A California highway transportation management center has to be able to respond quickly to emergencies but also withstand a catastrophic event.

Engineering for Emergencies

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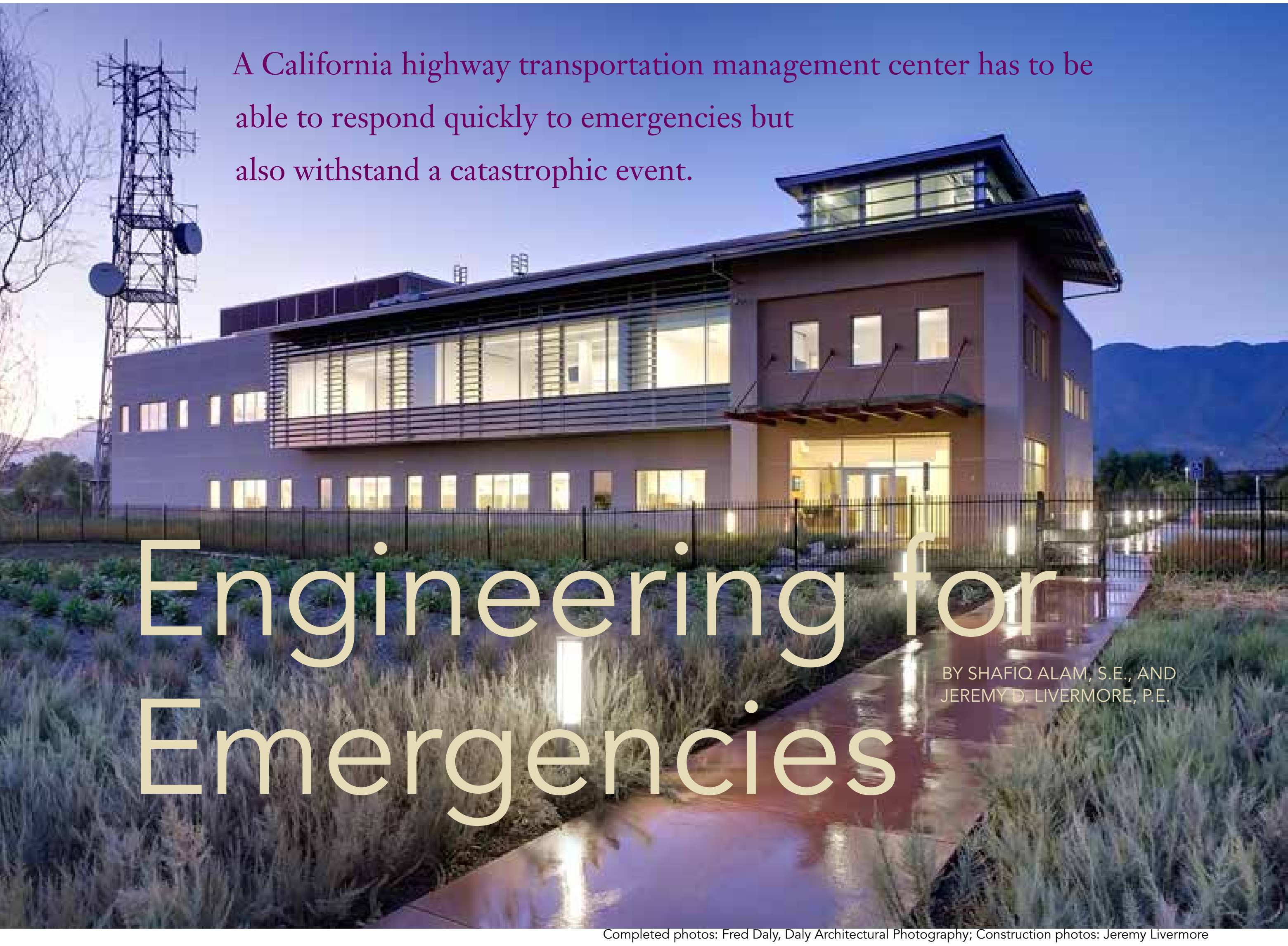
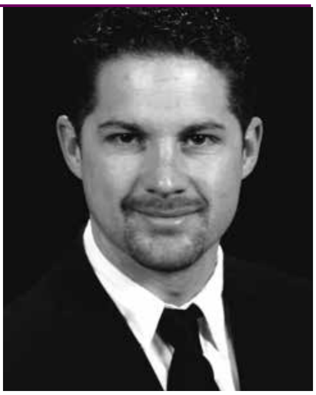


Completed photos: Fred Daly, Daly Architectural Photography; Construction photos: Jeremy Livermore

FOR THE CALIFORNIA DEPARTMENT OF TRANSPORTATION (Caltrans) and the California Highway Patrol (CHP), immediate response is the name of the game when it comes to highway emergencies.



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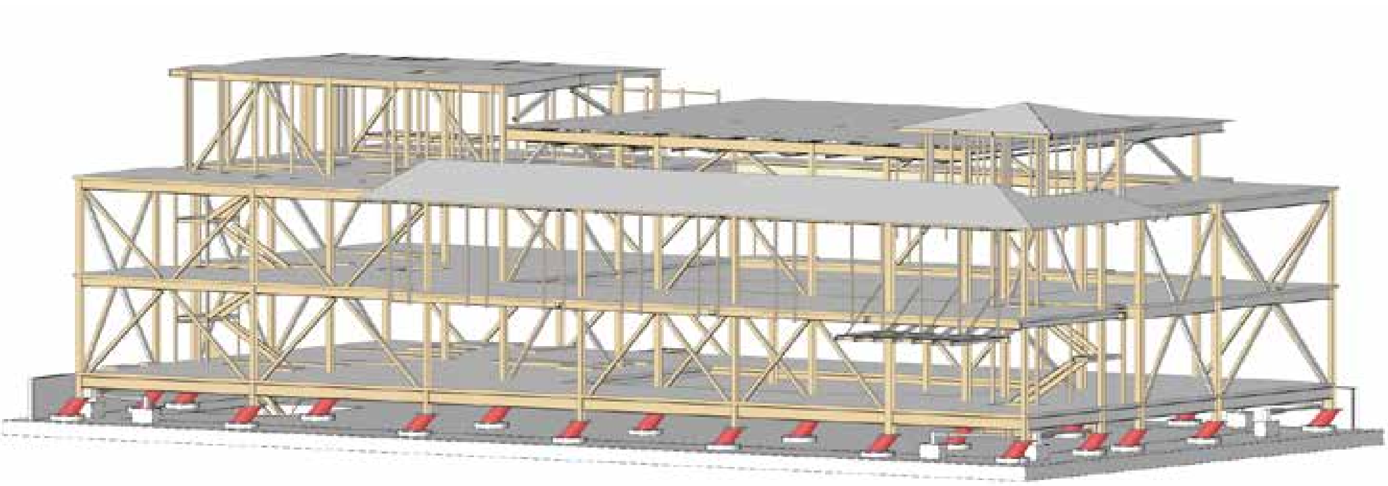
To improve response time to incidents that occur within the state's vast freeway network, these two state agencies are colocating their emergency personnel in new advanced facilities—transportation management centers that house integrated control room technology, operator and dispatch staff and even full-service kitchens, showers and locker rooms for overnight watches.

For one of these centers, the Inland Empire Transportation Management Center (IETMC), the features within the facility reveal only half the story. The building itself must be able to respond to extreme catastrophic incidents, namely a magnitude 7.5 earthquake; the California Building Code (CBC) requires the 43,000-sq.-ft "Essential Services Facility" to remain operational during and after catastrophic earthquakes.

At the Base

The ongoing operations capability of the IETMC created challenges for the structural design team, as the performance of non-structural components (IT servers, cable trays, chillers, etc.) was as critical as that of the main structural system. The team thus sought to use a lighter structure on base isolators with viscous fluid dampers (from Taylor Devices)



Locations of the base isolators.

The Inland Empire Transportation Management Center is designed to withstand a magnitude 7.5 earthquake.

and decided upon a steel framing system, which also allowed for long clear spans in the control room and provided clean framing for spaces cantilevered from the second floor. In addition, the exposed steel braced framed system in the interior provided the aesthetically pleasing technical elements appropriate for the advanced nature of the facility. Steel moment frames were used to frame out a basement space for isolator access and monitoring, and penthouse-level steel moment frames were used to create the brace-free rooftop "lighthouse" and California Mission-style overhangs.

The design team decided on 31 natural rubber base isolators to support the building. Base isolating a building enhances the performance of the structure by reducing its response to ground accelerations, which reduces the forces to the lateral load resisting system and to the non-structural components.

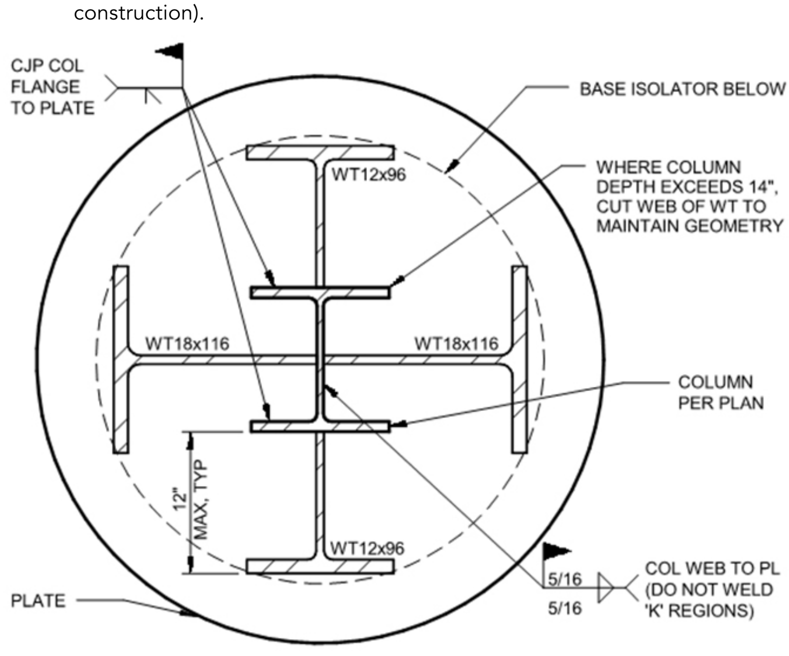
Base-isolated buildings require that there are no stiff non-structural elements in the space between the isolator and the basement retaining wall. For this reason, these buildings require flexible mechanical and electrical connections to outside utilities. These tethered systems are able to displace laterally and vertically in order to accommodate the expected earthquake induced displacement.

The IETMC project was designed for 26 in. of lateral displacement at the isolator level during a maximum credible earthquake (2,500 year return period) and remain "essentially elastic" for a design-basis earthquake (475 year return period). This was accomplished using a basement and floating moat slab cover at the retaining walls that provides space for the isolators, dampers, elevator pits, mechanical piping and electrical conduit to move.

The structural steel moment frame in the basement creates the first-floor steel framing system and shapes the basement space to monitor the performance of the isolators and dampers.

A base isolator with a viscous fluid damper.

Column shapes above the base isolators. (Note: Each base isolator was covered with sheet metal to prevent accidental gouges during construction).



Steel framing allowed for long clear spans in the control room.

The facility is 43,000 sq. ft.

Typical column sizes consisted of W12×96 and W14×132, and braces consisted of HSS8×8×0.500.

There are 31 base isolators in all.

WT18×116 and WT12×96 were used to create the massive cruciform-shaped moment frame column for bidirectional bending. The W24×162 steel girder moment frames were designed with stiffeners at predetermined jacking points allowing the building dead load to be temporarily removed from the isolators should they need replacement.

The isolation system also uses eight viscous fluid dampers. The dampers reduce the lateral drift demand on the isolators, resist a portion of the high wind loads expected at the site and accommodate a design velocity of 62 in. per second and MCE forces of 439 kips.

Modeling Isolation

Determining the seismic input data necessary for modeling of the building and isolation system was the first step in the design process. The CBC required a dual level earthquake design approach; therefore site-specific response spectra for both the DBE and the MCE events were developed by the geotechnical consultant, who then used these target spectra to scale three matched triaxial sets of earthquake ground motion time histories (two horizontal and one vertical axes). The three earthquake ground motion records used on the IETMC project were associated with the 1992 Landers Earthquake recorded at Yermo Station, the 1999 Izmit-Kocaeli Earthquake recorded at Yarimca Petkim Station and the 1994 Northridge Earthquake recorded at Rinaldi Station.

A three-dimensional computer model of the building was then developed using the nonlinear structural analysis software ETABS. The steel-braced framed superstructure was modeled as a linear system while the base isolation system was modeled using the nonlinear characteristics of the isolator type selected during preliminary design. In the case of IETMC, a bilinear biaxial (shear) hysteretic element with linear axial stiffness was used for the elastomeric isolators.

The damping elements were added to the model to reflect 3% critical damping in the time history analysis for all modes of vibration of the structure. The three sets of scaled time histories were run for each of the MCE and DBE events, and these were each analyzed in four orthogonal directions to determine which direction and time history produced the maximum response.

Mission Control

Operations required a two-story control room on the second floor to accommodate a 17-ft-tall x 42-ft-wide display area for the monitors, creating a split-level roof diaphragm. The design team added structural braced frames around the control room from the first floor up to the upper roof level, providing an interior with exposed braces as an architectural feature throughout the core of the inner structure.

Other diaphragm complexities came from the 18-in. access floors regions on the first and second floors, which were necessary to provide the required cable space for the IT equipment. The design engineers supported the composite-filled metal deck at the perimeter girders with angles and welded rebar to transfer the diaphragm forces vertically across the upper portion of the diaphragm. This access floor drop required tight detailing at each access floor column, as the top of the base isolator plate is only inches away.

The 14-ft-tall elevator "lighthouse" tower created an additional penthouse structure on the roof. The architect desired a braced, free structure as this tower would be surrounded by glass. This tower peaks at the center apex and a moment frame was used consisting of HSS8×8×½ columns.

The mechanical equipment room on the roof rises an additional 16 ft above the low roof level, and the design team decided to reduce construction cost by extending the building columns and braced frames up at this location.

To achieve the California Mission-style 10-ft overhang at the roof level, the design team used HSS8×6×0.375 joists with metal deck.

In general, typical column sizes consisted of W12×96 and W14×132, and braces consisted of HSS8×8×0.500. Due to the large amounts of equipment and highly integrated technical components running within the building, the design teams used BIM and clash-detection software (Autodesk Revit and Navis) for all disciplines of the project. This provided the client and the design team confidence that any constructability conflicts would be resolved in the design phase.

The end result is a $23 million dollar facility capable of survival during a catastrophic seismic event and one that will handle critical lifeline communication services for Southern California. MSC

Owner
State of California, Department of General Services

Architect and Structural Engineer
AECOM, Orange, Calif.

General Contractor
RC Construction Services, Rialto, Calif.