# FINAL REPORT ADDENDUM

At the request of the structural faculty members an additional investigation into the RAM Structural System Model was completed; with the intention of validating the final results of the braced frames. Two separate RAM models were examined during the course of this investigation. Initially the braced frames were designed as Ordinary Braced frames, however, due to the sufficiently large column sizes they were changed to Special Braced Frames.

The first model, the more briefly investigated one, was an earlier version of the final RAM model. This is the stage where the problems with the excessive column sizes were occurring. It should be noted at this point in the design process columns had a single splice with the first section of the columns spanning three stories, and the second section spanning two stories. This is important because a change to the design of the column at the first story has significant dead load implications due to the height of the column. Upon consultation it was suggested to have a typical column span of two stories. In this model the sums of the frame story shears were significantly different than that of building story shears for the seismic load cases in the principal X & Y direction. In the seismic load case in the Y-direction the sum of the frame story shears was 80 kips less at the fifth floor from the building story shears. Two stories below, at level three, this missing 80 kips was picked back up. Based on this it was determined that at this phase of the model generation there were sufficient errors in the framing of the model, however, during following phases leading up to the final model there were a significant amount of changes and corrections made. Due to these changes during the original design process the validity of the final model could not be determined based on this earlier version.

The second model was the final model whose designs were used for the final report. The applied loads calculated by the Equivalent Lateral Force Procedure have been verified in the original Final Report. In this version the sum of the frame story shears matches those of the building story shears, with a reasonable percent difference. Figure 1 shows this validation for the seismic load case in the X-direction. Following this verification that the story shears matched the forces in the braced frames were checked. Each frame was modeled as a planar truss. Due to the time constraints this could not be done manually. The frame story shears from RAM were applied to each braced frame in a RISA model. Following the analysis of these vertical trusses the column forces were examined and compared to that given by the RAM frame analysis. Due to RAM Structural System's assumption of infinitely rigid beam elements in braced frames, the beams & diagonal braces were not compared. A summary of the comparison of the axial forces due to the Seismic X-direction are shown in Figure 2, here the base level (below level 1) of the steel columns is the one included. At this point it was determined that the distribution of the lateral loads given by the Final RAM model was valid.

| Applied Forces [kips] | | | | | |
|---|---|---|---|---|---|
| | RAM Building Story Shears | | | ∑ RAM Frame Story Shears | |
| | X | Y | | X | Y |
| LVL 5 | 1518.65 | 0.00 | | 1518.64 | 0.09 |
| LVL 4 | 523.09 | 0.00 | | 523.10 | 0.01 |
| LVL 3 | 436.97 | 0.00 | | 436.96 | -0.03 |
| LVL 2 | 339.72 | 0.00 | | 339.73 | 0.03 |
| LVL 1 | 354.20 | 0.00 | | 341.20 | 0.02 |
| LVL D | 161.31 | | | 161.30 | 0.01 |

**Figure 1**

| COL | RAM | RISA | COL | RAM | RISA |
|---|---|---|---|---|---|
| 1 | -289.74 | -288.44 | 16 | -577.79 | -579.37 |
| 2 | 271.27 | 271.59 | 17 | 10.09 | 10.21 |
| 3 | -474.89 | -473.61 | 18 | -10.49 | -10.34 |
| 4 | 470.36 | 472.53 | 19 | -32.47 | -31.20 |
| 5 | 497.76 | 498.60 | 20 | 30.58 | 32.03 |
| 6 | -497.76 | -498.15 | 21 | -1112.71 | -1130.11 |
| 7 | 504.79 | 502.81 | 22 | 1138.68 | 1123.00 |
| 8 | -501.74 | -504.24 | 23 | 1082.07 | 1094.34 |
| 9 | -494.73 | -495.74 | 24 | -1113.04 | -1104.09 |
| 10 | 497.53 | 496.01 | 25 | -29.99 | -29.35 |
| 11 | 51.56 | 53.21 | 26 | 32.83 | 33.82 |
| 12 | -51.38 | -50.01 | 27 | 1086.26 | 1087.23 |
| 13 | 505.14 | 505.36 | 28 | -1089.84 | -1086.72 |
| 14 | -505.14 | -506.15 | 29 | 35.35 | 36.25 |
| 15 | 572.56 | 572.13 | 30 | -34.97 | -34.08 |

**Figure 2**

Following the verification of lateral loads one set of frame columns was examined for gravity loading; the loads were applied based on tributary areas for the columns. The dead and live loads are summarized by the spreadsheet in Figure 3 for braced frame 304R (which is labeled as Frame # 3 in the RAM model). The manual/spreadsheet check is reasonably different than the RAM results, therefore the RAM gravity analysis for Frame members is deemed valid.

| | Column 1 | | | | | | Column 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frame 3 | Trib Area | DL [psf] | DL [lb] | LL [psf] | LL [lb] | D+L | Trib Area | DL [psf] | DL [lb] | LL [psf] | LL [lb] | D+L |
| Roof | 315 | 62 | 19553.25 | 20 | 6307.5 | 25860.75 | 675 | 62 | 41850 | 20 | 13500 | 55350 |
| Mech | 210 | 40 | 8410 | 20 | 4205 | 12615 | 675 | 40 | 27000 | 20 | 13500 | 40500 |
| LVL 5 | 421 | 62 | 26071 | 75 | 31537.5 | 57608.5 | 290 | 62 | 17980 | 100 | 29000 | 46980 |
| LVL 4 | 841 | 62 | 52142 | 75 | 63075 | 115217 | 290 | 62 | 17980 | 75 | 21750 | 39730 |
| LVL 3 | 841 | 62 | 52142 | 75 | 63075 | 115217 | 290 | 62 | 17980 | 75 | 21750 | 39730 |
| LVL 2 | 841 | 62 | 52142 | 75 | 63075 | 115217 | 290 | 62 | 17980 | 75 | 21750 | 39730 |
| LVL 1 | 841 | 62 | 52142 | 75 | 63075 | 115217 | 290 | 62 | 17980 | 75 | 21750 | 39730 |
| | | subtotal | 262602.25 | subtotal | 294350 | | | subtotal | 158750 | subtotal | 143000 | |
| | | Self Wt | 41781.52 | Additonal | 0 | | | Self Wt | 20210.27 | Additonal | 0 | |
| | | TOTAL: | 304.38377 | TOTAL: | 294.35 | | | TOTAL: | 178.9603 | TOTAL: | 143 | |
| | | (D + L) TOTAL: | | 598.73377 | kips | | | (D + L) TOTAL: | | 321.9603 | kips | |

**Figure 3**

| | DL | | LL | |
|---|---|---|---|---|
| | RAM | Check | RAM | Check |
| Column 1 | 330.47 | 304.3838 | 243.69 | 294.35 |
| Column 2 | 153.71 | 178.9603 | 132.63 | 143 |

**Figure 4**

## Conclusion

Both the check of lateral forces and that of gravity forces support the results of the Final RAM model. It appears that the existence of errors in the earlier model combined with the 3 story span of Frame columns and the lower response modification factor were the reason for the excessive columns sizes. Since each of these issues was dealt with in the development of the final model used for design, it can be concluded that the design submitted in the final report is valid. While the validity of this model has been verified the reasoning for switching to Special Braced Frames may no longer exist. Given more time Ordinary Braced Frames would have been reconsidered in order to minimize construction costs.