" x 20 gauge Type VL galvanized steel decking, and the slabs of the main structure are composed of 6½" thick, monofilament synthetic polypropylene fiber reinforced, 3,000 psi lightweight concrete. The slab of the Northeast pavilion / mechanical area is composed of 5½" of normal weight concrete. Secondary reinforcing consists of 6x6-W2.0xW2.0 welded wire mesh in both types of concrete. A cross-section of the typical interior slab can be seen in figure 4 and a photo of the slab as placed in construction can be seen in figure 5.

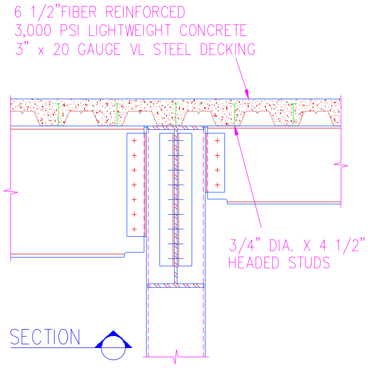

Figure 4:
Cross-section of typical slab

Figure 5: Composite slab as placed during construction[1]

Lateral Resisting System

Original drawings for Boyds Bear Country in Pigeon Forge, Tennessee call out two lateral systems, that of masonry shear walls and steel braced frames. In specific study of the design documents, it can be found that the primary lateral resistance system is concentric steel braced frames. A secondary masonry lateral resistance system can be found in 5 of the 8 braced frames in the building. These frames sit on either one or two masonry piers which are incorporated within reinforced block walls. All eight of these frames can be seen, highlighted in red, in figure 6.

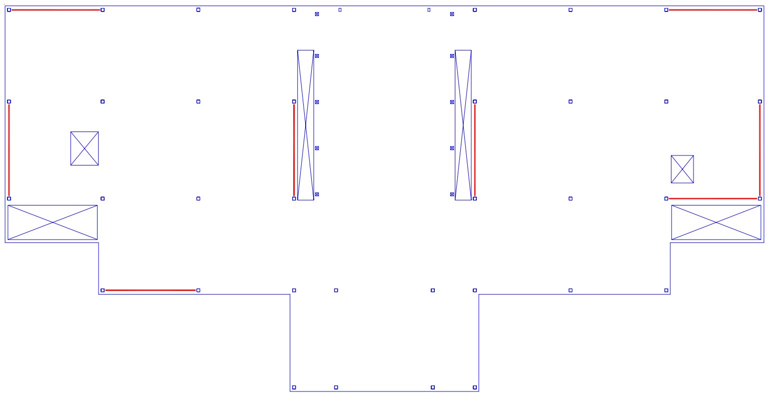

Figure 6: Lateral Resistance System Plan

The floor system of composite steel beams, girders, and concrete deck acts as a diaphragm, transferring lateral forces to the frames at each of four elevated floor levels. Both wind and seismic forces are imparted as lateral loads on the structure, and through design calculations included in this report, it is found that seismic forces control the design of the structure.

Figure 7:
Frame with double angle cross-bracing[1]

Figure 8:
Frame with tube chevron bracing[1]

Foundation System

Foundations of the building consist of shallow footings and piers. All wall footings are simple thickened slabs measuring 2'-0" wide and 1'-0" thick. Column footings extend to a maximum of 3'-0" thick. Piers are located scattered through the foundation, mainly located underneath columns adjacent to bathrooms and mechanical areas.

Foundations of the building are designed with a bearing pressure of 3,000 psf based on geotechnical investigations of the site. Typically, exterior footings extend to 3' below finished grade, to account for frost depths.

Footings and most piers consist of 3,000 psi cast in place concrete with reinforcing billet steel of ASTM A615, grade 60, with class B splices. Masonry piers in the building are constructed of Ivany block. Footings which have a pier located underneath the column are highlighted in figure 9.

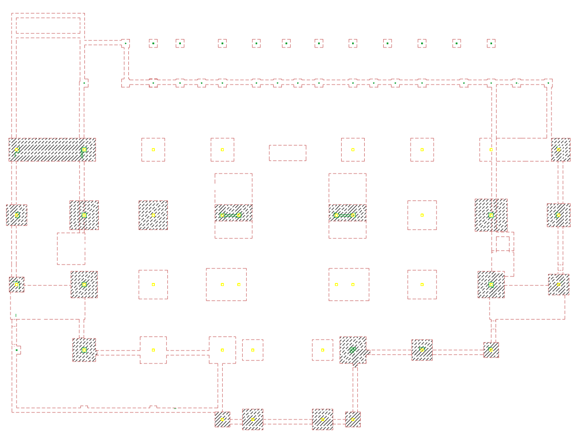

Figure 9: Foundation Plan

Problem Statement:

Boyds Bear Country in Pigeon Forge, Tennessee was built as a combination of several materials, creating difficulties in both construction and design. The materials present in the building can be described as follows:

Steel
- Hot rolled structural members
- Metal decking
- Shear studs
- Light gauge steel framing

Concrete
- Cast-in-place elevated slabs
- Lightweight cast-in-place elevated slabs
- Cast-in-place slab on grade
- Shallow foundations

Masonry
- Normal CMU block
- Ivany (high strength) CMU block
- Structural Piers

Wood
- Manufactured trusses
- Timbers

Large variety of Finish Materials
- Gypsum board
- Plywood, etc.…

The design of the building is complicated by the number of materials used in the building. These require additional analyses of material properties and interactions which can impact nearly all aspects of design. Structurally, one result of the use of numerous materials can be seen in the lateral resisting system as studied in Technical Report 3. Here, the use of concentric steel braced frames is further complicated by the introduction of masonry piers and masonry walls which creates a large amount of additional considerations to successfully determine the behavior of the system. Systems such as mechanical duct work, electrical wiring and lighting all must be altered to adapt to these materials. Mechanical systems must account for variations in thermal properties, electrical systems must account for variations in conductivity, and lighting layouts must account for variations in the quality of finish materials. Overall, the inclusion of multiple materials in the building creates additional difficulties and considerations within the design process.

Completing the construction of a building also becomes more complicated with the use of numerous materials. This requires the attainment and coordination of many contractors. In the case of Boyds Bear Country, separate suppliers were used for each trade including structural steel members, masonry block, cast-in-place concrete, wooden trusses, wooden timbers, mechanical equipment, electrical equipment, elevators, and

sprinklers. A separate contractor was used for site work, general contracting (which included aspects such as roof trusses, exterior stone work, and light gauge steel), structural steel, mechanical systems, electrical systems, elevator systems, and sprinklers. With the addition of each contractor and each supplier, the required amount of coordination and the potential for error increases.

Solution to the Problem:

In order to lessen the downfalls created by the application of multiple materials, options will be considered to transform the building into primarily a single material.

The first option to be studied in depth will be the application of structural pre-cast concrete system. As initially identified in Technical Report 2, a wholly pre-cast system will focus on double-tees supported by pre-cast beams, girders, and columns. The application of double-tees adapts well to the grid system currently developed for the building, and will utilize columns spaced at 30' and 60' on center. The strength and stability of this system will adapt well to areas of varied loading within storage areas of the building. Lateral forces will be resisted by pre-cast shearwalls located around areas of vertical transportation. In addition to the pre-cast members in the building, wooden trusses will be used to frame the roof as applied in the current structure. This will allow for the completion of a roof with several complicated gambles, as designed. Foundations will be concrete poured on site.

The second option to simplify the use of materials in the structure comes in the use of wooden framing, as studied briefly in Technical Report 2. Primary members of the structure will be engineered wood products as opposed to large scale timbers; this ensures pieces free of large defects, with known properties, with higher strengths, and supporting sustainable design. Typical bays will remain unchanged and measure 30' by 30'. Additional research will be required to satisfy vibration and deflection within the floor system. Additional materials will be incorporated in the design with the use of masonry retaining and shear walls and cast-in-place concrete foundations.

Solution Method:

The pre-cast concrete redesign option will be completed using the propitiatory 15' wide double-tees created by High Concrete Structures in Denver, Pennsylvania, and thus will be designed using load tables provided by the supplier. Supporting members will be designed to meet PCI and ACI 318-05 standards using Risa-3D and supplier load tables. Additional considerations such as floor diaphragms will be designed by hand.

The wooden redesign option will be completed using engineered wood products and thus will be designed primarily using supplier load tables and backed by hand calculations. Members will be designed to meet NDS requirements. Additional requirements in the areas of vibration and deflection will be researched and completed by matching IBC and NDS requirements with available materials and suppliers.

Breadth Investigations:

Cost, Schedule, Coordination Analysis

As in with the introduction of any changes to a building, cost will be a consideration in the viability of the new systems. Schedule and coordination adjustments will be rather large in the proposed adjustments. In accomplishing the goal of minimizing the number of materials used in the building, it is inevitable that these will be simplified. Fewer design firms, suppliers and contractors will be required in both options of the redesign.

Architectural Impact

Both redesign options will have an impact on the architectural design of the building as its materials will be changing. The purpose of Boyds Bear Country is to act as a welcoming oversized Pennsylvania Dutch barn. It must hold to the appearance of a classic country barn on both the interior and exterior while also being massive in scale. Considerations will be made to balance the performance of the system as a structural frame and the appearance of the system within required design architectural goals.

Tasks:

1. Loading Determination
    a. Verify loading assumptions to match requirements of pre-cast system,
    b. Verify loading assumptions to match requirements of wood system.
2. Design Pre-Cast Floor System
    a. Use load tables and supporting information to determine members for use in pre-cast system.
    b. Adjust self weight if required.
3. Design Wooden Floor System
    a. Use load tables and NDS to determine members for use in wood system.
    b. Adjust self weight if required.
    c. Determine requirements for vibration and deflection and adjust design accordingly.
4. Design Lateral Resisting Systems
    a. Verify loading assumptions for wind forces.
    b. Adjust seismic loads for use in pre-cast system.
    c. Adjust seismic loads for use in wood system.
    d. Size members for pre-cast system.
    e. Size members for wood system.
    f. Check drift, stresses, and deflections and adjust members as required.
5. Complete Cost, Schedule, and Coordination Analysis.
6. Complete Architectural Impact Analysis
7. Prepare Final Presentation.

Time Table:

Dates [week #]	**Task**
01-15 / 01-21 [1]	Loading Determination
01-22 / 01-28 [2]	Design Pre-Cast Floor System
01-29 / 02-04 [3]	Design Wooden Floor System
02-05 / 02-11 [4]	Design Wooden Floor System
02-12 / 02-18 [5]	Design Lateral Resisting Systems
02-19 / 02-25 [6]	Size members for pre-cast system.
02-26 / 03-04 [7]	Size members for wood system.
03-05 / 03-11 [8]	Check drift, Stresses, and Deflections
03-13 / 03-18 [9]	Spring Break = No Work
03-19 / 03-25 [10]	Complete Cost, Schedule, and Coordination Analysis
03-26 / 04-01 [11]	Complete Architectural Impact Analysis
04-02 / 04-08 [12]	Prepare Final Presentation
04-09 / 04-15 [13]	Prepare Final Presentation
04-16 / 04-20	Thesis Presentations

Citation Note: [1] Photographs c/o Kinsley Construction.
[2] Photographs by Lauren Wilke.