10.0 STRUCTURAL/CONSTRUCTION BREADTH: ROOF REDESIGN & DETAILED COST ESTIMATES FOR AHU RELOCATION

The entire system redesign proposal focuses primarily on the HVAC systems. However, each change or alteration to the existing mechanical system directly affects other building systems. The building background portion of this report explains that the existing 14 air handling units are housed in an elevated mechanical mezzanine floor. Since the redesigned mechanical system replaced 10 of the 14 air handling units with 2 smaller dedicated outdoor air units, there is now a large amount of empty space in the mezzanine floor. The next phase in the redesign addresses the relocation of the 6 air handling units for the supply center to the large open flat roof. This directly affects the roof structure, and the cost of not having to buy and construct the mezzanine floor is added into the overall redesign cost savings.

Figure 10-1 illustrates where the elevated mechanical mezzanine room is located within the supply center. There are four main areas that housed the air handling units on this mezzanine floor. They are all connected to each other with elevated cross walks.

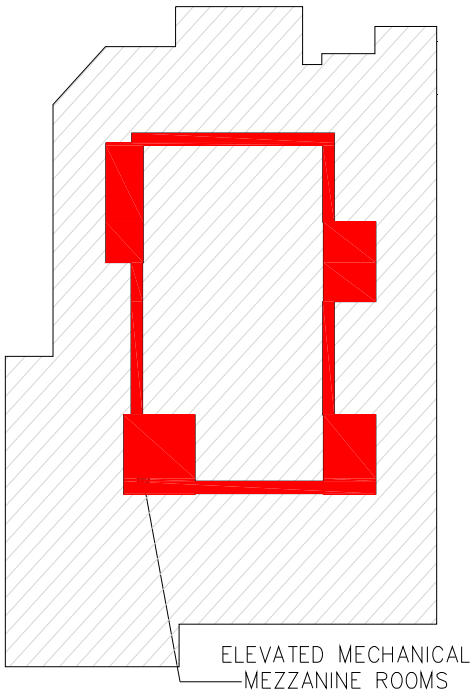

Figure 10-1 Elevated Mechanical Mezzanine Room Location

10.1 AHU RELOCATION STRUCTURAL IMPACT

The roofing of the supply center consists of a flat center core that is located directly above the kitchen and bakery portions of the supply center. The roof over the mezzanine floor is part of a higher, sloped perimeter roof. Figure 10-2 is the Architect's rendering of the supply center. The figure illustrates the high sloped portion of the roof that is above the mezzanine room.

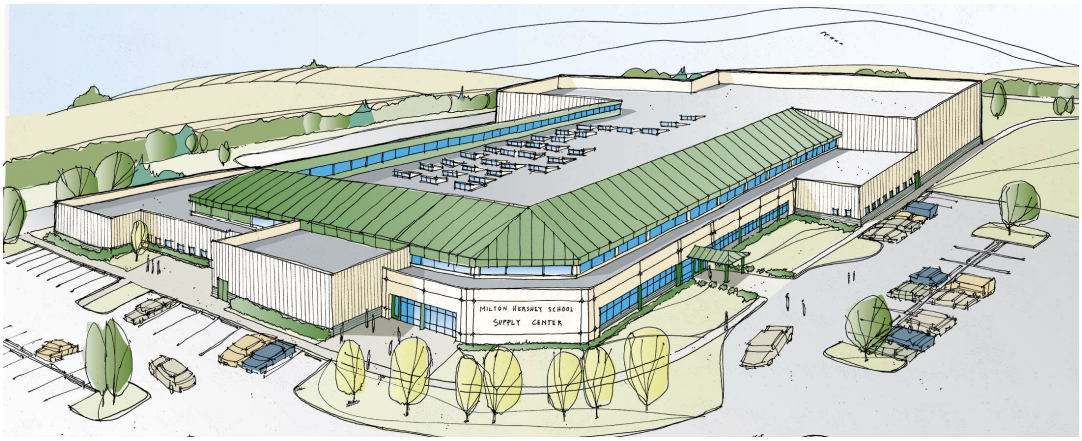

Figure 10-2 Architectural Rendering Illustrating Roofing

This high roof is important because it creates a visual boundary from ground level. The flat center core portion of the roof, where the air handling units are relocating, is hidden by this high roof. Therefore, any mechanical equipment on the roof does not alter the architecture of the building. There are also 21 skylight windows located on this flat portion of the roof. The air handlers' relocation must take the position of these windows into consideration so not to disrupt any natural light entering the building. Figure 10-3 is the roof plan of the supply center that clearly shows the exact location of the flat roof and the skylight windows. The six air handlers that are relocated are also shown in the figure.

The blue air handlers represent the 4 existing units that are serving the kitchen, bakery, and loading docks. The red air handlers are the new dedicated outdoor air units. The locations of the air handlers are carefully placed so that they are not within 15 feet of the general building exhaust fans (shown in magenta). The hatched area represents the finished metal paneling that is attached to the sloped high roof. Also seen on the roof plan are the skylight windows. Each window is 10'x10' and provides natural light to the kitchen and bakery spaces since they are interiorly located.

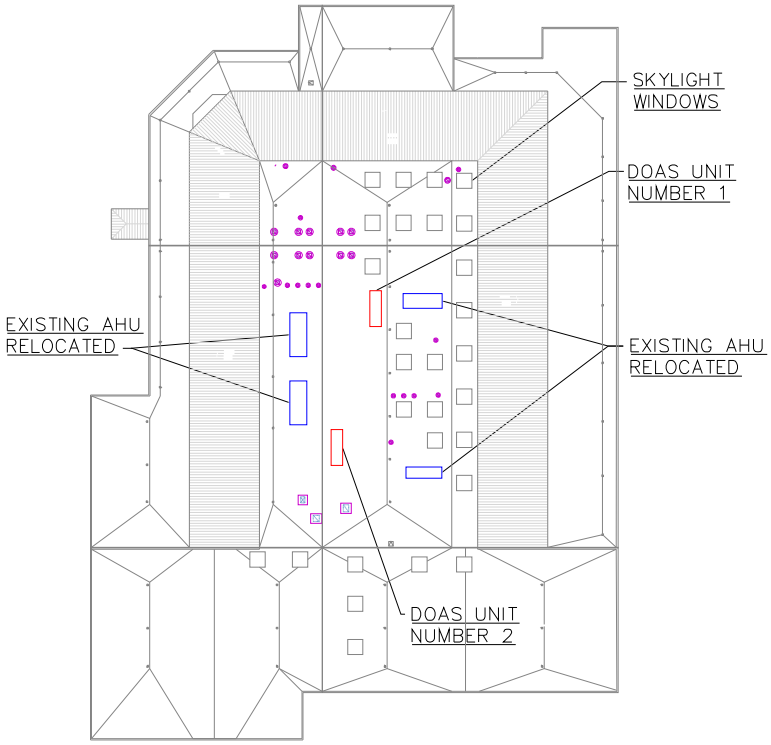

Figure 10-3 Relocated AHU Roof Plan

The next phase of this relocation process is to analyze the impact of the additional weight on the roof structure. Using RAM Structural System software and the structural design documents provided by H.F. Lenz Company and engineered by Barry Isett and Associates, Inc., the flat roof portion of the structural system is modeled.

The loads from the AHUs are inserted into the program at the appropriate locations, and the software calculates any changes required to the existing structure. The existing structure consists of steel columns supporting steel beams that frame out the structural grid. K-series steel joist carry the roof loads to the beams and columns in the open areas of the roof. The area's containing skylight windows consists of W-flanged steel beams framing the opening with K-series joist handling the remaining roof load.

Figure 10-4 is the RAM model used for the calculations. The blue lines represent the steel joist, and the dark green represent the steel beams.

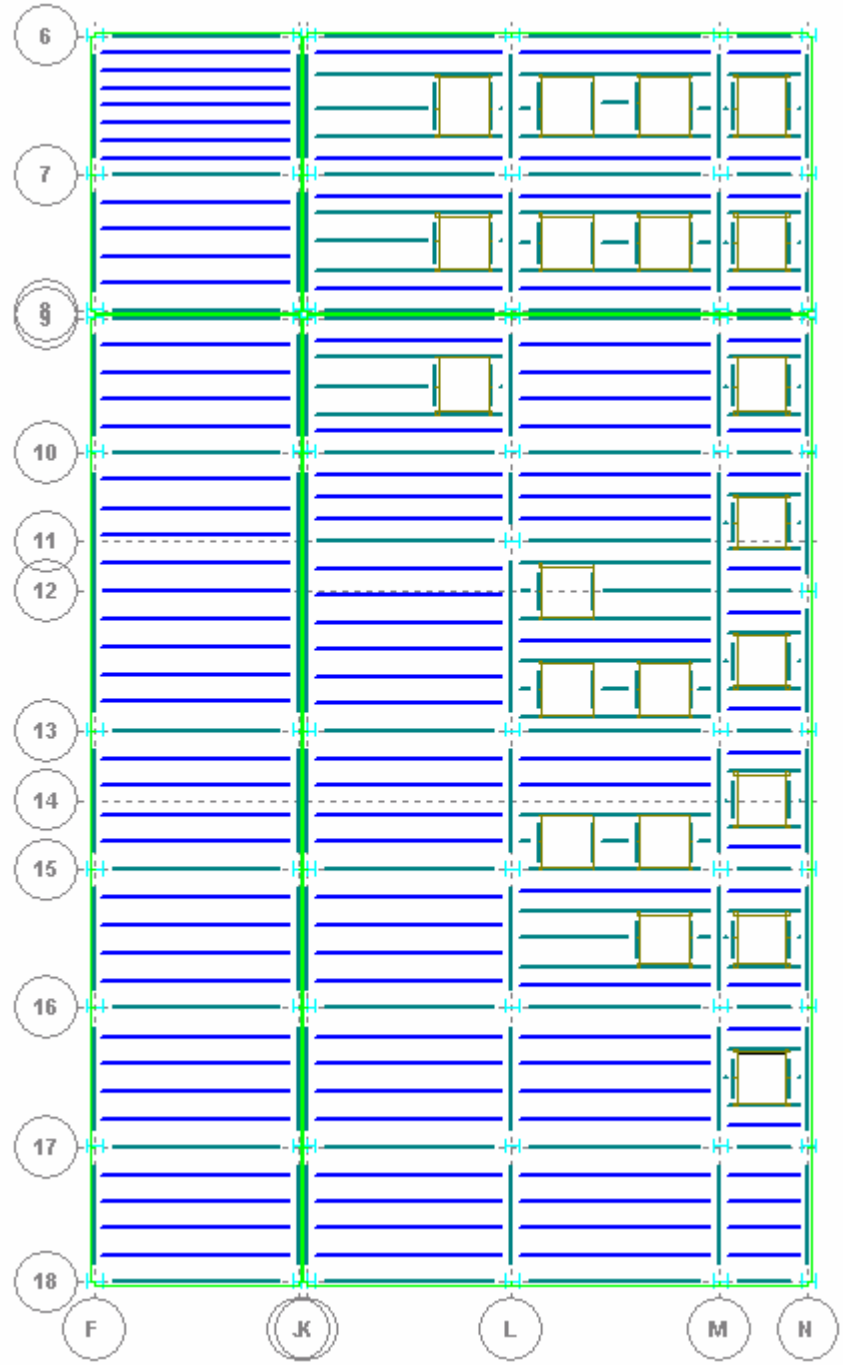

Figure 10-4 Existing Roof Structural System

Figure 10-5 is a 3-D view of the structural system. The figure showcases the open-web steel joist connecting to the W-flanged steel beams.

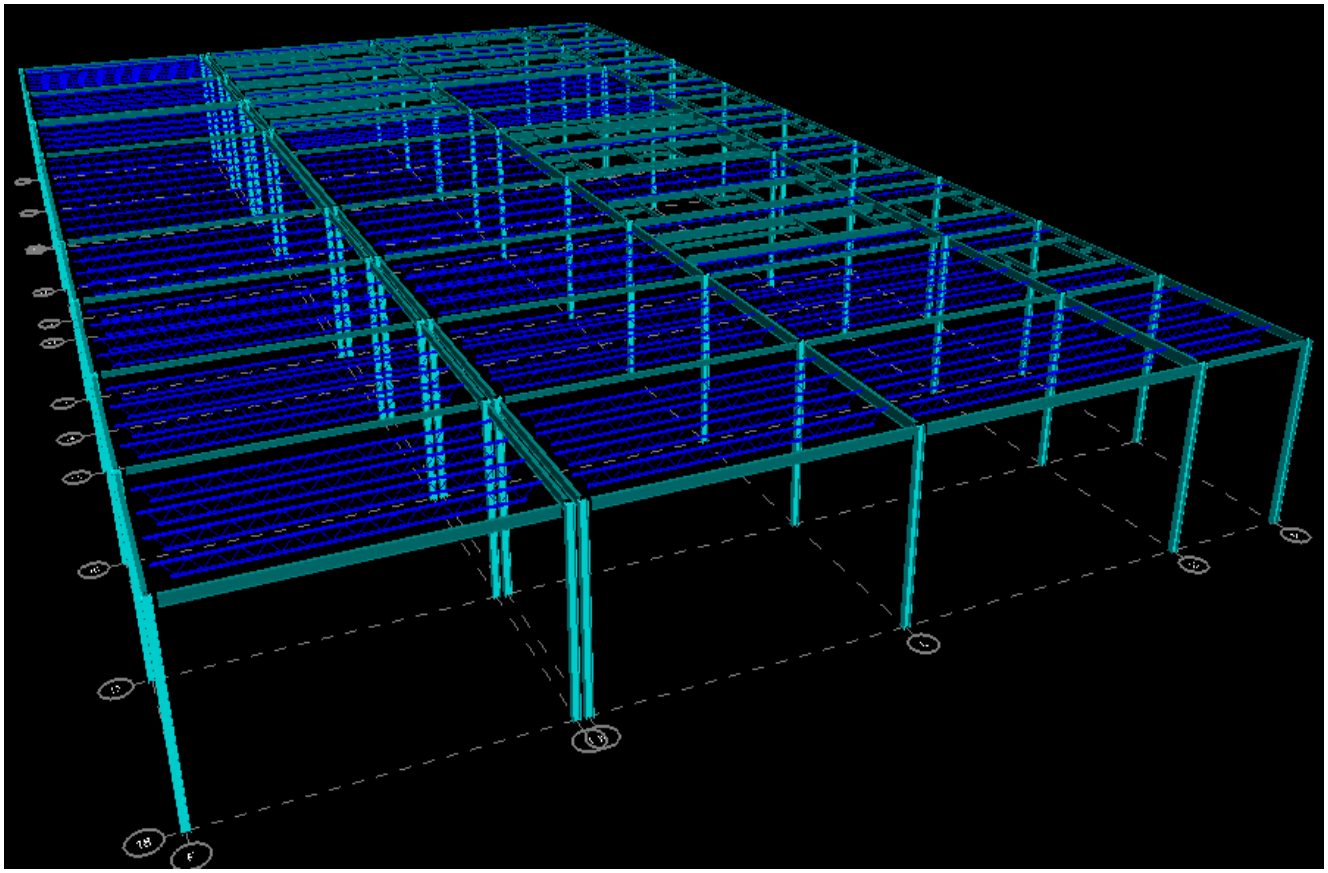

Figure 10-5 3-D View of Structural System

The air handling units are then placed in the appropriate locations as shown in figure 10-3. Table 10-1 outlines the operating weights for each air handling unit. The structural software then recalculates the loads on the each of the steel members.

Table 10-1 AHU Operating Weights

AHU 1	AHU 2	AHU 6	AHU 8	DOAS 1	DOAS 2
11,125 lbs	11,125 lbs	6,404 lbs	5,989 lbs	4,000 lbs	4,700 lbs

The resulting load calculations on the roof structure indicate that the open web K-series joist do not have the capacity to support the additional weight. Therefore, these joists are replaced with W-flanged steel beams. Figure 10-6 illustrates the portions of the structure that fail from the AHU relocation.

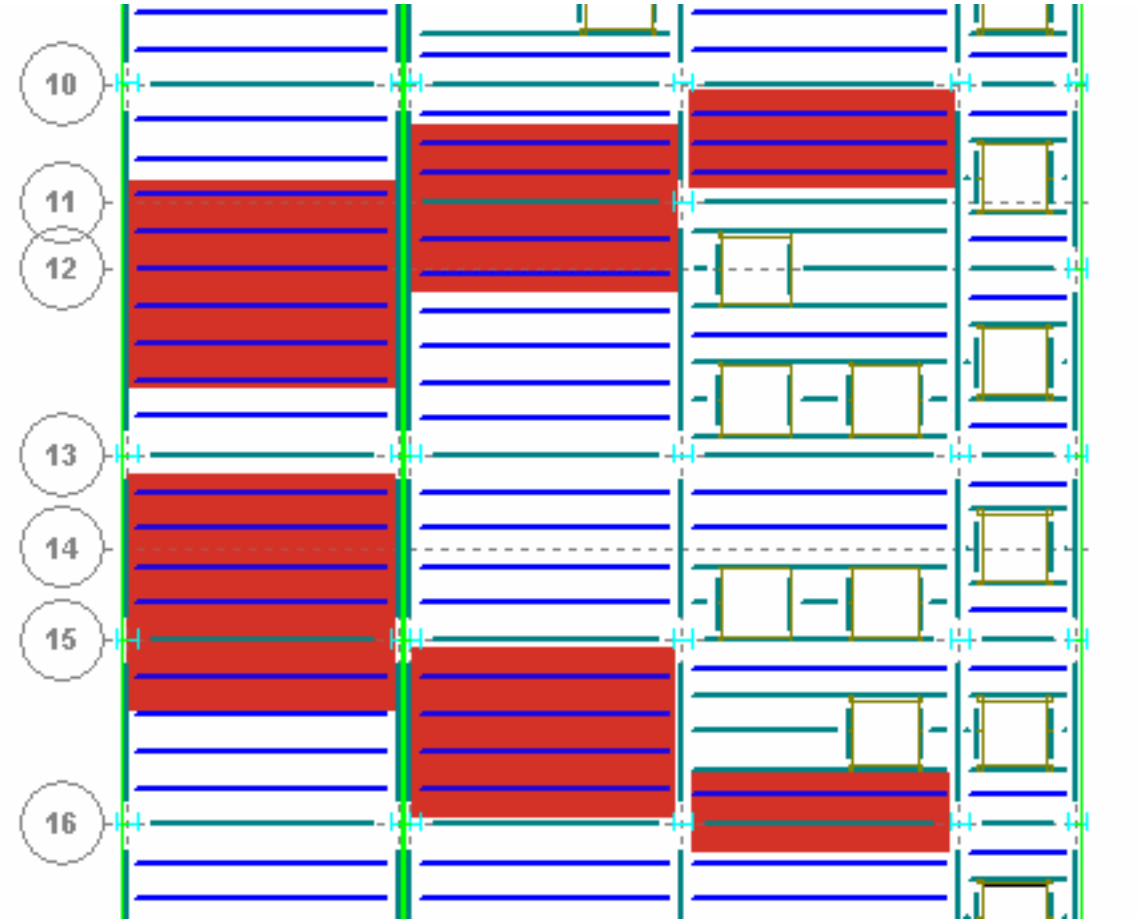

Figure 10-6 Failed Joist to Replace

The RAM program resizes all of the new steel beams and recalculates the self weight of the new structure. The existing beams create the structural bays with the columns are not affected by the changes. These beams along with their respectful columns are already sized large enough to handle the additional load. Therefore, the only adjustments required are deal with the joists.

10.2 STRUCTURAL SYSTEM ALTERATION COST ANALYSIS

The additional cost of upgrading the roof structure from relocating the six air handling units is now calculated. There is no real pay back or benefit to this relocation process until the cost of constructing the elevated mezzanine floor is calculated. Moving the AHUs to the roof is beneficial if the additional cost of roof structural changes is offset by the cost savings of not building the elevated mezzanine floor.

Since the roofing structure is built regardless of the results of this study, the material cost of the K-series joists and the W-flanged beams are in question. The

cost to construct is not a factor for this portion of the analysis. The structural system alteration just involves the replacement of 22 joists with more expensive beams. The economic analysis on the cost to construct the mezzanine floor includes labor and equipment as well as the material cost. The overall study focuses on the cost savings from not having to completely construct the mezzanine floor, therefore requires a more detailed estimate.

Table 10-2 illustrates the additional cost of replacing the K-series joists with W-flanged beams. The table indicates that it is only approximately $300 more expensive than the existing structure. This is almost meaningless in the grand picture of the total project cost.

Table 10-2 Structural Alteration Additional Cost

BEAM/JOIST	LENGTH	AMOUNT	$COST/LF	TOTAL COST
28KCS5	37	14	11	$5,698
26K7	37	8	6.35	$1,879.6
			JOIST TOTAL COST	$7,577.6
W 8x10	37	22	9.65	$7,855.1
			Difference	**$277.5**

10.3 ELEVATED MEZZANINE FLOOR ELIMINATION COST ANALYSIS

The intent of the elevated mechanical mezzanine floor is to house the air side HVAC equipment for the supply center. The floor is constructed of structural steel beams and columns supporting a 4" thick 4000psi concrete floor. The entire floor, including its four connecting walkways is approximately 11,300 square feet.

The floor is a good size to house the 14 air handling units. However, the mechanical redesign requires only 6 AHUs to meet the demands. Building this large room for the redesigned mechanical system is a waste of resources and labor. Therefore, the AHUs are moved to the roof which previously did not have the space for all 14 units. The relocation of the AHUs creates a major cost savings opportunity.

The cost of constructing the structure consisting of 217 W-flanged steel beams supporting a 4" concrete floor with a metal roof deck is calculated to estimate the savings of relocating the AHUs. Table 10-3 illustrates the results from the detailed cost estimate. R.S. Means 2005 is used for the estimates, and the prices include material, equipment cost, and labor.

Table 10-3 Elevated Mezzanine Floor Construction Cost

	Total Construction Cost
Steel Members	$122,986.1
1-1/2" Steel Decking	$19,762.75
139 C.Y. of 4000psi Concrete	$11,709.6
TOTAL FLOOR COST	**$154,458.45**

The mechanical redesign proved to save yearly operational cost for the supply center. The redesign, however, affected the buildings structural system. The goal of integrating the mechanical system with other building systems is carried through in this portion of the study. The relocation of the air handling units to the roof structure is totally dependant on the replacement of 10 VAV air handling units with 2 DOAS units. The additive cost in supporting the extra weight on the roof structure is very small, and large cost savings are found in not constructing the mezzanine floor. The mechanical system redesign now sees a first cost savings of $154,000 to go along with its yearly energy cost savings when compared to its original design.