

07/20

TECHNICAL BULLETIN 15

Reducing Seismic Losses by Using DuraFuse Frames

Paul Richards, PhD, PE¹

Abstract: Buildings that are designed with current codes are expected to be damaged during severe earthquakes. SP3 software was used to perform FEMA-P58 analyses to compare expected losses for DuraFuse Frames vs. other special moment frames. Three building archetypes (3-, 9-, and 18-stories) were considered in combination with three sites (San Francisco, Northridge, Santa Monica). The FEMA-P58 analyses showed that DuraFuse Frames reduced structural losses by 60 to 73 percent as compared to other special moment frames.

Background

Buildings that are designed with current codes are expected to be damaged during severe earthquakes. In many cases, damaged buildings will not be economical to repair and will be a total loss. For example, after the 2011 Christchurch, New Zealand earthquake, 70% of buildings in the Central Business District required demolition (Spencer, 2016).

In the past 20 years, there has been a coordinated effort in the research community towards quantifying expected building losses from earthquake hazards. FEMA-P58 is a probabilistic performance prediction method that was developed for FEMA by the Applied Technology Council (ATC, 2019a; ATC, 2019b). FEMA-P58 takes site hazard, structural response, and fragility curves, and uses Monte Carlo simulation to generate loss estimates (economic loss, repair time, and casualties).

Technical Bulletin 10 (Richards, 2020) summarizes work that was done to develop fragility curves for DuraFuse Frames and compare expected losses for DuraFuse Frames vs. other special moment frames (SMFs). DuraFuse Frames fragility curves have been incorporated into SP3 (Haselton Baker Risk Group, 2020) so that FEMA-P58 analyses can be easily performed for buildings with DuraFuse Frames. This technical bulletin expands on the previous study by using SP3 to perform FEMA-P58 analyses for a variety of building archetypes and sites.

Study

FEMA-P58 analyses were performed for three building archetypes at three sites in order to quantify the difference in losses when DuraFuse Frames were used rather than traditional special moment frames (SMFs.) The web-based version of the SP3 program was used to perform each FEMA-P58 analysis. The analyses were performed using the SP3 Risk Model.

The three building archetypes were based on the 3-, 9-, and 18-story archetypes used for SAC moment frame studies (Foutch, 2000). The information that was input for the FEMA-P58 analysis that varied for each archetype is listed in Table 1. The following parameters were assumed the same for all archetypes: cost of \$300 per square foot, story height of 15 ft, constructed in 2020, commercial office occupancy, no vertical or plan irregularities, special detailing, risk category II, and importance factor 1. No other specific structural or component information was included in the analyses.

Table 1 Input parameters that varied for the building archetypes

Archetype	Total Square Ft	Aspect Ratio
3-story	64,800	1.5
9-story	202,500	1.0
18-story	216,000	1.2

¹ Vice President, DuraFuse Frames, 5801 West Wells Park Road, West Jordan, UT 84081. Email: paul.richards@durafuseframes.com

Table 2 Input information for the three sites used in the study

Address	Latitude	Longitude
1 Dr. Carlton B. Goodlett Place, San Francisco, CA, 94102	37.77927	-122.41924
9301 Tampa Ave., Northridge, CA, 91324	34.23841	-118.55609
1685 Main St., Santa Monica, CA, 90401	34.01163	-118.49137

Three sites were considered for the study; one in San Francisco, one in Northridge, and one in Santa Monica. All sites were assumed to be Class D. The address of each site and the latitude and longitude used in the analyses are summarized in Table 2.

Reports for each FEMA-P58 analysis included a breakdown of expected annual losses from plumbing and HVAC, exterior cladding, partition walls, interior finishes, other non-structural, structural components, residual drift, and collapse.

For this bulletin, the key results that were collected and graphed were the combined annual losses from structural components, residual drift, and collapse. Expected annual loss is meaningful because it combines the probability of different levels of earthquake shaking, with the cost to repair the building damage corresponding to those different levels of shaking.

Results

Figure 1 shows the expected annual losses (from structural components, residual drift, and collapse) for the 3-story building archetype at the three sites.

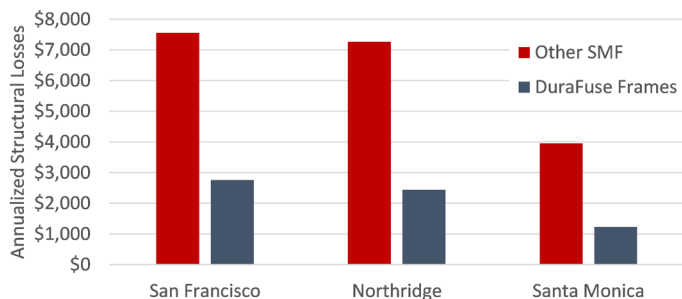


Fig. 1 Annualized losses from damaged structural elements, residual drift, and collapse for 3-story archetype

The reduction in losses with DuraFuse Frames ranged from 63 to 69 percent with similar absolute reduction at the San Francisco and Northridge sites and the greatest percent reduction for the Santa Monica site.

Fig. 2 and 3 show similar results for the 9-story and 18-story archetypes. For the 9-story archetypes, there was a 67 to 73 percent reduction in losses from damaged structural elements, residual drift, and collapse for the DuraFuse Frames buildings as compared to other SMFs (Fig. 2). The greatest absolute reduction was for the San Francisco site and the greatest percentage reduction was for the Santa Monica site. For the 18-story archetypes, there was 60 to 67 percent reduction in structure-related losses (Fig. 3).

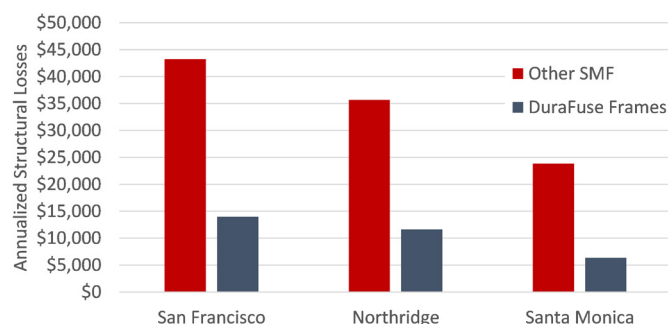


Fig. 2 Annualized losses from damaged structural elements, residual drift, and collapse for 9-story archetype

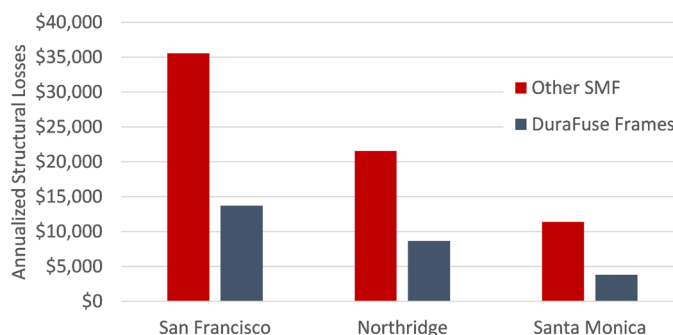


Fig. 3 Annualized losses from damaged structural elements, residual drift, and collapse for 18-story archetype

Discussion

DuraFuse Frames systems were developed to improve resilience and to reduce up-front costs of special moment frames. The savings that are shown in Figs. 1-3 are in addition to the up-front savings from using DuraFuse Frames. Up-front savings with DuraFuse Frames are a result of reduced beam and column sizes, reduction in beam lateral bracing, and elimination of field welding and inspection.

Summary and Conclusions

Buildings that are designed with current codes are expected to be damaged during severe earthquakes. The FEMA-P58 methodology takes site hazard, structural response, and fragility curves, and uses Monte Carlo simulation to generate loss estimates (economic loss, repair time, and casualties). The software SP3 facilitates FEMA-P58 analyses. SP3 has fragility curves for typical special moment frames and DuraFuse Frames.

A study was conducted to evaluate the difference in annual losses from structural damage, residual drift, and collapse, when DuraFuse Frames are used rather than typical special moment frames. Three building archetypes (3-, 9-, and 18-stories) were considered in combination with three sites (San Francisco, Northridge, Santa Monica).

The FEMA-P58 analyses showed that DuraFuse Frames reduced structural losses by 60 to 73 percent as compared to traditional moment frames. The greatest absolute reductions were for the San Francisco site, while the greatest percentage reductions were for the Santa Monica site. The range of percentage reductions were similar for the three building archetypes.

References

- ATC. (2019a). FEMA P-58: Seismic Performance Assessment of Buildings Volume 1 – Methodology. Applied Technology Council, Redwood City, CA.
- ATC. (2019b). FEMA P-58: Seismic Performance Assessment of Buildings Volume 1 – Implementation. Applied Technology Council, Redwood City, CA.
- Foutch, D. A. (2000). “State of the art report on performance prediction and evaluation of steel moment-frame buildings.” FEMA-355F, FEMA, Washington, D.C.
- Haselton Baker Risk Group. (2020). Creation of DuraFuse Frame Fragilities with Repairable Residual Considerations for FEMA P-58 Assessments. Haselton Baker Risk Group, Chico, CA.
- Richards, P.W. (2020). “Difference in repair cost of DuraFuse Frames vs. other steel moment frame systems.” Technical Bulletin 10. DuraFuse Frames, West Jordan, UT.
- Spencer, J. (2016). Redeveloping the CBD: Christchurch 5 years After the Earthquake. Cornell Real Estate Review. <https://blog.realestate.cornell.edu/2016/03/07/redeveloping-the-cbd-christchurch-5-years-after-the-earthquake/>



IAPMO UES ER 610

5801 WEST WELLS PARK ROAD • WEST JORDAN, UT 84081 • PHONE 801.727.4060 • durafuseframes.com



THE RESILIENT SEISMIC SOLUTION

All rights reserved. For informational purposes only. Durafuse Frames reserves the right to alter or withdraw the bulletin content without notice.