INTRODUCTION

Structures may experience unforeseen operating environments or site-specific hazards leading to changes in the structures performance, safety, and longevity. These changes often prompt asset owners to undertake analysis efforts to ensure satisfactory structural performance for the updated conditions. However, conventional analyses which fail to capture the true behavior of a structure can lead to inaccurate analysis results, causing owners to make less than ideal asset management decisions. Structural Integrity Associates (SI) is uniquely positioned to pair our dynamic characterization and advanced structural analysis capabilities to generate a better structural model. SI vibration experts use impact testing, forced vibration, or ambient excitation sources, along with proprietary signal processing software, to non-destructively characterize the dynamic behavior of structural systems. This characterization is used to inform advanced structural analyses by SI analysis experts to provide more accurate results related to operational improvements, damage location, and retrofits.
Better DECISIONS

**PROJECTS**

**STRUCTURE:** High-Rise Concrete Hotel  
**OWNER:** Private Owner  
**EXCITATION:** Ambient (Wind) Vibration  
**ANALYSIS TYPE:** Nonlinear Time History & Nonlinear Pushover  
**OBJECTIVE:** Support New Design

Tobolsk Watkins Engineering (TWE), acquired by SI in 2017, provided structural and seismic consulting related to the nonlinear analysis of a 30-story hotel to determine acceptable performance of the building during large earthquakes and tropical storms. TWE developed a 3D finite element model of the building to perform nonlinear time history analyses, modal analyses, and nonlinear pushover analyses. Additional work included in-situ testing of the main tower to determine the damped natural frequencies of vibration of the bare frame structure, prior to the construction of building cladding and nonstructural components. The purpose of the testing was to provide input for calibrating the finite element model of the building and for use as input to extreme wind load calculations.

**STRUCTURE:** Induced Draft Fan  
**OWNER:** Power Utility  
**EXCITATION:** Impact Hammer, Externally Driven & Operationally Driven  
**ANALYSIS TYPE:** Foundation Investigation  
**OBJECTIVE:** Root Cause Analysis

A power utility noted excessive operational vibrations in an induced draft fan forcing the fan to be pulled from service, lowering the plants power output and daily revenue. SI was brought in to investigate the fans concrete foundation as a potential cause. SI performed a variety of in-situ dynamic tests to characterize the system including impact hammer tests of the stationary fan blades and concrete foundation, a frequency sweep of the system using a linear mass shaker and recorded 96 channels of data at various points in the system during quasi-operational runs. Interpretation of the recorded data led to a shift in focus from the foundation to the fans bearing. Disassembly of the fan bearing revealed several issues that were quickly resolved. Quasi-operational runs after reassembly showed a marked reduction in the operational vibrations, leading the fan to be put back into service.

**STRUCTURE:** Remote Shutdown Console  
**OWNER:** Nuclear Utility  
**EXCITATION:** Shake Table  
**ANALYSIS TYPE:** Nonlinear Time History Analysis  
**OBJECTIVE:** Seismic and Shock Base Isolation

Due to an increase in the required seismic ground motion and the inclusion of an aircraft impact load case a nuclear utility sought to base isolate a remote shutdown console. Since the console needed to remain operational after the dynamic load cases a fragility analysis was also needed. SI developed a finite element model of the console and used shake table test data, provided by the equipment manufacturer, to validate the modeling approach. SI then performed nonlinear time history analyses to investigate the feasibility of a shock mount system for the console. The in-console response was used to determine the fragility demands imposed on the console which were compared to client-defined thresholds.

**PROJECTS**

**STRUCTURE:** Nuclear Fuel Packages on a Vehicular Trailer  
**OWNER:** Nuclear Fuel Manufacturer  
**EXCITATION:** Highway Transportation Vibration  
**ANALYSIS TYPE:** Spectral Analysis and Operational Deflected Shapes  
**OBJECTIVE:** Vibration Study

A fuel manufacturer ships nuclear fuel across the country via trailer transport. SI was contracted to develop a test procedure and a mobile data acquisition system to measure the vibration acceleration experienced by the trailer and fuel packages during shipments across the United States. The system measured accelerations over the course of the multi-day shipment. SI analyzed the data to better characterize the vibration acceleration amplitudes as well as frequency content of the trailer-package-fuel assembly system as vibration is transmitted from the road through the trailer suspension, packages, and into the fuel assemblies. The improved understanding of the vibration signature for the transport system assists the manufacturer in making decisions on how to best mitigate vibration levels during future transportation.

**STRUCTURE:** Hydroelectric Dam  
**OWNER:** Water and Power Utility  
**EXCITATION:** Ambient  
**ANALYSIS TYPE:** Nonlinear Time History Analysis  
**OBJECTIVE:** Seismic Vulnerability and Retrofit Assessment

The owner of an unreinforced concrete arch dam was required to address design and safety issues due to increased seismic hazard classification and probable maximum flood levels prior to relicensing by FERC. Built in the 1920’s, this dam has significant concrete degradation due to seepage and many freeze thaw cycle. SI performed nonlinear time history analyses evaluating the as-built vulnerabilities of the structure and assessing the efficacy of several retrofit modifications. Previously, another consultant instrumented the dam to determine the dynamic characteristics, natural frequencies and mode shapes. As part of SI’s scope of work eigenmode analyses were performed with the finite element model. The calculated natural frequencies were within a percent of the on-site measured frequencies. This close agreement gave confidence to the owner and FERC regulators in SI’s nonlinear analysis methodology.
KEY PROFESSIONAL STAFF

Derrick Watkins, PhD, SE. Dr. Watkins has over 20 years of experience in the seismic design, analysis, construction, and repair of heavy industrial structures, including fossil and nuclear facilities. This includes over 10 years of experience working on projects at DOE sites. His skills include complex finite element analysis, seismic design for moderate and extreme earthquake events, design of rotating and vibrating equipment supports and foundations, anchorage to concrete, and equipment seismic qualification.

Mark Jaeger, PE. Mr. Jaeger works to address structural adequacy and operational longevity problems at power generation and process plants. His areas of expertise include vibration, piping design and analysis, fatigue and stress evaluation, failure analysis, and instrumentation and monitoring of plant systems and components. His proficiencies include management of on-site sensor installation and data collection, analysis and evaluation of acquired data, and technical application of results to address regulatory requirements and/or resolve problems.

Eric Kjolsing, PhD, PE. Dr. Kjolsing is heavily involved with the development of finite element models to facilitate analyses of both concrete and steel structures. Representative work includes impact, prestress loss, seismic and shock analyses of assets managed by power utilities.

SUMMARY

Analysis models based on plan sets, construction documents or other limited information may lead to models which do not represent the true in-situ state of a structure. To improve asset management decisions, analyses should be informed by real-world testing. Structural Integrity Associates (SI) has the capabilities and experience to both dynamically characterize a structural asset and build a test informed analysis model. Test informed analysis models lead to more confidence in the analysis results and subsequent asset management decisions. With both characterization and analysis competencies in-house, SI offers a one-stop shop to help owners better manage their high-value assets.