Impact on the Structural System

The changes created by the mechanical system redesign discussed in the previous sections will affect other disciplines throughout the building. The two largest areas affected come from the structural reinforcement and the electrical system power requirements. This section of the report will discuss the structural changes needed in order to support the new mechanical equipment, while the next section will discuss the electrical changes.

Structural System Analysis

The existing mechanical system is comprised of four direct-expansion rooftop units that are located on the retail sections roof. The other mechanical equipment belongs to the Snowdome and is located inside of a mechanical room adjacent to the Snowdome. For the redesign the Snowdome mechanical equipment remains unchanged and will remain located in the same mechanical room. The changes in the mechanical system redesign that will affect the structural system result from the addition of new equipment. The existing four rooftop units are being replaced with four new units that are provided their cooling and heating capacity from the absorption chiller/heater. While the rooftop units will be simply replaced, the remaining equipment will be entirely new and represent loads that were not in the previous design. Table 6 below lists the existing equipment and new equipment weights.

Table 6: Mechanical Equipment Weight

Equipment	Existing (lb)	Redesign (lb)	Difference (lb)
RTU-A1	16,000	18,000	2,000
RTU-A2	16,000	17,800	1,800
RTU-A3	17,000	17,500	500
RTU-A4	17,000	17,300	300
Jenbacher Engine	0	41,350	41,350
Chiller/Heater	0	24,700	24,700
Cooling Tower	0	7,500	7,500
TOTALS	**66,000**	**144,150**	**78,150**

As shown in Table 6 the mechanical system redesigns introduce just over 78,000 pounds of loads that will need to be supported on the retail section's roof. In the case of the replaced rooftop units there is very little difference between the existing weight and the new weight. For this reason the ventilation system redesign was designed in order to keep the four rooftop units in the same location in an attempt to reduce the impact on the structural system.

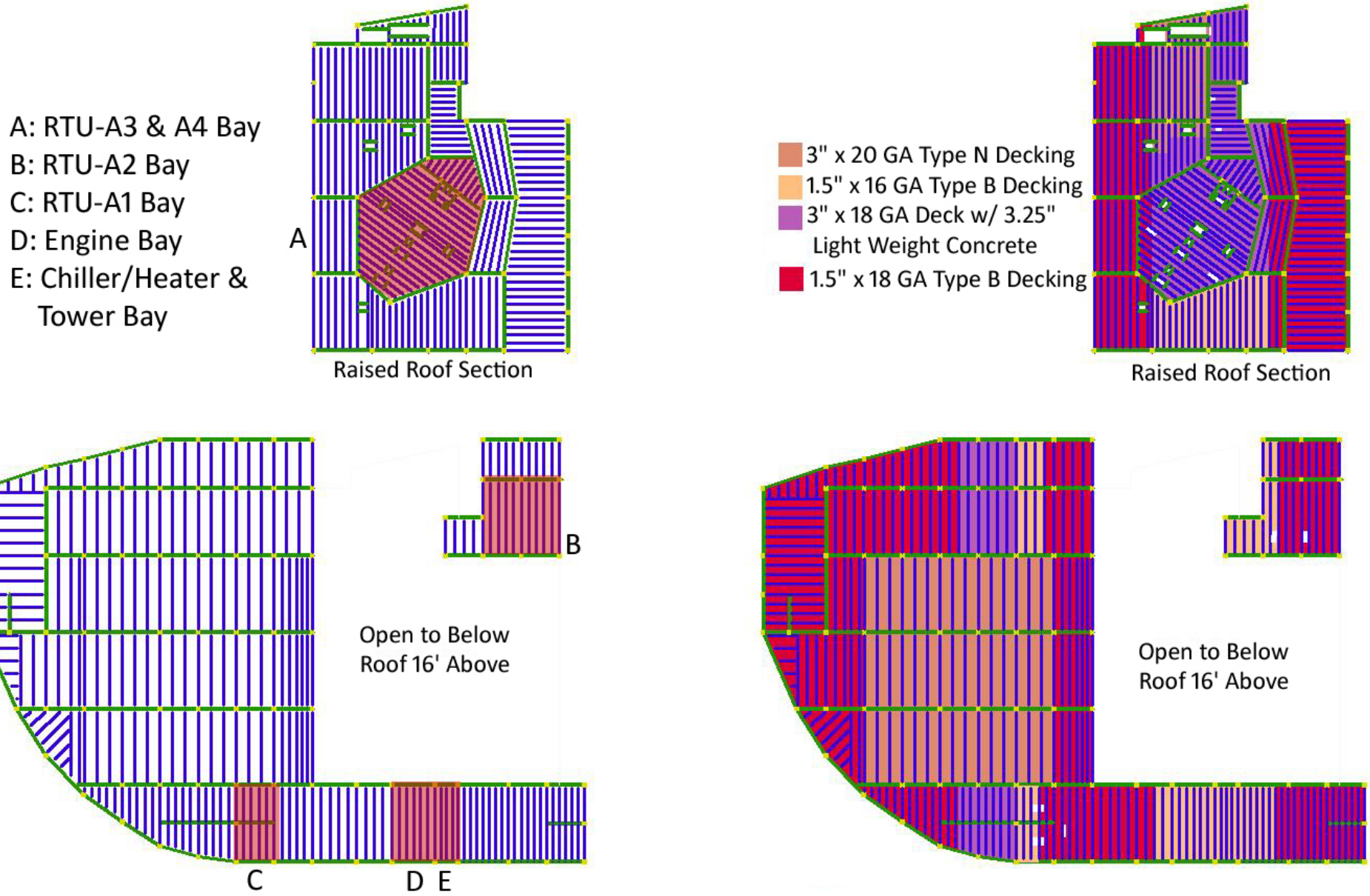

Figure 33: Structural System Layout

Figure 33 on the previous page shows the layout of the structural system on the retail's section roof. In the figure the green lines represent girders while the blue lines represent joists and the yellow boxes represent columns. The majority of the roof is at an elevation of 71 feet, however, the section of roof over the atrium is raised to an elevation of 91 feet. The left side of the figure shows the location of bays affected by the mechanical system redesign in red. Bay A, on the raised section of the roof, will support rooftop unit A3 and A4, Bay B will support rooftop unit A2, Bay C will support rooftop unit A1, Bay D will support the Jenbacher Engine, and Bay E will support both the absorption chiller/heater and cooling tower. The right side of the figure shows the varying types of decking on the roof. The majority of the roof is covered with just a roofing membrane, however, some spots have been covered with 3" of lightweight concrete.

In order to evaluate the mechanical system redesign impact on the structural system RAM Structural System software was used. In order to simplify the structural calculations only the affected bays were created in the RAM model. Based on the structural drawings used for construction all proper dimensions and existing loads were used. Based on the existing structural calculations, a live load of 25 pounds per square foot (psf) to compensate for snow was used, and a dead load of 30 psf was used on the areas of roofing that are free of lightweight concrete. The dead load for the areas of concrete have a dead load comprised of 48 psf for the concrete slab and a superimposed load of 22 psf to create a total dead load of 70 psf. The equipment loads were placed in the proper location in the bay, and point loads were modeled to simulate the equipment loads. The representation of the structural calculations and the RAM member sizing output can be found in Appendix E of this report. Figure 34 below shows a sample of a structural bay model in the RAM Structural System software.

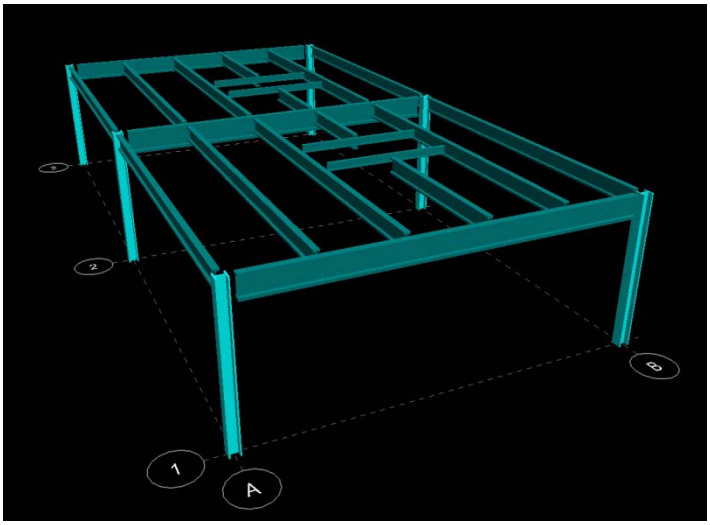

Figure 34: Example of Structural Bay Model

With the existing dead loads, live loads, and new equipment loads the new structural members were sized. In general all the members were sized to eliminate any cambers. However, if the existing structural member was designed with a camber, the redesigned member was designed with the same length of camber. This was done in an attempt to keep the redesigned system as close as possible to the existing. The largest change between the existing system and redesigned system comes with the replacement of size 36LH12 joists in the structural bay where the engine will reside. Due to the increase in gravity loads and vibrations the engine will introduce into the system the joists were replaced with wide flanged members. This bay's deck was also changed from just a roofing membrane to a heavier construction using 3.5" of concrete. In addition to the composite system, the engine will reside on a housekeeping pad and will be placed on an inertia base as specified by General Electric.

With the new members sized a cost comparison between the existing and redesigned systems can be determined. For the structural members of W36 or lower and for the 36LH12 joists R.S. Means was used to estimate the total cost per linear foot. However, R.S. Means does not provide pricing information for wide flange members over the size of W36. A price of $3,500 per ton or $1.75 per pound of steel was used to price the remaining members. The results are shown in Table 7 on the next page. The results show that the existing structural bays will cost approximately $508,556 and the redesigned bays will cost $638,177. The total increase of cost to reinforce the structural system then comes to approximately $130,000. While the mechanical system redesign provides much lower annual costs and lower annual emissions, the initial cost is approximately $7,433,000 more than the existing mechanical system as discussed in the previous section of this report. With the addition of the structural reinforcement the total initial cost comes to $7,563,000 more than the existing system. This additional cost plus the cost of the additional electrical work will be factored into the overall feasibility of the system redesign.

Table 7: Structural System Take Off and Cost Comparison

Existing				Redesign			
Member	Length (ft)	Cost ($/foot)	Total Cost	Member	Length (ft)	Cost ($/foot)	Total Cost
W8X10	42	23	$966	W8X10	42	23	$966
W10X12	83	25.5	$2,117	W12X14	198	25	$4,950
W12X14	198	25	$4,950	W12X16	34	27.8	$945
W12X16	34	27.8	$945	W12X19	21	31.9	$670
W12X19	21	31.9	$670	W14X22	105	40.5	$4,253
W14X22	153	40.5	$6,197	W16X26	248	40.5	$10,044
W16X26	365	40.5	$14,783	W16X31	161	48	$7,728
W16X31	60	48	$2,880	W18X35	55	54.5	$2,998
W18X35	52	54.5	$2,834	W21X44	94	66	$6,204
W18X40	37	61	$2,257	W24X55	60	80	$4,800
W21X44	59	66	$3,894	W24X62	90	89.5	$8,055
W24X55	176	80	$14,080	W24X76	52	108	$5,616
W24X68	90	97.5	$8,775	W27X84	172	119	$20,468
W24X76	608	108	$65,664	W30X90	67	139	$9,313
W24X103	60	145	$8,700	W30X108	120	151	$18,120
W27x84	156	119	$18,564	W33X118	873	164	$143,172
W30X99	244	139	$33,916	W33X130	120	164	$19,680
W36X130	60	185	$11,100	W36X135	226	187	$42,262
W36X130	60	187	$11,220	W40X149	162	260.75	$42,242
W36X130	60	233	$13,980	W40X167	90	292.25	$26,303
W40X149	97	260.8	$25,293	W40X183	152	320.25	$48,678
W40X167	60	292.3	$17,535	W40X211	64	369.25	$23,632
W40X183	197	320.3	$63,089	W40X215	159	376.25	$59,824
W40X215	162	376.3	$60,953	W40X297	64	519.75	$33,264
W40X324	128	567.0	$72,576	W44X262	205	458.5	$93,993
W44X230	60	402.5	$24,150				
36LH12 SP2	540	30.5	$16,470				
TOTAL:			**$508,556**	**TOTAL:**			**$638,177**