Load combination FAQ

This page is devoted to **frequently asked questions** (FAQ) related to load combinations.

On this page:

How is loading applied in an arbitrary direction?

Extended Question: I am working on a building which has a wing non-orthogonal to X and Y. I would like to apply an auto seismic load both parallel and perpendicular to this orientation. How is loading applied at an angle relative to principal axes?

Answer: To apply loading along a user-defined orientation, use statics to resolve X and Y force components, then combine these contributions within a load combination.

As an alternative, the model may be rotated such that the direction of interest aligns with an orthogonal axis.

How should I define load combinations for several nonlinear load cases?

Extended Question: I have a 3D SAP2000 model with nonlinear gap and hook links located at restraint supports. The system is subjected to static loading. To run a steel LRFD check, should I factor and combine load patterns by using a load case, or a by using a load combination?

- **Load case** seems reasonable because combined loads may affect the links differently from when loads are applied separately and then summed.
- **Load combination** also seems reasonable because nonlinear links are dependent upon displacements, and therefore, perhaps factors should be applied after the analysis is run.

Answer: Nonlinear response is dependent upon the sequence in which loads are applied. Because code-specified load-combination factors account for the statistical variability inherent to various load types, it is most exact to include factors in the load case. This applies worst-case scenario during nonlinear analysis.

Consider, for example, a nonlinear load case with 1.2*DL and 1.6*LL. First, load patterns DL and LL are defined at service levels. Then to factor these loading conditions, a series of approaches are possible. From most accurate to least, options include:

1. To account for both the loading sequence and nonlinearity from factored loading, nonlinear load case DL should first be created where load pattern DL is applied with a factor of 1.2. Next, nonlinear load case LL should be created where load pattern LL is applied with a factor of 1.6. Further, load case LL should use the stiffness at the end of load case DL. Finally, load case LL should be used for design.
2. To account for nonlinearity from factored loading, but not loading sequence, create a nonlinear load case DL+LL where load pattern DL is factored by 1.2, and LL by 1.6. Use this load case for design.
3. The least accurate method, which accounts for neither the loading sequence nor nonlinearity from factored loading, is where load cases DL and LL are created with service-level loading, where load patterns DL and LL are factored by 1.0. Next, load combination 1.2DL+1.6LL is created with the associated factors, and used in design. This method may still be reasonable if nonlinearity is small. Please note that load combinations may be converted to nonlinear load cases through Define Load Combinations > Convert Combos to Nonlinear Load Cases.

How does the software handle load combinations for static multi-step load cases?

Extended Question: I am doing a static multi-step analysis to simulate a wave load which passes through the structure. When I combine this load case with the dead load case, results are only returned for one step. How can I run analysis without defining a new load case for each wave-crest position?

Answer: When a static load case (dead load) and a static multi-step load case (wave load) form a load combination, an envelope load combination is generated. This envelope reports a single set of results which is generated from the combination of the static case and the min/max condition of the multi-step case.

A load combination which combines dead load and any step of the wave load may still be created, though it must be created manually by post-processing results.

How do load combinations which include response spectrum (RSA) load cases run?

Answer: During response-spectrum analysis, for a given time-history record and direction of ground motion, maximum displacements, forces, and stresses are calculated throughout the structure for each vibration mode. Using one of the modal combination methods (CQC, SRSS, or ABS), these values are combined to produce a **single positive result of likely maximum magnitude** for each response measure. Response-spectrum analysis provides no information on when response values occur and how parameters correlate.

An explanation of how CSI Software combines results from static and response-spectrum analysis is as follows:

If response-spectrum analysis generates a result *M*, then results are within the range of -M to +M. When response spectrum is combined with another load case *P*, these positive and negative extreme values are paired with the static load pattern as follows:

- P, Mx, My
- P, Mx, -My
- P, -Mx, My
- P, -Mx, -My
- -P, Mx, My
- -P, Mx, -My
- -P, -Mx, My
- -P, -Mx, -My

Given a combination which includes only the response-spectrum case, the software will produce forces as follows:

- Max = P = +100 kips, M2 = +200 kips-ft and M3 = +300 kips-ft
- Min = P = -100 kips, M2 = -200 kips-ft and M3 = -300 kips-ft

Assume that gravity load is as follows:

- P = +500 kips, M2 = -50 kips-ft and M3 = +100 kips-ft

Gravity and response-spectrum forces combine to form a load combination of scale factor 1.0. In this combination, analysis forces are as follows:

- Max = P = (+500+100) = +600 kips, M2 = (-50+200) = +150 kips-ft and M3 = (+100+300) = +400 kips-ft
- Min = P = (+500-100) = +400 kips, M2 = (-50-200) = -250 kips-ft and M3 = (+100-300) = -200 kips-ft

During design, the software goes further to account for interacting quantities. Using the same example, design forces are considered as follows:

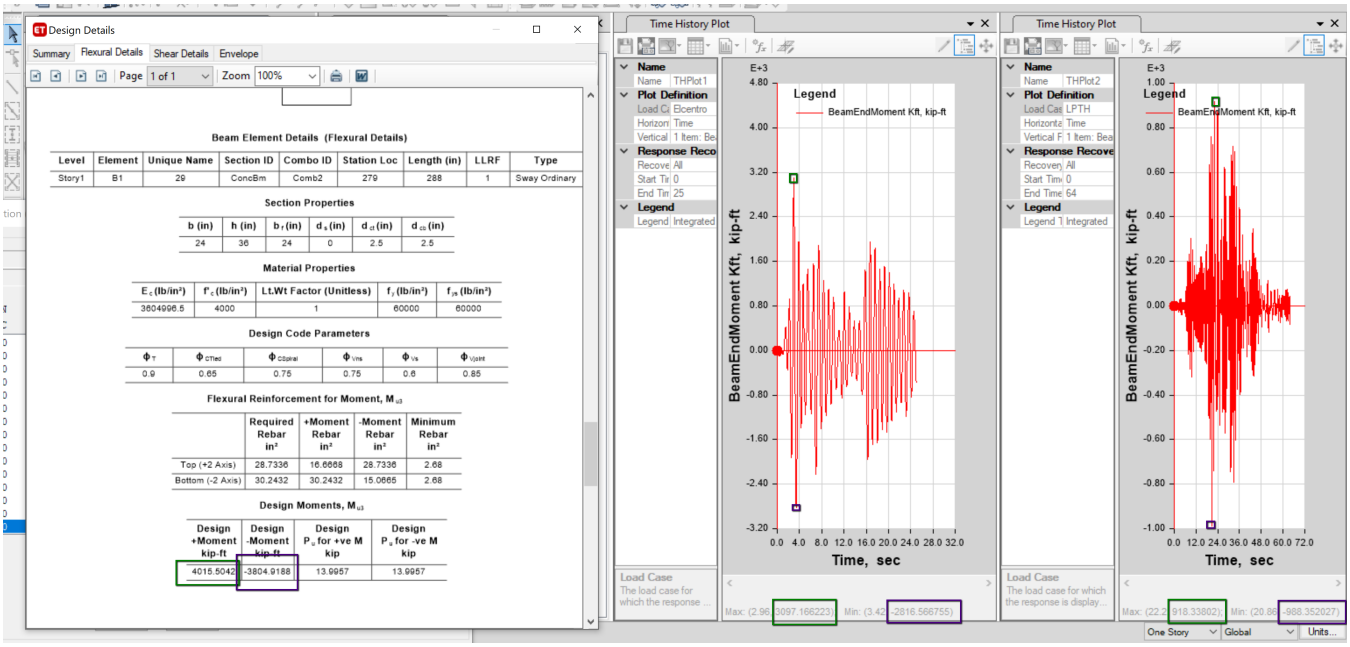
- **Comb-1** P = (+500+100) = +600 kips, M2 = (-50+200) = +150 kips-ft and M3 = (+100+300) = +400 kips-ft
- **Comb-2** P = (+500+100) = +600 kips, M2 = (-50-200) = -250 kips-ft and M3 = (+100+300) = +400 kips-ft
- **Comb-3** P = (+500+100) = +600 kips, M2 = (-50+200) = +150 kips-ft and M3 = (+100-300) = -200 kips-ft
- **Comb-4** P = (+500+100) = +600 kips, M2 = (-50-200) = -250 kips-ft and M3 = (+100-300) = -200 kips-ft
- **Comb-5** P = (+500-100) = +400 kips, M2 = (-50+200) = +150 kips-ft and M3 = (+100+300) = +400 kips-ft
- **Comb-6** P = (+500-100) = +400 kips, M2 = (-50-200) = -250 kips-ft and M3 = (+100+300) = +400 kips-ft
- **Comb-7** P = (+500-100) = +400 kips, M2 = (-50+200) = +150 kips-ft and M3 = (+100-300) = -200 kips-ft
- **Comb-8** P = (+500-100) = +400 kips, M2 = (-50-200) = -250 kips-ft and M3 = (+100-300) = -200 kips-ft

While this description is specific to frame forces, it also applies to pier forces.

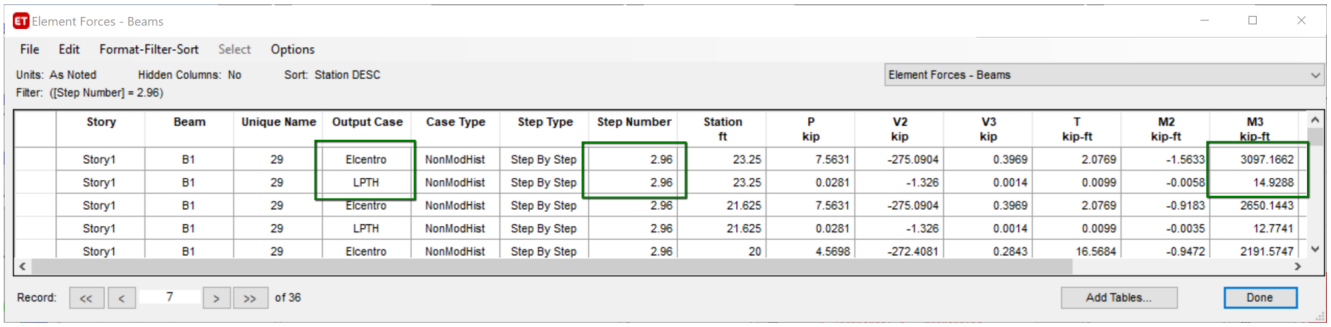
How are load combinations which include two or more time history load cases handled in analysis and design?

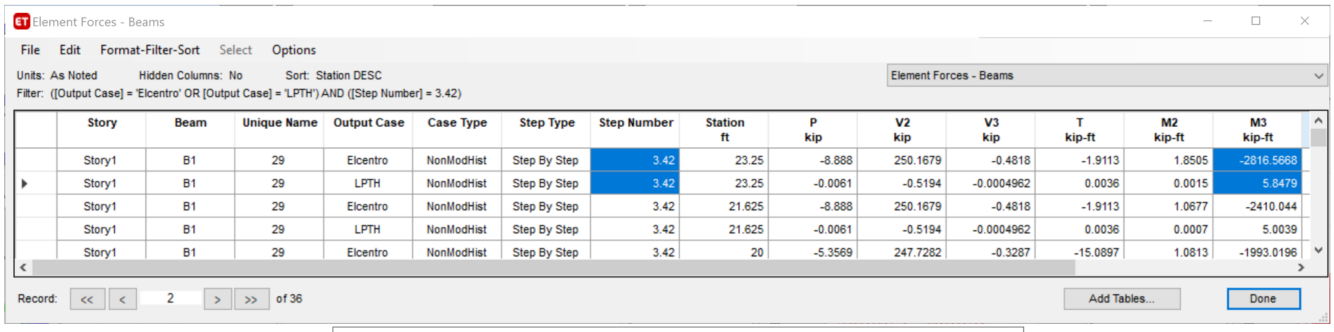
Answer: Time history (TH) load cases combined using Linear Add load combination type are handled differently in analysis vs design. **For design**, the program finds the maximum and minimum response values for each TH load case, multiplies them by their respective load combination scale factor and adds the maximums and minimums respectively. Note that the maximums/minimums of each TH in general will not occur at the same time step. To find an average of the values you can use a factor for each case equal to 1 over the number of cases. For example, below load combination Comb2 is a Linear Add combination of the two TH load cases for which beam design moments are shown. The design results of Comb2 are: Mmax=3097.16+918.34=4015.5 k-ft and Mmin=(-2816.57)+(-988.35)=-3804.92 k-ft. **For analysis**, element forces are linearly added for the same time step number then the maximum and minimum among all steps are reported. For the aforementioned beam example, the analysis results of Comb2 correspond to time steps 2.96 sec and 3.42 sec: Mmax=3097.16+14.93=3112.09 Kft and Mmin= (-2816.57)+(5.85)=-2810.72 Kft. To find an average of the maximum and minimum of TH analysis values similar to the way design values are calculated, define one load combination per TH case using envelope type, then define a linear add load combination consisting of those enveloped type combos using a factor for each case equal 1 over the number of cases.

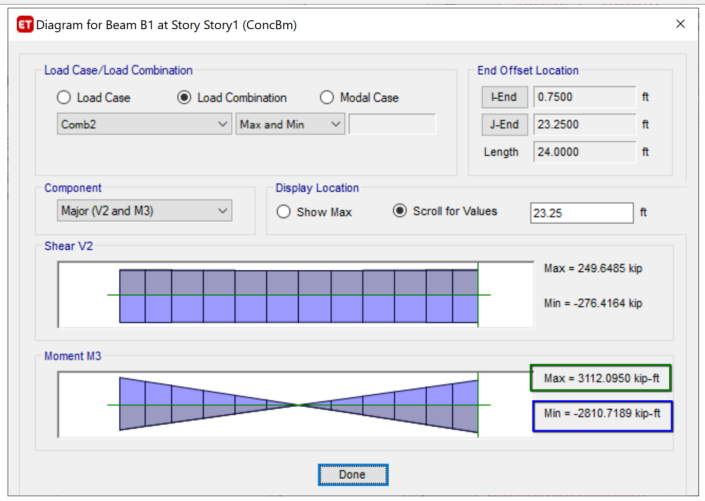
For Design:



For Analysis:







When time histories are combined using envelope type combination then the program finds and reports the maximum and the minimum from all time history cases in the load combination.

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