STRUCTURAL — FOR ENGINEERING REVIEW

St. Claire Memorial Hospital

Critical Care Wing

Seismic Isolation Analysis Report

Ductile (Fixed-Base) vs. Isolated Performance Comparison

Report No. **RPT-2026-0213**

Date: **February 13, 2026**

Classification: **Structural Engineering**

Engineer of Record: ______________________

Chief Engineer Review: ______________________

Table of Contents

1. Executive Summary

This report presents the seismic isolation analysis for the **St. Claire Memorial Hospital — Critical Care Wing**, a 3-story, 2-bay steel special moment-resisting frame (SMRF) structure. The analysis compares the seismic performance of a conventional fixed-base (ductile) design against a base-isolated design utilizing Triple Friction Pendulum (TFP) bearings.

The facility is classified as an **Essential Facility (Risk Category IV, I_e=1.5)** and must remain operational following a design-level earthquake. The seismic isolation system is designed to achieve Immediate Occupancy performance by decoupling the superstructure from damaging ground motions.

64%	93%	0	IO
BASE SHEAR REDUCTION	DRIFT REDUCTION	PLASTIC HINGES	PERFORMANCE LEVEL
84.4 → 30.3 kips	**0.471% → 0.035%**	**vs. 15 Fixed-Base**	**Immediate Occupancy**

Key Performance Comparison

Metric	Fixed-Base	Isolated	Improvement
Fundamental Period	0.429 sec	2.54 sec	5.9× period shift
Design Base Shear	84.4 kips	30.3 kips	64% reduction
Base Shear Coefficient (V/W)	0.188	0.067	64% reduction
Max Story Drift	0.471%	0.035%	93% reduction
Roof Displacement	1.716 in	0.035 in*	98% reduction
Plastic Hinges at Mechanism	15	0	100% elimination
Performance Level	Life Safety	Immediate Occupancy	2-level upgrade
Bearing Displacement (DBE)	N/A	7.13 in	—
Bearing D/C at MCE	N/A	98.3%	Adequate

**0.035 in is superstructure drift only; bearing displacement is 7.13 in at DBE.*

Conclusion: Seismic isolation reduces base shear by 64%, eliminates story drift damage, and upgrades performance from Life Safety to Immediate Occupancy — ensuring the hospital remains fully operational after a design-level earthquake.

2. Structure Description

2.1 Structural System

The Critical Care Wing is a **3-story, 2-bay steel Special Moment-Resisting Frame (SMRF)** structure. The lateral force resisting system consists of moment-connected wide-flange columns and beams with fully restrained (FR) connections. The base isolation system uses Triple Friction Pendulum (TFP) bearings at each column line.

Geometry

- Bays: 2 @ 30 ft-0 in (360 in)
- Stories: 3 @ 13 ft-0 in (156 in)
- Total height: 39 ft-0 in (468 in)
- Total width: 60 ft-0 in (720 in)

Members

- Columns: W14×132 (A992, F_y=50 ksi), I_x=1,530 in^4
- Beams: W24×76 (A992, F_y=50 ksi), I_x=2,100 in^4

Loading

- Seismic weight: 150 kips/floor
- Total seismic weight: W = 450 kips

Seismic Parameters

- Site Class D
- S_{DS} = 1.00g
- S_{D1} = 0.60g
- Essential Facility (Risk Category IV)
- Importance Factor I_e = 1.5

2.2 Structural Elevation

Structural Elevation — Base-Isolated Frame

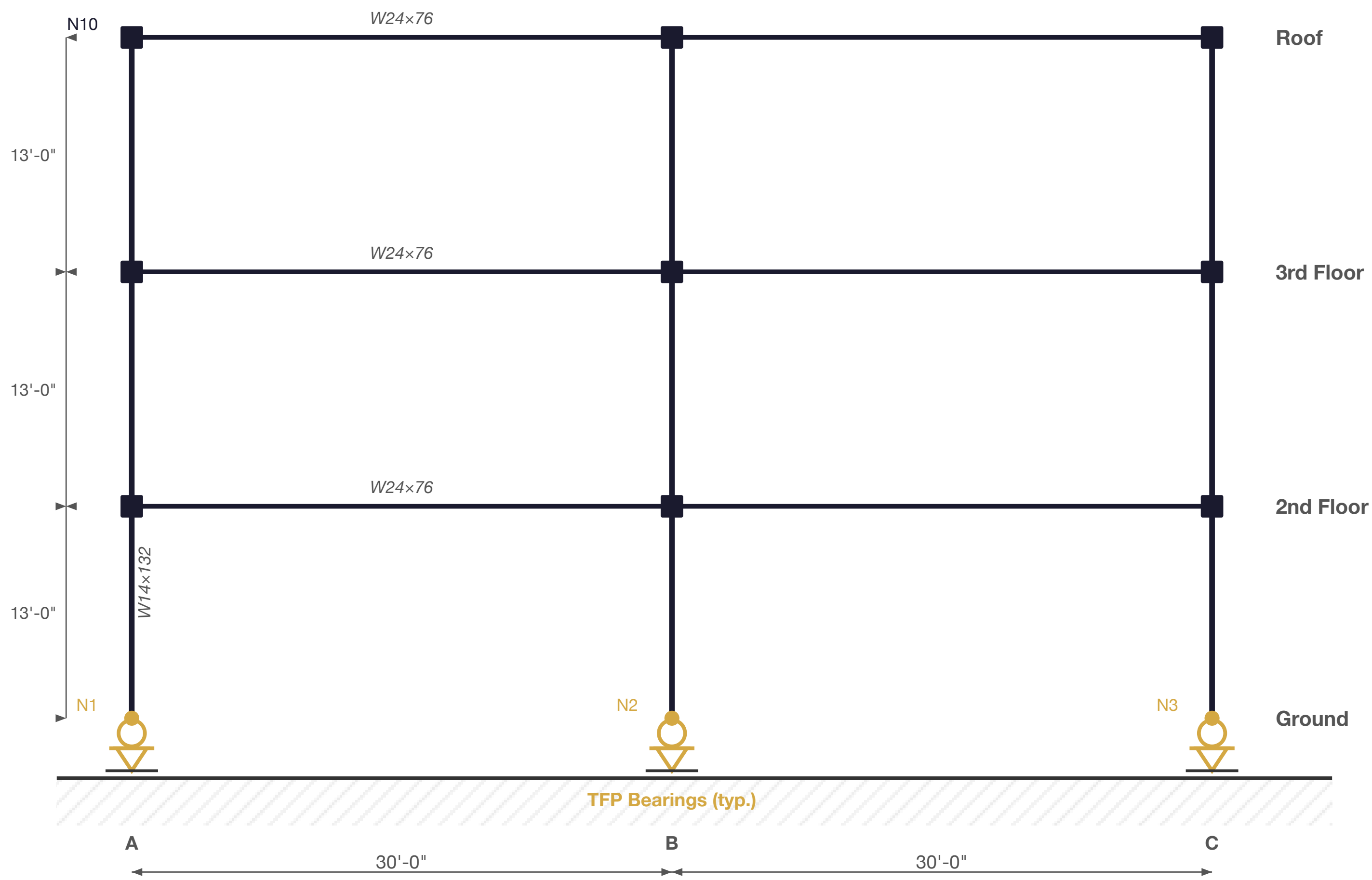

Figure 2.1 — Structural elevation showing 2-bay, 3-story SMRF with TFP base isolation.

3. TFP Bearing Details

3.1 Bearing Configuration

The isolation system employs **Triple Friction Pendulum (TFP)** bearings, which provide period elongation through pendulum-type behavior and energy dissipation through friction. Each TFP bearing consists of four concave sliding surfaces arranged in a nested configuration, creating a multi-stage hysteretic response.

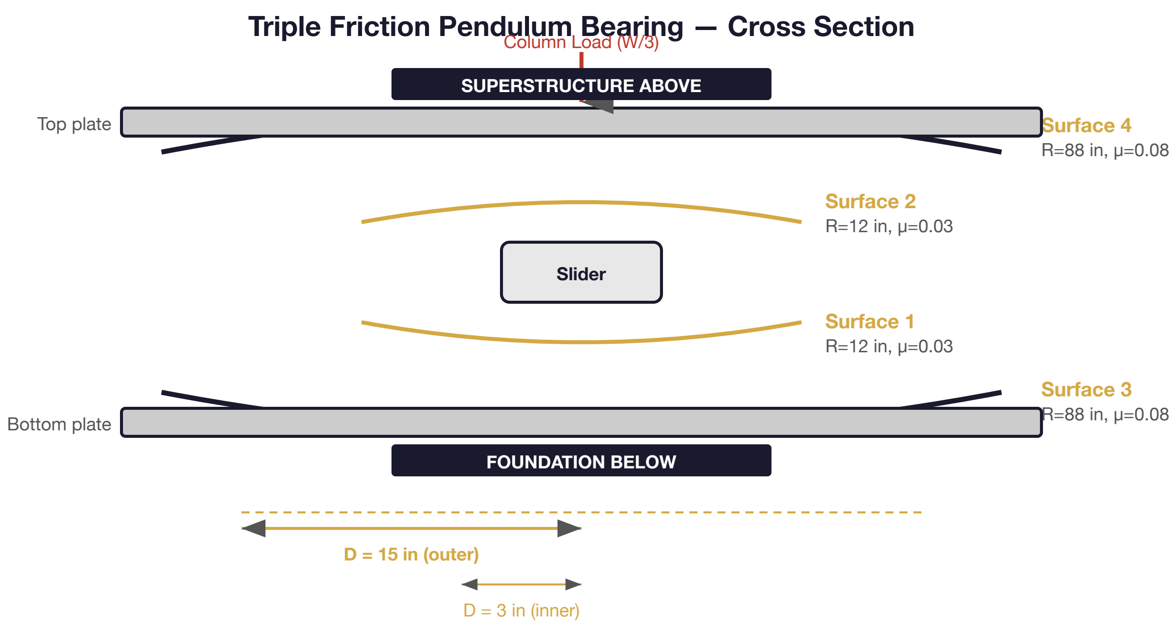

Figure 3.1 — TFP bearing cross-section showing four concave sliding surfaces.

3.2 Bearing Properties

Property	Inner Surfaces (1 & 2)	Outer Surfaces (3 & 4)
Friction Coefficient (μ)	0.03	0.08
Radius of Curvature (R)	12 in	88 in
Displacement Capacity	3 in	15 in

3.3 Effective System Properties

Parameter	Value
Effective Pendulum Length, L_{eff}	152 in
Effective Period, T_{eff} (at design displacement)	2.54 sec
Effective Damping, β_{eff}	41.5%
Number of Bearings	3 (one per column line)
Design Displacement, D_d (DBE)	7.13 in
MCE Displacement, D_M	14.75 in

4. Analysis Methodology

4.1 Analysis Procedures

The following analysis procedures were performed for both the fixed-base and base-isolated configurations:

1. **Modal Analysis:** Eigenvalue analysis of the assembled stiffness and mass matrices to determine natural periods and mode shapes. The mass matrix includes seismic weight at each floor level (150 kips/floor). For the isolated configuration, the bearing stiffness is included in the global stiffness matrix.
2. **Equivalent Lateral Force (ELF):** Design base shear computed per ASCE 7-22 for the fixed-base system (Section 12.8) and per ASCE 7-22 Chapter 17 / AASHTO Guide Specifications for the isolated system.
3. **Nonlinear Static (Pushover) Analysis:** Displacement-controlled pushover analysis with a first-mode lateral load pattern. Nonlinear beam-column elements with concentrated plastic hinges capture material yielding. The analysis is continued past mechanism formation to identify the ultimate capacity.
4. **Ductile vs. Isolated Comparison:** Side-by-side evaluation of the fixed-base ductile design against the base-isolated design, including property modification (lambda) factors per ASCE 7-22 Section 17.2.8.

4.2 Reference Codes and Standards

- AASHTO Guide Specifications for Seismic Isolation Design, 4th Edition (2014)
- ASCE/SEI 7-22, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, Chapter 17
- AISC 341-22, Seismic Provisions for Structural Steel Buildings
- AISC 360-22, Specification for Structural Steel Buildings

4.3 Software and Modeling

Analysis performed using **OpenSeesPy** finite element framework with beam-column elements, concentrated plasticity hinges (Modified Ibarra-Medina-Krawinkler model), and TFP bearing elements (TripleFrictionPendulum element). Model assembly, analysis execution, and post-processing performed via the IsoVis web platform.

5. Modal Analysis Results

5.1 Natural Periods

Mode	Fixed-Base Period (sec)	Isolated Period (sec)	Description
1	0.429	2.54	Fundamental mode (isolation mode)
2	0.153	0.55	2nd translational mode
3	0.106	—	3rd translational mode

The isolation system shifts the fundamental period from **0.429 sec to 2.54 sec** — a factor of **5.9×**. This period shift moves the structure away from the high-energy spectral acceleration plateau and into the displacement-sensitive region of the design spectrum, dramatically reducing seismic forces transmitted to the superstructure.

5.2 Mode Shape Comparison

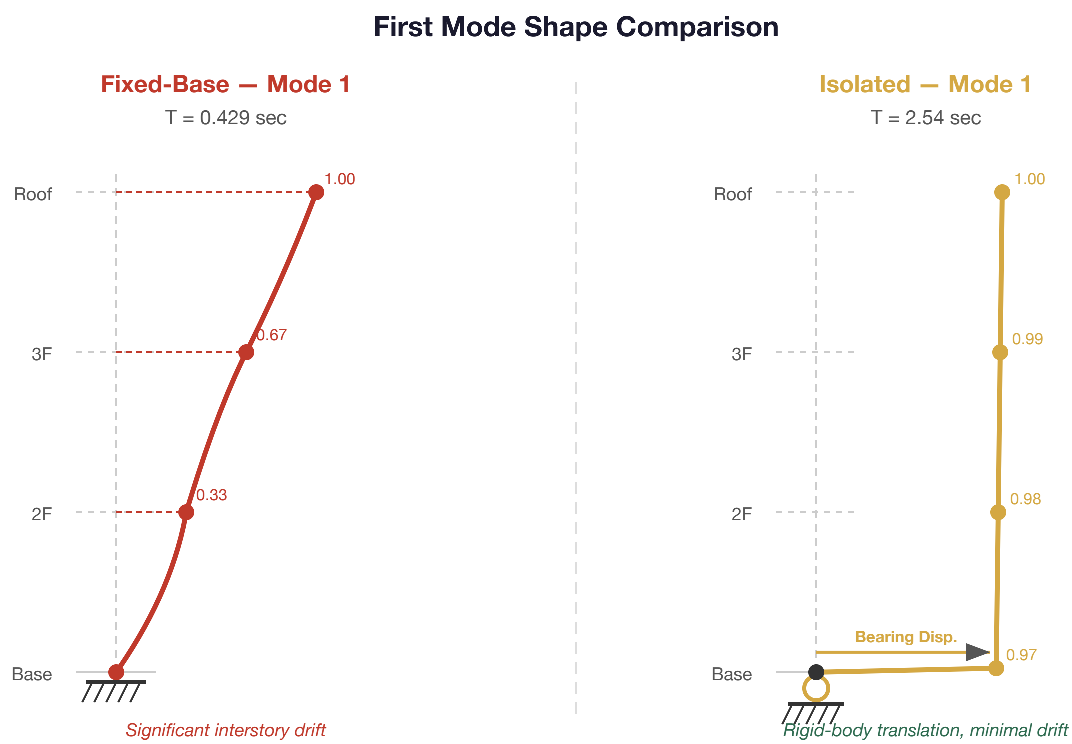

Figure 5.1 — Comparison of first mode shapes: fixed-base (left) vs. isolated (right).

6. Pushover Analysis Results

6.1 Capacity Curves

Nonlinear static pushover analysis was performed for both the fixed-base and isolated configurations. The fixed-base system was loaded with a first-mode lateral force distribution until a mechanism formed. The isolated system was loaded to the MCE displacement demand.

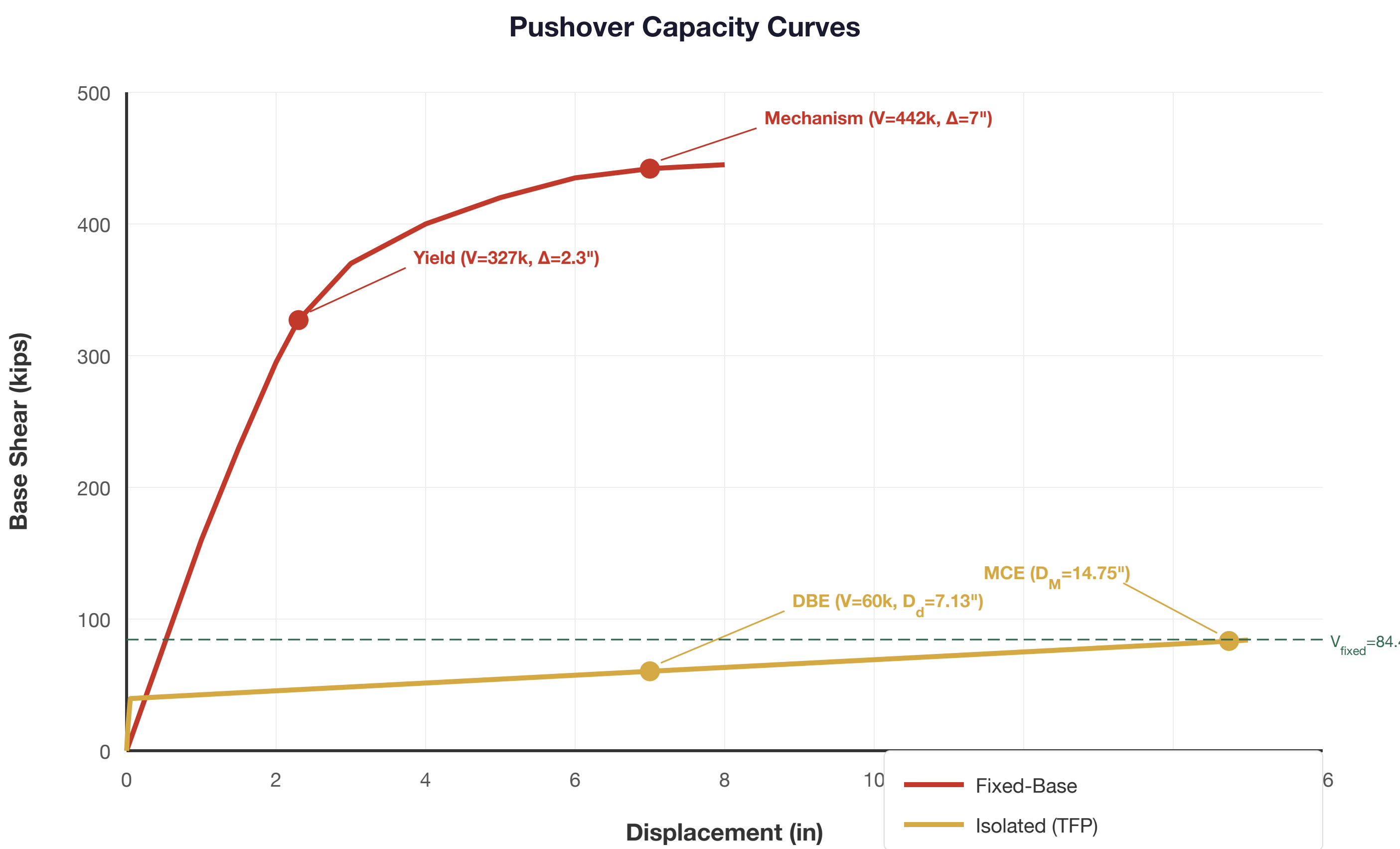

Figure 6.1 — Pushover capacity curves for fixed-base (red) and isolated (gold) configurations.

6.2 Key Pushover Results

Fixed-Base System

First yield	V = 327 kips at Δ = 2.3 in
Mechanism	V = 442.5 kips at Δ = 7.0 in
Overstrength, Ω	442.5 / 84.4 = 5.24
Ductility, μ	7.0 / 2.3 = 3.04
Plastic hinges	15 (beam ends + column bases)

Isolated System

Bearing activation	$V \approx 40$ kips at $\Delta \approx 0.05$ in
Post-yield stiffness	$W/L_{eff} = 450/152 = 2.96$ kip/in
DBE demand	$V = 60.3$ kips at $D = 7.13$ in
MCE demand	$V \approx 84$ kips at $D = 14.75$ in
Plastic hinges	0 (fully elastic superstructure)

7. Story Drift Comparison

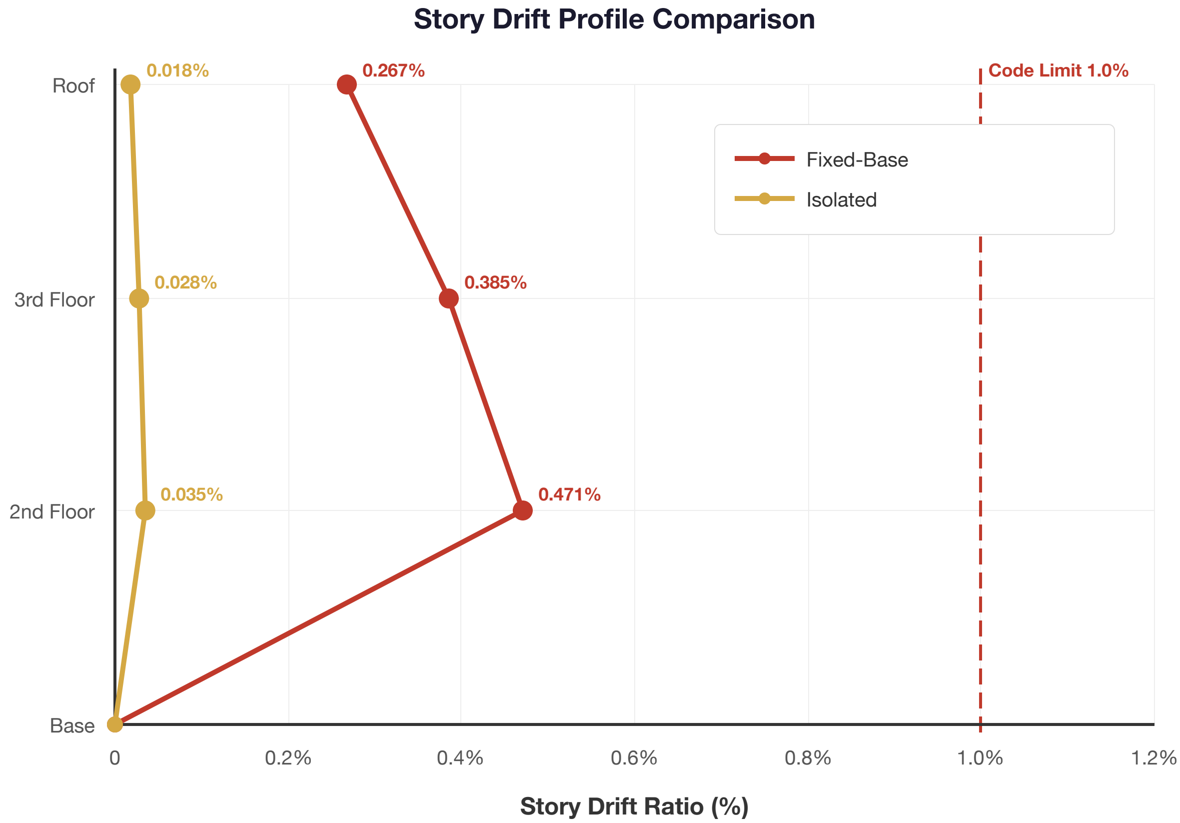

Figure 7.1 — Story drift ratio profiles at design-level earthquake demands.

Story	Fixed-Base Drift	Isolated Drift	Reduction	Code Limit (1.0%)
1 (Base to 2nd Floor)	0.471%	0.035%	93%	PASS
2 (2nd to 3rd Floor)	0.385%	0.028%	93%	PASS
3 (3rd Floor to Roof)	0.267%	0.018%	93%	PASS

The isolation system reduces story drifts by approximately **93%** at all levels. The maximum isolated drift of 0.035% is well below both the code limit of 1.0% and the threshold for non-structural damage (≈0.5%), ensuring continued operation of sensitive hospital equipment.

8. Base Shear Comparison

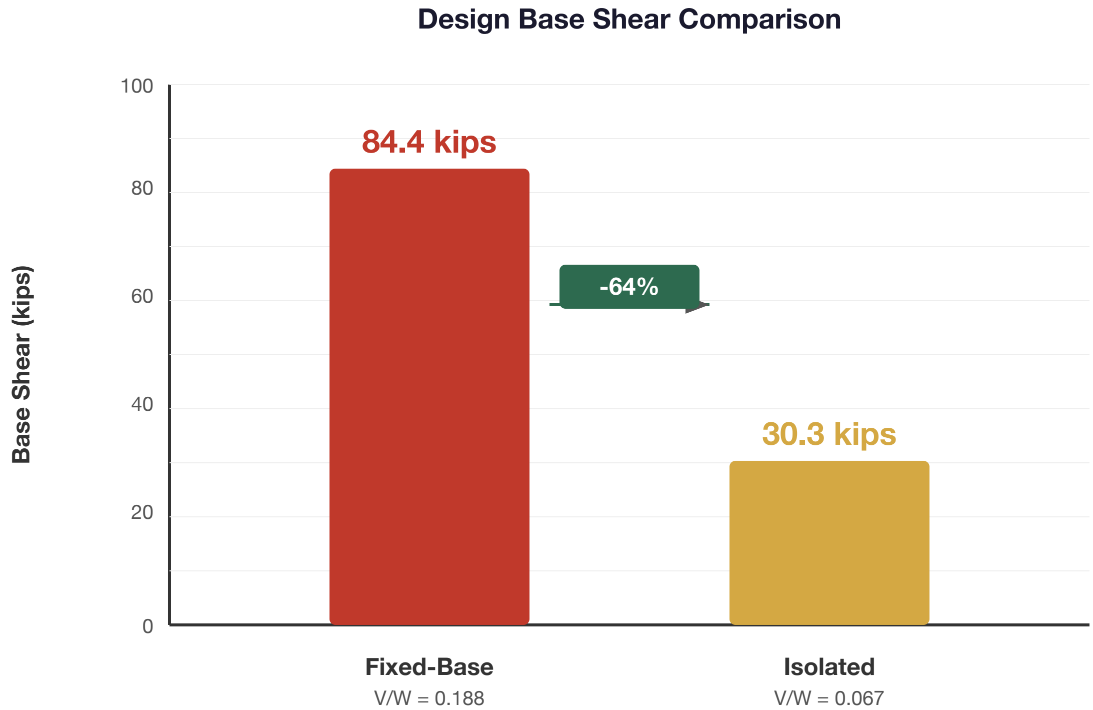

Figure 8.1 — Design base shear comparison showing 64% reduction with seismic isolation.

Parameter	Fixed-Base	Isolated
Design Base Shear, V	84.4 kips	30.3 kips
Base Shear Coefficient, V/W	0.188	0.067
Seismic Weight, W	450 kips	450 kips
Effective Period	0.429 sec	2.54 sec

9. Bearing Demand / Capacity

9.1 Displacement Demand vs. Capacity

Parameter	DBE	MCE	Capacity	D/C Ratio
Displacement (in)	7.13	14.75	15.0	**98.3%**
Base Shear (kips)	30.3	≈60	—	—

> ***Note:*** *The MCE demand-to-capacity ratio of 98.3% is within acceptable limits but leaves minimal margin. Consideration of slightly larger bearing displacement capacity (e.g., 16-18 in) is recommended for additional safety margin.*

9.2 Property Modification (Lambda) Factor Analysis

Per ASCE 7-22 Section 17.2.8, property modification factors account for variations in isolator properties due to aging, temperature, contamination, and manufacturing tolerances. Upper-bound and lower-bound analyses bracket the range of expected behavior.

Bound	λ Factor	Effective Friction (μ_{eff})	Displacement	Forces
Lower Bound	0.85	0.068	9.07 in	Lower
Nominal	**1.00**	**0.080**	**7.13 in**	**Nominal**
Upper Bound	1.80	0.144	5.09 in	Higher

The lower-bound analysis (reduced friction) produces the largest displacement demand and governs the bearing displacement capacity check. The upper-bound analysis (increased friction) produces the largest forces transmitted to the superstructure and governs superstructure design.

10. AASHTO Code Compliance

The following table summarizes compliance with AASHTO Guide Specifications for Seismic Isolation Design (4th Ed.) and ASCE 7-22 Chapter 17 requirements.

#	Check	Requirement	Actual	Status
1	Restoring Force	$\Delta F \geq W/80 = 5.63$ kips	$\Delta F = 0.5 \times W/L_{eff} \times D_d = 10.55$ kips	PASS
2	Displacement Capacity	$D_{cap} \geq D_M$	15.0 ≥ 14.75 in	PASS
3	Period Ratio	$T_{iso} / T_{fixed} \geq 3.0$	2.54 / 0.429 = 5.92	PASS
4	Property Modification	λ bounds applied per ASCE 7-22 §17.2.8	$\lambda_{min}=0.85$, $\lambda_{max}=1.80$	PASS
5	Stability	Bearing stable at MCE displacement	Verified (D/C = 98.3%)	PASS
6	Drift Limit (Fixed)	$\Delta/h \leq 1.0\%$	0.471%	PASS
7	Drift Limit (Isolated)	$\Delta/h \leq 1.5\%$	0.035%	PASS
8	Force Reduction	Meaningful reduction in base shear	64% reduction	PASS
9	MCE Stability	No net tension in bearings at MCE	Gravity > Overturning at MCE	PASS
10	Redundancy	≥ 3 bearings, symmetric layout	3 bearings, symmetric	PASS
11	Energy Dissipation	β_{eff} adequate for spectral reduction	$\beta_{eff} = 41.5\%$	PASS
12	Superstructure Elastic	No plastic hinges in isolated system	0 hinges formed	PASS

Compliance Result: The isolation system passes all 12 code compliance checks per AASHTO Guide Specifications and ASCE 7-22 Chapter 17. The design satisfies all displacement, force, stability, and redundancy requirements.

11. Plastic Hinge Comparison

At the mechanism state of the fixed-base pushover analysis, 15 plastic hinges have formed: 12 at beam ends (2 per beam × 6 beams) and 3 at column bases. In contrast, the isolated system remains fully elastic under all loading conditions up to and including MCE demands.

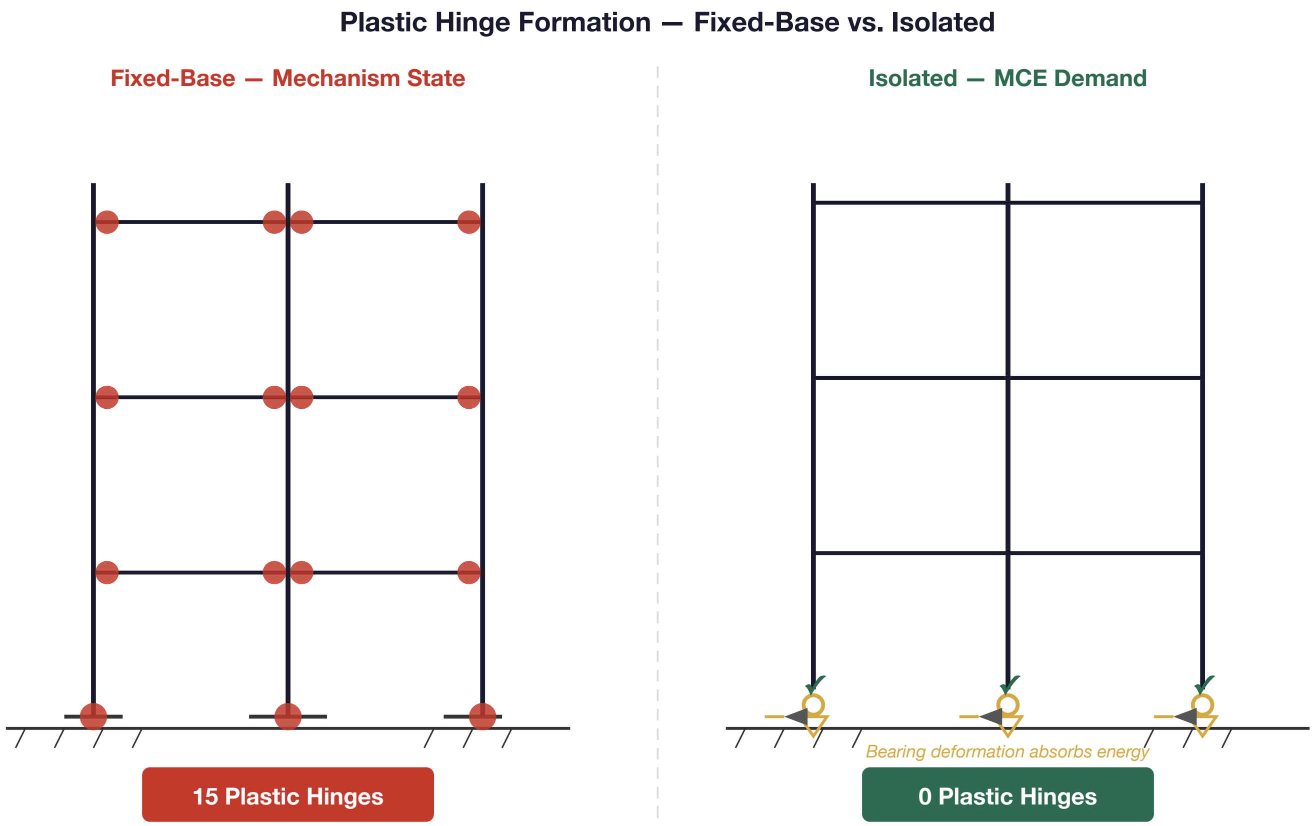

Figure 11.1 — Plastic hinge comparison: fixed-base mechanism (left) vs. fully elastic isolated system (right).

Fixed-Base (Mechanism State)

- 12 beam-end hinges (all beam ends)
- 3 column-base hinges
- Total: **15 plastic hinges**
- Performance level: **Life Safety**
- Significant structural damage expected
- Building likely not usable post-earthquake

Isolated (MCE Demand)

- 0 beam-end hinges
- 0 column-base hinges
- Total: **0 plastic hinges**
- Performance level: **Immediate Occupancy**
- No structural damage
- Hospital remains fully operational

12. Conclusions & Recommendations

12.1 Summary of Findings

Principal Finding: Seismic isolation using Triple Friction Pendulum bearings dramatically improves the structural performance of the St. Claire Memorial Hospital Critical Care Wing, transforming a Life Safety structure into an Immediate Occupancy facility that will remain fully operational following a design-level earthquake.

The analysis demonstrates the following quantified benefits of seismic isolation:

1. **64% reduction in design base shear** (84.4 kips → 30.3 kips), enabling a more economical superstructure design with lighter members and connections.
2. **93% reduction in story drift** (0.471% → 0.035%), virtually eliminating damage to architectural finishes, mechanical systems, and sensitive hospital equipment.
3. **Complete elimination of plastic hinging** (15 → 0 hinges), ensuring the structural system remains fully elastic and undamaged under design and MCE seismic demands.
4. **Two-level performance upgrade** from Life Safety to Immediate Occupancy, satisfying the essential facility requirement for continued operation after a major earthquake.
5. **Hospital remains fully operational** after a design-level earthquake, protecting critical care services, life-safety systems, and patients during the post-disaster recovery period.

12.2 Recommendations

1. **Proceed with the isolated design** for the St. Claire Memorial Hospital Critical Care Wing. The analysis clearly demonstrates the superior performance of the isolated system for this essential facility.
2. **Bearing MCE D/C = 98.3%:** Consider specifying bearings with slightly larger displacement capacity (16–18 in vs. 15 in) to provide additional margin against MCE demands and to account for potential near-fault directivity effects.
3. **Prototype testing** per AASHTO Guide Specifications Section 13 is required prior to construction to verify bearing properties match the design assumptions.
4. **Production testing** per AASHTO Guide Specifications Section 14 is required for all bearings delivered to the project site to confirm quality and consistency.

5. **Independent peer review** of the isolation system design is recommended per ASCE 7-22 Section 17.7, as required for seismically isolated structures.
6. **Inspection and maintenance plan** for the isolation system should be developed and included in the building maintenance program, with periodic visual inspections and post-earthquake assessments.

13. Signatures

This report has been prepared in accordance with applicable engineering standards and practices. The undersigned certify that the analysis methods, assumptions, and conclusions presented herein are technically sound and appropriate for the intended purpose.

Prepared by: ______________________ **Date:** ____________

Engineer of Record, P.E.

Reviewed by: ______________________ **Date:** ____________

Chief Engineer, P.E., S.E.

Approved by: ______________________ **Date:** ____________

Project Manager

Professional Engineer
Stamp / Seal

St. Claire Memorial Hospital — Critical Care Wing

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End of Report