Technical Report 1

Hakuna Resort

Swift Water, Pennsylvania


Image Courtesy of LMN Development LLC

Young Jeon
Structural Option
Advisor: Heather Sustersic
13 September 2014

Table of Contents

Technical Report 1 1
Executive summary 3
Purpose and Scope 4
Building General Description 4
Structural System 6
Brief Description of Structural System 6
Foundation 6
Floor Systems 8
Lateral Load Resisting Elements 9
Framing System 11
Typical Bay 11
Columns 13
Roofing System 14
Joint Details 14
Design Codes and Standards 16
Design Loads 16
Load Paths 17
Gravity Load Path 17
Lateral Load Path 17
Conclusion 18

Executive summary

Hakuna Resort is a jungle/safari theme hotel that includes a huge indoor water park as well as outdoor pool. The other side of the resort is convention centers which provides multiple meeting spaces. Designed into three distinctive spaces, the indoor water park and convention space are adjacent to each end of hotel space. These spaces are connected with expansion joints, therefore, can be looked at as three separate buildings.

The hotel building has total of eight stories above ground with total height of 101'-5" to the top of roof excluding the basement. With each floor having approximately 45,000 SF, the hotel portion of the resort has 395,938 SF by itself. Therefore, with the help of expansion joints, this report will only focus on hotel part of Hakuna Resort.

The foundation is consisted of cast in place concrete with footings, piers and slab on grade while north-west portion of building is partially unexcavated. The excavated basement space is utilized by concrete and masonry walls.

The floor system is mostly consisted of 10" precast prestressed hollow core planks except the excavated basement floor and first level floor above unexcavated foundation where slab on grade concrete is used. The precast planks are supported by masonry shear walls throughout the structure. However, in service areas like sauna, message and treatment on second floor, steel framing system was used to maximize the space usage.

The structural system took advantage of repetitive hotel room layout and placed masonry shear walls in between almost every room. Like mentioned earlier, these shear walls are supporting precast planks, therefore resisting gravity load as well.

In conclusion, while dominant structural system is masonry shear walls with precast planks, there are also structural wide flange steel framing in appropriate spaces, as well as reinforced concrete walls in lower levels. This usage of multiple structural system will be analyzed throughout this report.

Purpose and Scope

The purpose of this technical report is to describe and demonstrate the understanding of the existing condition of the structure of Hakuna Resort at Swiftwater, PA. The scope of this report includes detailed description existing structure system and its purpose. This system includes foundation, floor system, gravity system and lateral resistant system.

Building General Description

Hakuna Resort is a jungle theme resort which includes both indoor waterpark and outdoor pool as well as convention centers while providing luxury hotel space. The indoor waterpark, located north-west to the hotel, has square footage of 143,798 SF in first floor and 73,905 SF in second. As can be seen in figure 1, the convention center is located the opposite, south-east side of the hotel. With basement space of 18,802 SF, the convention center has first floor space of 92,668 SF. The biggest space, however, is the hotel with total of 394,938 SF distributed throughout eight stories and a basement.

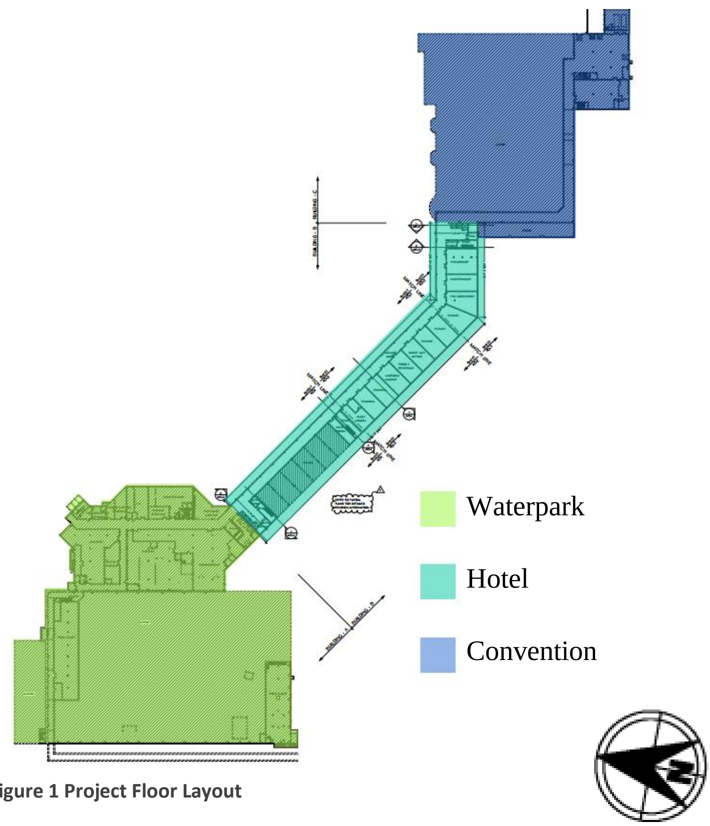


Figure 1 Project Floor Layout

Started constructing in March 2014, Hakuna Resort is to be completed and be open to public in summer of 2015. The project is also looking ahead for potential of three additions in the future (figure 2). The hotel, tallest part of the project, is 101’-5” tall and has the most visual impact when confronted to the site.

The façade of hotel building has color tone of brown, red, and grey to give earth-like feeling. At the corners of building, architectural finish will be done to resemble ancient stone. Also little more distinctive color finishes will be used at the top of hotel façade to give tribal character to the building. The interior designs are also jungle theme. Most of the furniture in hotel have bark surface finishes.

The floor plan layout is very simple in hotel building. Most of hotel rooms are identical and located adjacent to one another. The rooms facing southern side of building has balconies and northern side does not. Also, the rooms at the angled middle corner section and all rooms in the top floor have bigger suite.

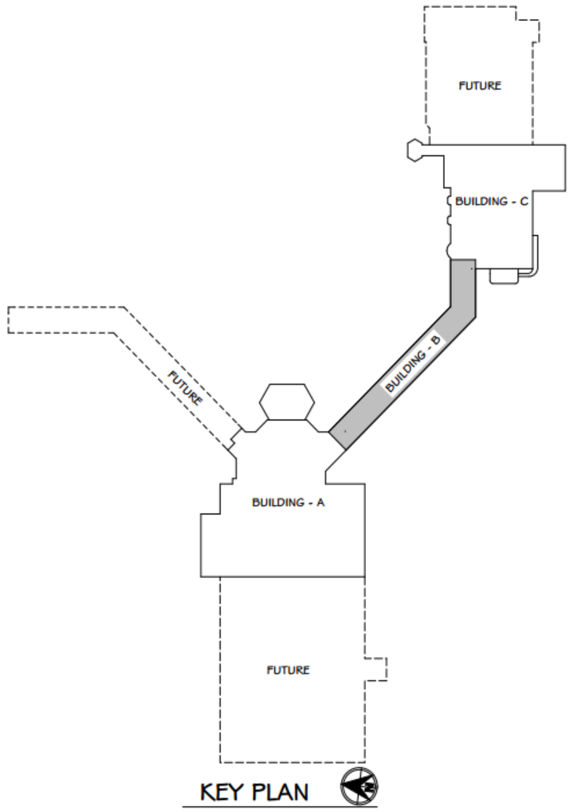


Figure 2 Project Future Additions

Figure 3 Hotel Building Rendering (looking from south)

Structural System

Brief Description of Structural System

Hakuna Resort is composed with three major components: indoor waterpark, hotel, and convention center. These components are connected by expansion joints, which allows each section to be looked at as separate independent buildings. As stated before, only hotel building will be described in this report due to its size. The main structural system used in this building is masonry shear walls and precast planks. There are also concrete piers, spread and strip footings, walls and masonry walls in the foundation and steel framing system in areas that require more flexible open spaces. The roof system is also precast hollow core planks.

Foundation

The foundation of Hakuna Resort has spread and strip footings or varying sizes to support concrete columns, exterior walls, steel columns and concrete shear walls. According to the geotechnical report done by Pennoni Associates Inc., spread footing foundations is feasible in dense natural soils, weathered rock or compacted load-bearing fill. Both spread and strip footings have allowable bearing pressure of 4,000 and 6,000 psi with varying steel reinforcements.

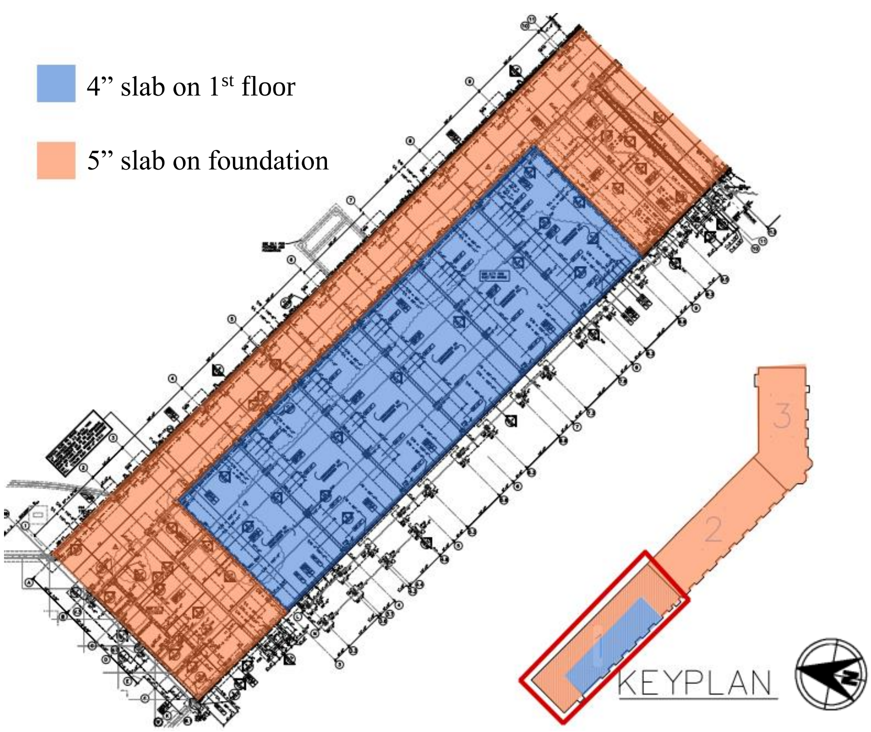


Figure 4 Partial Foundation Plan (S0.1)

For floor slabs, the geotechnical report approved using slab on grade with the usage of 4 inches thick layer of granular, free draining aggregate base course directly below the bottom of the slabs to provide a uniform bearing surface and improve overall slab performance. Figure 4 illustrates areas where 4" or 5" slab on grade is used.

A typical section of strip footings supporting the 1' wide concrete shear walls is shown in figure 5. Because these footings are supporting the lateral resisting system, their depth range from 2' to 3'-6" whereas the strip footings of exterior walls are below 2'. The width of footings for shear

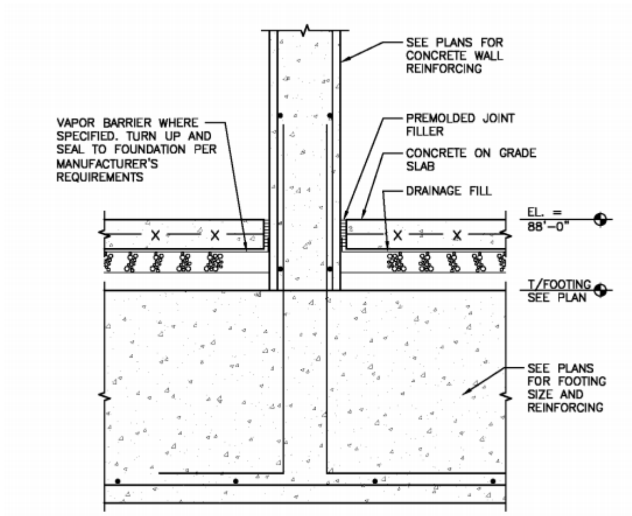


Figure 5 Concrete Wall Footing Section (S12.01, Drawing 14)

walls are also 12'-6" wide compared to exterior wall strip footing width, 2'-6". Similarly, the spread footings supporting concrete columns and steel columns are shown below in figure 6 and 7.

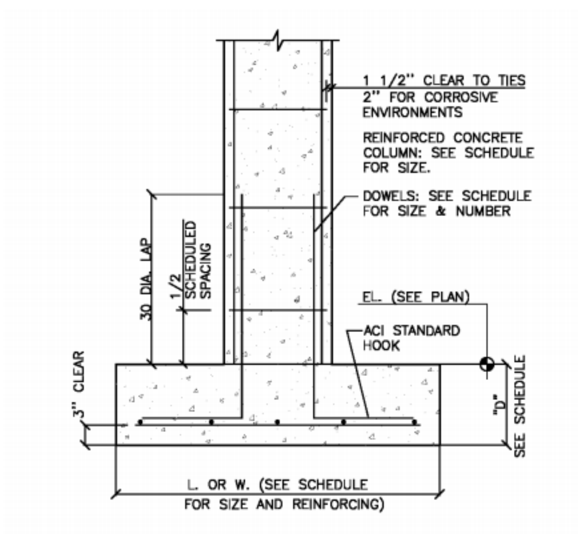


Figure 7 Typical Concrete Column Footing (S12.00 Drawing 10)

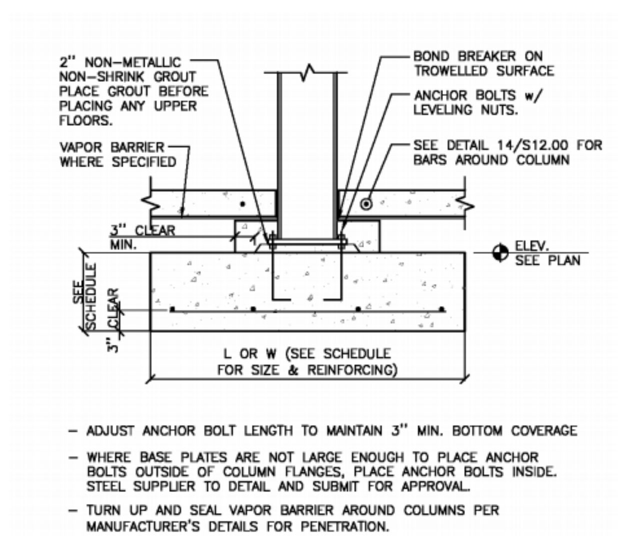


Figure 6 Steel Column on Footing (S12.00 Drawing 16)

Floor Systems

Hakuna Resort’s main floor system is prestressed precast hollow core planks. The hotel is a very narrow rectangular building with slight turn at the south-east end. The north-west side is about 501’-6” by 69’ and south-east is 151’-6” by 69’. Choosing precast planks and spanning them through the longer side of rectangle allowed one way slab effect and therefore only requiring load bearing walls in one direction. This is a very effective choice of system while utilizing the architectural layout of hotel. Because the floor layout is repetitive with identical hotel rooms next to one another, putting loadbearing walls in between the rooms to support the precast planks is efficient approach.

There are two different thickness of precast planks. As shown in figure 8, there is 10” and 12” thick precast planks. 10” thick planks are mostly used almost throughout the building typically spanning 28’, except the corner with bigger suite which required longer span of 40’ in one side where balconies are. The balcony is also precast but solid plank that is 1’-½” thick which is supported by 1’ x 1’ precast columns at each exterior corner.

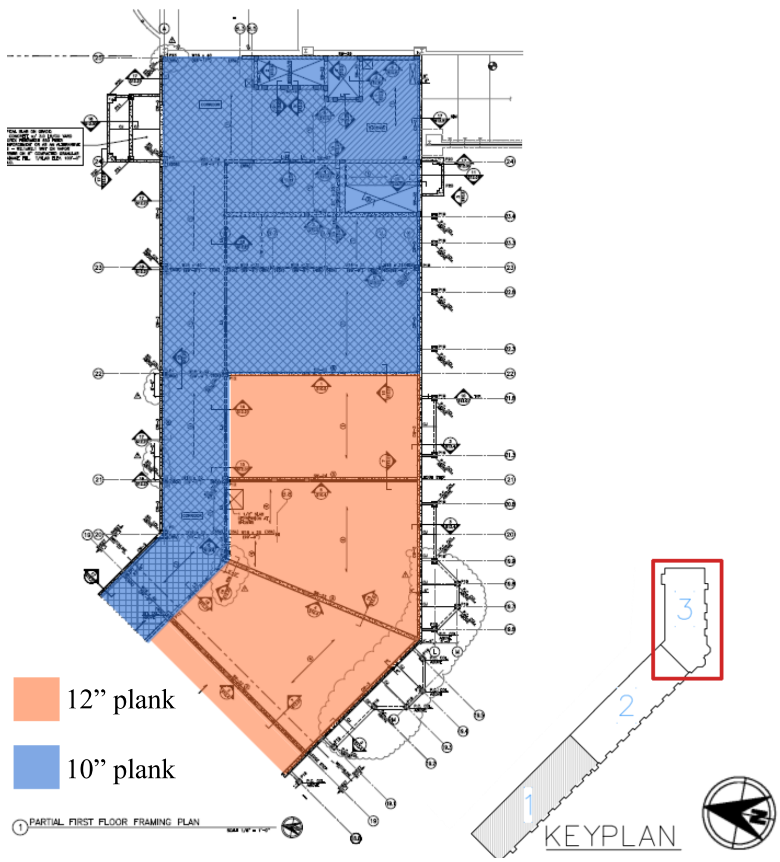
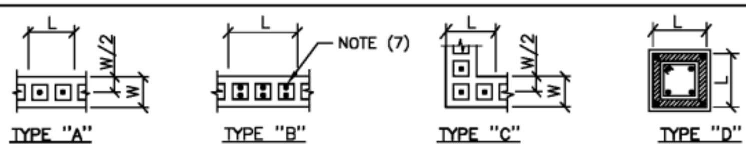


Figure 8 Partial First Floor Plan (S1.3)

Lateral Load Resisting Elements

The main lateral force resisting system for Hakuna Resort consists of fully grouted 12” thick masonry walls. These masonry blocks are structured to have masonry piers at each ends and sometimes in the middle as well to eliminate usage of columns. The masonry pier schedule can be found in figure 10. The blocks have F’m of 2000 psi which requires a net area compressive strength of 2800 psi and grouted with 3000 psi grout. The typical layout of masonry shear walls can be found in figure 9.

MASONRY PIER SCHEDULE



MARK	TYPE	SIZE (L) IN INCHES	VERTICAL REINFORCMENT (NOTE 2)	TIES	REMARKS
MP1	"A"	16	(2) – #5 BARS		
MP2	"A"	24	(3) – #5 BARS		
MP3	"A"	32	(4) – #5 BARS		
MP4	"A"	16	(2) – #5 BARS	NOTE (3), (8) #2 @ 8" o/c	
MP5	"A"	24	(3) – #5 BARS	NOTE (3), (8) #2 @ 8" o/c	
MP6	"A"	48	(6) – #5 BARS	NOTE (3), (8) #2 @ 8" o/c	
MP7	"C"	16 x 16	(3) – #5 BARS		
MP8	"C"	24 x 24	(5) – #5 BARS		
MP9	"A"	40	(5) – #5 BARS	NOTE (3), (8) #2 @ 8" o/c	
MP10	"D"	16 x 16	(4) – #5 BARS	NOTE (6) #3 TIES @ 16" o/c	

Figure 10 Masonry Pier Schedule (S13.3)

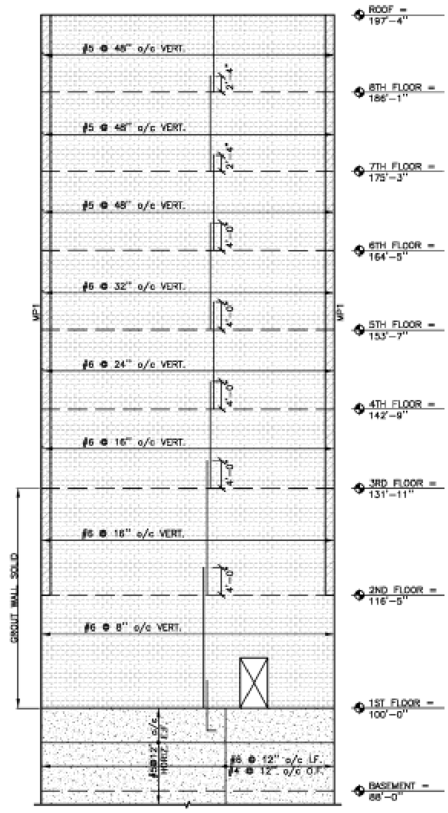


Figure 9 Masonry Shear Wall (S10.3 Drawing 2)

The size of vertical reinforcement for the masonry shear walls vary from #5 to #8. The spacing of the reinforcements also vary from 8” to 48” o.c. as the placement of reinforcing become higher in elevation. #5 bars, which is used the most throughout the shear walls, have 2’-4” of splice, #6 bars have 4’-0” splice and #8 bars do not require any.

Another lateral force resisting system is reinforced concrete shear walls that erect from the foundation and up to first and second level of the hotel structure. Varying from 12” to 14” thick, the concrete shear walls are vertically reinforced with #5 or #6 for walls from basement to first floor and #7 for walls from basement to second floor with varying spacing from 12” to 16” o.c. The horizontal reinforcement uses #5 or #6 bars.

The last lateral force resisting system is steel moment frame. Due to the demand and purpose of certain spaces that require spacious area, reinforced concrete and masonry shear walls were not adequate. Therefore, to remove the abruptness of blocking space from solid shear walls, steel moment frames was chosen. The spaces which required these moment frames are the themeshop located in the basement level, service area such as reception, massage, relaxation rooms on second floor, and deluxe suite located on eighth floor.

The most influential space out of these three is the service area. While the other two spaces only require moment frame that replaces half of shear walls in one grid line, the service area has entire gridline to have moment frame as illustrated in figure 11. The frame uses smallest beam of W27x102 to biggest size of W36x330. The columns of the moment frame vary from W12x65 to W14x120.

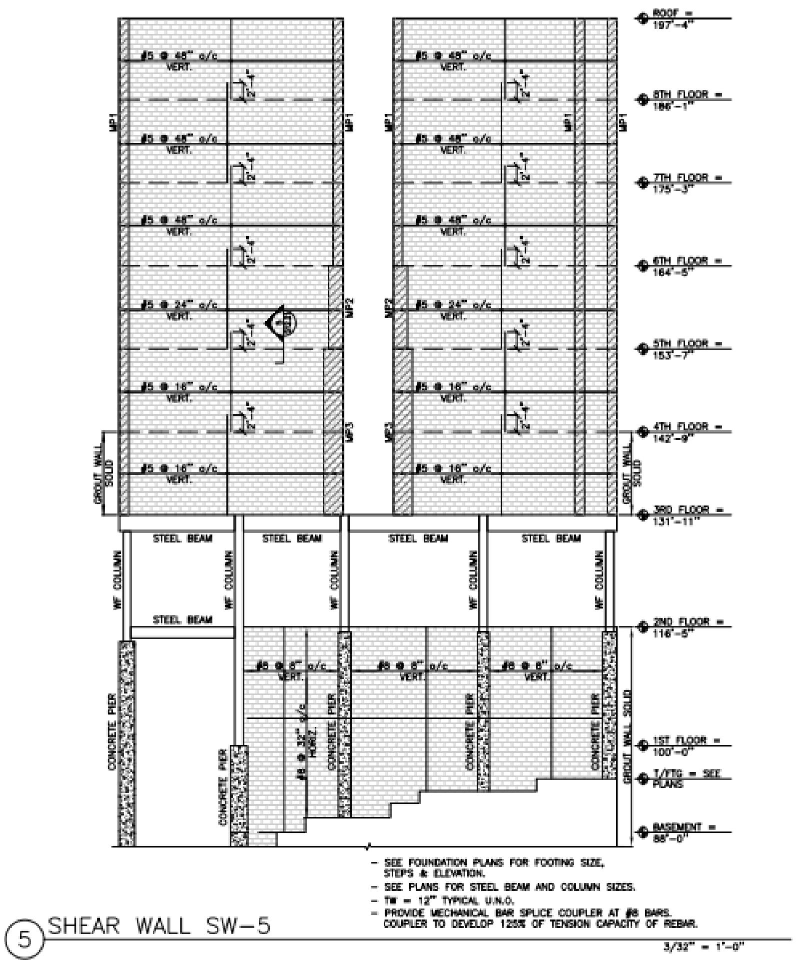


Figure 11 Shear Wall with Steel Moment Frames (S10.1 Drawing 5)

Framing System

As described above, the structure is mostly comprised of 10" or 12" precast plank supported by masonry loadbearing shear walls oriented in one direction. The shear walls use 12x8x16 blocks fully grouted. While this framing system is dominantly present in this project, there are steel moment frame systems in some portion of the structure as described above section of this report.

Typical Bay

The most replicated typical bay can be found in fourth floor layout, figure 12. This 69' by 28' bay is used from fourth floor to eighth floor. Due to precast planks forming stable frame system with masonry shear walls only in one direction, any need of beam spanning in the direction that is perpendicular of shear walls was eliminated; therefore, resulting such large typical bay.

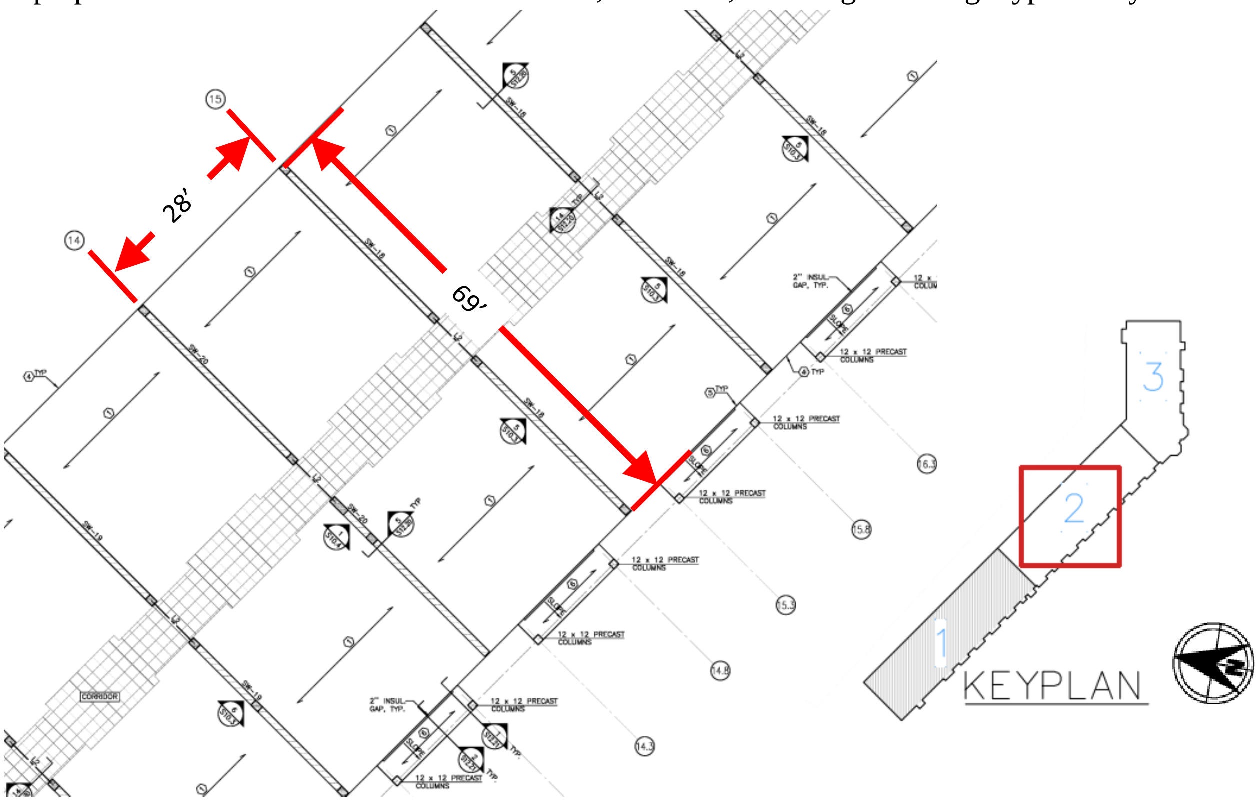


Figure 12 Typical Bay of Fourth Floor Plan (S4.2)

The 12" fully grouted masonry loadbearing shear walls with vertical reinforcement size of #5 with varying spacing per level are supporting 10" prestressed precast hollow core planks with 3" composite topping and bearing of 5.5". These planks have 1 hour fire rating.

To leave the opening for the corridor but to not disrupt supporting planks, lintel system which consists of HHS 10x4x3/8 and steel plate of 1/2” deep and 12” wide is placed in between the two shear walls adjacent to the corridor, bearing 4” into the shear walls. As shown in figure 13, this lintel allows the precast planks to sit on it, leaving an opening beneath.

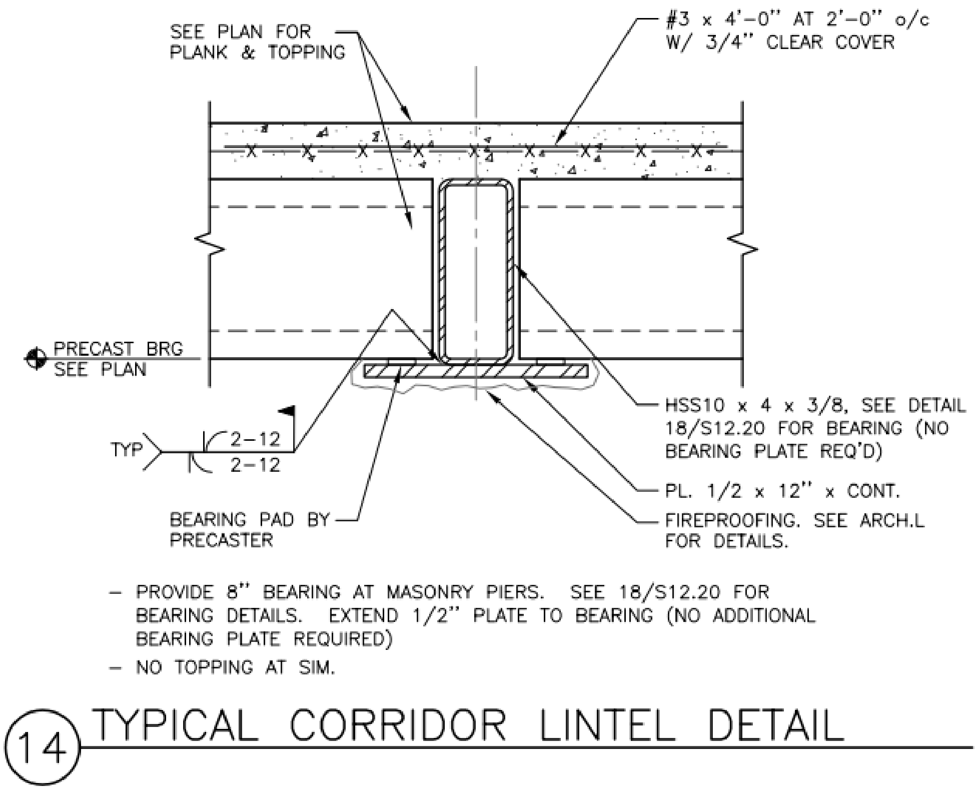


Figure 13 Typical Corridor Lintel Detail (S12.20)

Columns

Concrete piers were majorly used in basement and first level only where steel columns are located in order to support them. These concrete piers are in great number of various sizes. It ranges from a maximum size of 2' by 3'-4" to a minimum size of 16" by 16", shown below in figure 14. The steel columns that sits on top of concrete pier or right above foundation slab on grade have great number of varieties as well. To a minimum size of W10x49 to maximum of W14x120.

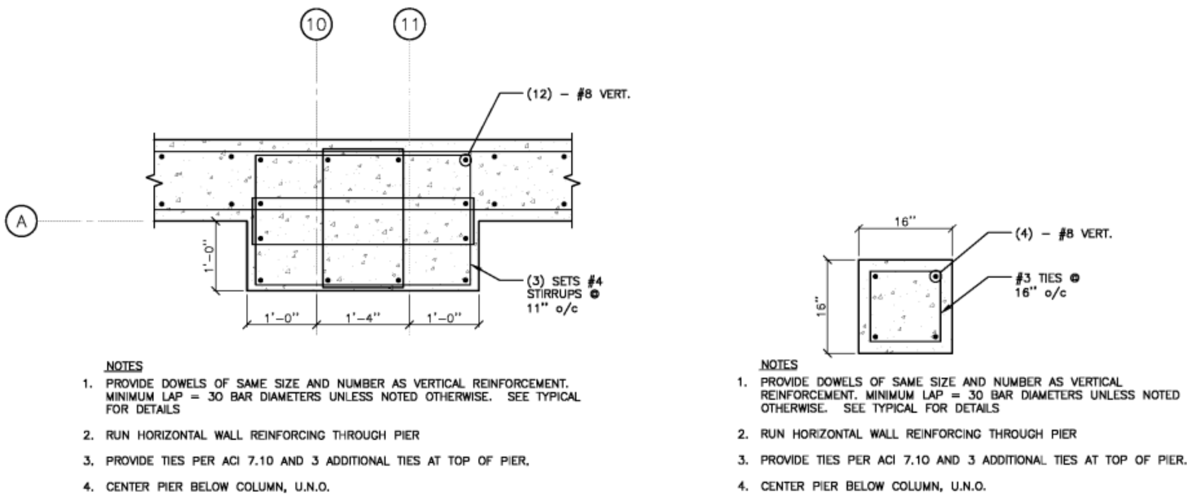


Figure 14 Concrete Piers (S12.02 Drawing 2 and 19)

There are also 12"x12" precast concrete columns that are supporting the balconies. Another interesting feature in columns from this structure is the canopy to support small roof that sheds an emergency exit, shown below in figure 15.

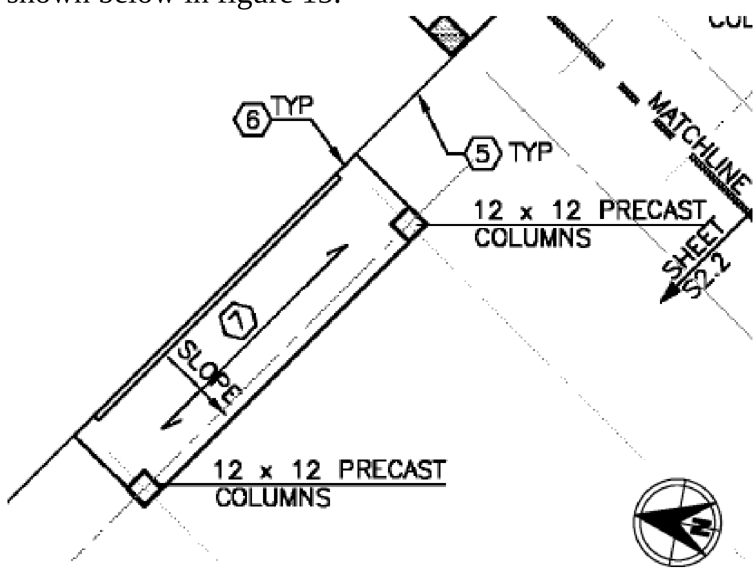


Figure 15 Typical Balcony Layout (S4.2)

Roofing System

Roofing uses exactly the same 10” and 12” thick precast planks at the same locations as floors below but except without toppings. As can be seen in figure 16, 6” galvanized lightgage metal stud parapet is connected by galvanized steel angle beam L4x4x3/8. There are also roofing above balconies (only on eighth floor) and entrances/exits. These hip roofs are supported by light case steel trusses at 24” o.c.

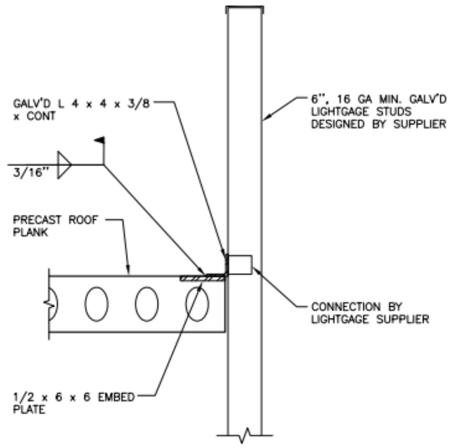


Figure 16 Typical Parapet Section (S12.30 Drawing 11)

Joint Details

As previously described, the precast planks bears on top of shear walls that are topped with masonry bond beams and sits on bearing strips (figure 19). The planks that are connected to the wide flange beams are set on top of weld anchor finished with grouted butt joint, shown in figure 18 below. Precast planks supported by steel column will be connected by steel angle with stiffener plate in its center, shown in figure 17.

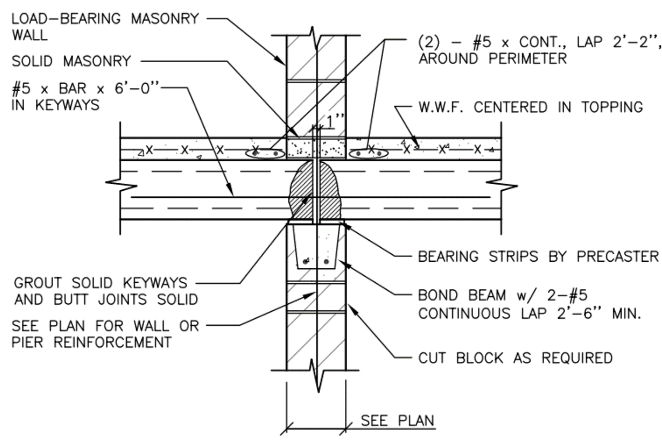


Figure 19 Precast Plank Bearing on Masonry Shear Wall (S12.20 Drawing 10)

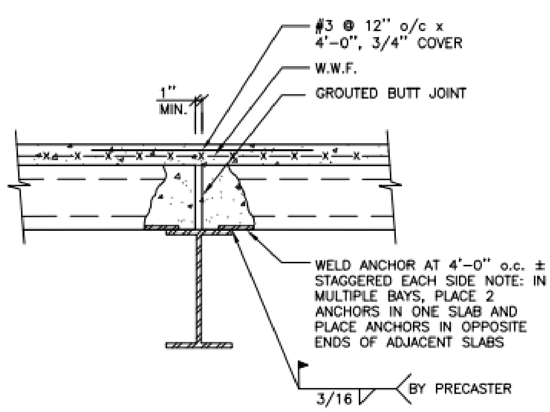


Figure 18 Precast Plank Bearing on Steel Beam (S12.20 Drawing 11)

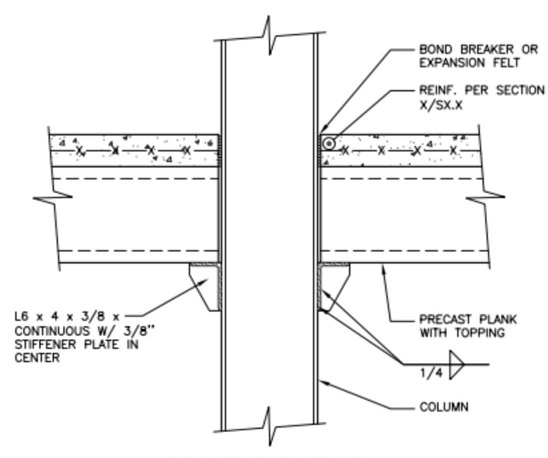


Figure 17 Precast Plank Support at Steel Column (S12.20 Drawing 8)

The typical steel framing section is as shown in figure 21. The column web holds double angle connection as well as clip angle to support wide flange beams. A typical steel moment connection shown in figure 20 has welded double angle connection with erection bolts.

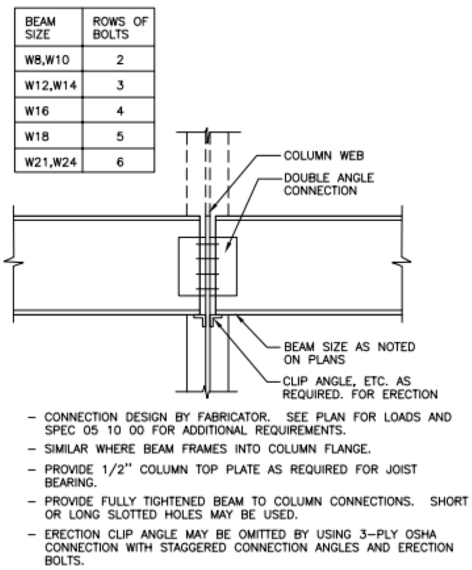


Figure 21 Typical Steel Framing Section

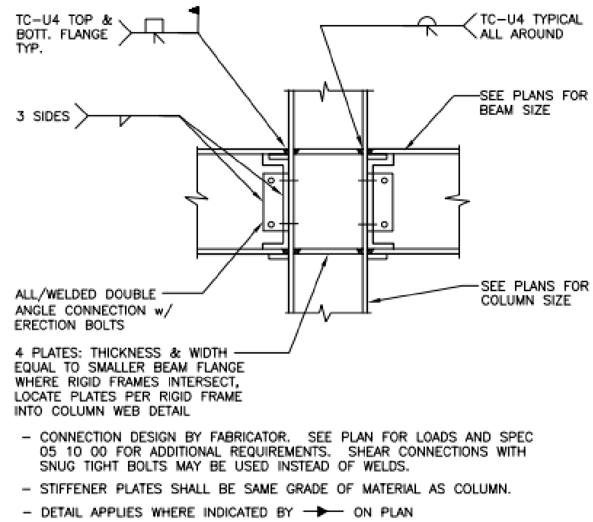


Figure 20 Typical Moment Connection

The steel column will be connected to the base plate shown in figure 22 that is sitting on non-shrink grout concrete pier. The anchor bolts with leveling nuts are placed through the base plate.

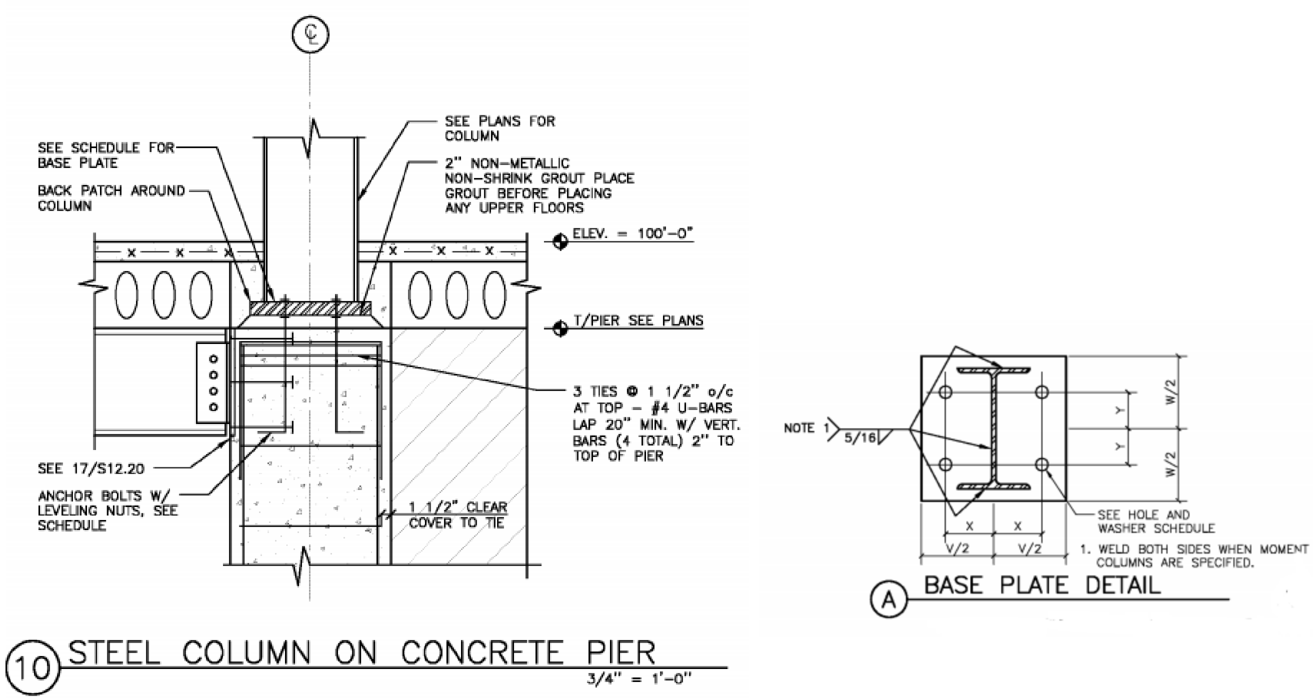


Figure 22 Steel Column on Concrete Pier and Base Plate Detail (S12.22 Drawing 10, S13.3 Drawing A)

Design Codes and Standards

International Code Council

- IBC 2009 – International Building Code 2009

American Concrete Institute

- ACI 318-08 – Building Code Requirements for Structural Concrete
- ACI 530-08 – Building Code Requirements and Specification for Masonry Structures

American Institute of Steel Construction

- AISC 360-05 – Specifications for Structural Steel Buildings (Steel Construction Manual 13th Edition)

American Society of Civil Engineers

- ASCE 7-05 – Minimum Design Loads for buildings and Other Structures

Precast/Prestressed Concrete Institute

- PCI MNL 120-04 – PCI Design Handbook, Precast and Prestressed Concrete 6th Edition

Design Loads

National Codes for Design Loads

Live Load – ASCE 7-05 Chapter 4
Dead Load – Superimposed dead load of 10 psf, self-weight of non-bearing masonry walls and composite topping above planks were added.
Wind Load – ASCE 7-05 Chapter 6 - Method 2 (analytical procedure)
Seismic Load – ASCE 7-05 Chapter 12
Snow Load – ASCE 7-05 Chapter 7, snow drift load plan also drawn in S9.1 – S9.3
Rain Load – IBC Figure 1611.1

Load Paths

Gravity Load Path

Starting from the composite topping or non-loadbearing walls above precast planks, the gravity load will transfer through the precast planks to their appropriate support system, masonry shear wall or structural steel beam. If the load were to transfer to the masonry shear wall, the load then will transfer straight down to the foundation and dissipate in soil. If the load were to transfer to wide flange beam, the load will then transfer through the wide flange column then to concrete pier and ultimately foundation footing, to be dissipated in soil.

The gravity load from the roof top follows exactly same process. The roofs of balconies, however, transfers some of their loads directly to the precast column and the rest to the exterior wall, which then transfers to the solid precast balcony plank that is connected to the hollow core floor plank and precast balcony columns. Loads that went to the floor plank will transfer to the shear wall and to foundation and loads that went to the precast column will transfer straight down to foundation footing.

Lateral Load Path

The wind load distributed through the façade of the building will transfer its way to the precast plank floor diaphragm. This horizontal force will be resisted by the masonry shear walls. The overturning moments created by this lateral force can be also resisted by the gravity load that the shear walls are carrying. Transferred though the shear walls or steel moment frames, the lateral wind load will move its way down to the foundation and will dissipate the base shear through soil.

Conclusion

Through this technical report, the existing condition of Hakuna Resort's structural system was explored in detail. Starting from the foundation, this report described the floor system, roofing system, lateral load resisting elements, framing system, joint details, load paths and design codes.

One of the most impressive characteristics of the structure is the usage of many different structural material. From traditional reinforced concrete in lower level to masonry walls, steel frames and precast concrete planks, this structure almost had it all. The fact that these different structural materials were transparent through the lateral resisting elements showed its character even more vividly.

The structure's main framing system, masonry shear wall and precast planks, is believed to open lots of opportunity for the future phases of the thesis. Having loadbearing shear walls to carry precast planks spanning only in one way resulted significant reduction in number of structural member oriented the other way. Also the floor layout is so repetitive and identical. With these two factors combined, there is a lot of options if the proposed topic were to be redesign in structural material.

However, the number of different structural material present in this building can make the future technical reports more challenging. The greater number of structural material means the more design codes and references that need to be looked at. In order to analyze the systems as a whole, it may require even more meticulous job at studying different codes and references.

It was also interesting to find out why the engineer of record made the decision in certain structural system and understand the intent. Hakuna Resort will be a great educational tool as the further analysis and study continue.