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# SEISMIC STRENGTHENING OF PALO ALTO CIVIC CENTER

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## SUMMARY

The City of Palo Alto Civic Center (PACC), constructed in 1968-1970, is located five miles east of the San Andreas fault (see Fig. 1). PACC houses about 200 City administrative employees.

Indications of potential structural problems first appeared in 1975; from 1975 to 1982 additional weaknesses were observed. After a detailed seismic risk study and structural evaluation, design documents were completed in early 1984. Repairs started in June 1984, and were completed in August 1986. All work was performed while the building was occupied and in full operation.

## INTRODUCTION

The first structural concerns arose in 1975 when cracking and some spalling of the precast concrete columns were observed. After assessment, EDAC (Engineering Design Analysis Company) recommended repairs plus a seismic analysis of the tower because the lateral force resisting system did not appear complete. The exterior facade columns were caulked and painted in 1978.

In 1982, the City authorized EDAC to make a seismic risk study of the facility. Strengthening of the lateral resisting system was recommended plus reinforcement of the three stories of concrete columns supporting the tower. These columns had exhibited cracking patterns indicating potential overstress. Design documents were started in 1983 and were completed in early 1984. Bids were taken, work started in June 1984 and was completed in August 1986.

The initial design and construction for the building was in general accordance with the 1961 Uniform Building Code. The building consists of an 85-foot square eight-floor tower supported on a three-story below-grade parking garage 242 by 272 ft. in plan (see Fig. 2 and 3), with elevators serving all floors. The tower is constructed with reinforced cast in place concrete columns and walls, and post-stressed slabs and girders. The garage is constructed with reinforced concrete columns and exterior walls with post-stressed concrete slabs and girders. An expansion/contraction joint divides the garage into two parts.

The tower's exterior cladding is precast concrete facade columns with window walls in between. Tower story heights are 12 feet except for 23 high for the first and the eighth stories (see Fig. 4). The parking story heights vary from 10.00 ft to 13.75 ft. Lateral force resistance was provided by the walls of the elevator shaft and the exit stairways, and the rear wall of the restroom areas

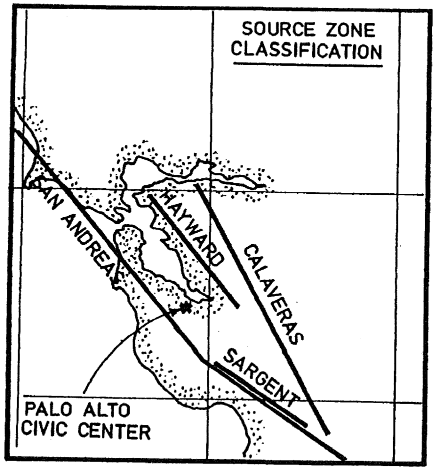


FIGURE 1. FAULT SOURCES

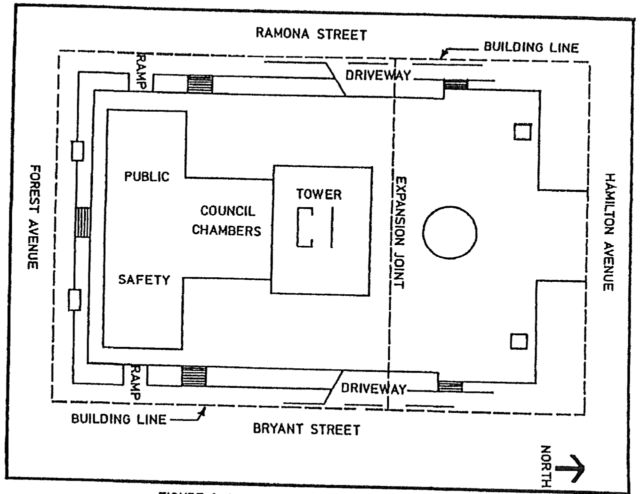


FIGURE 3. PALO ALTO CIVIC CENTER PODIUM LEVEL

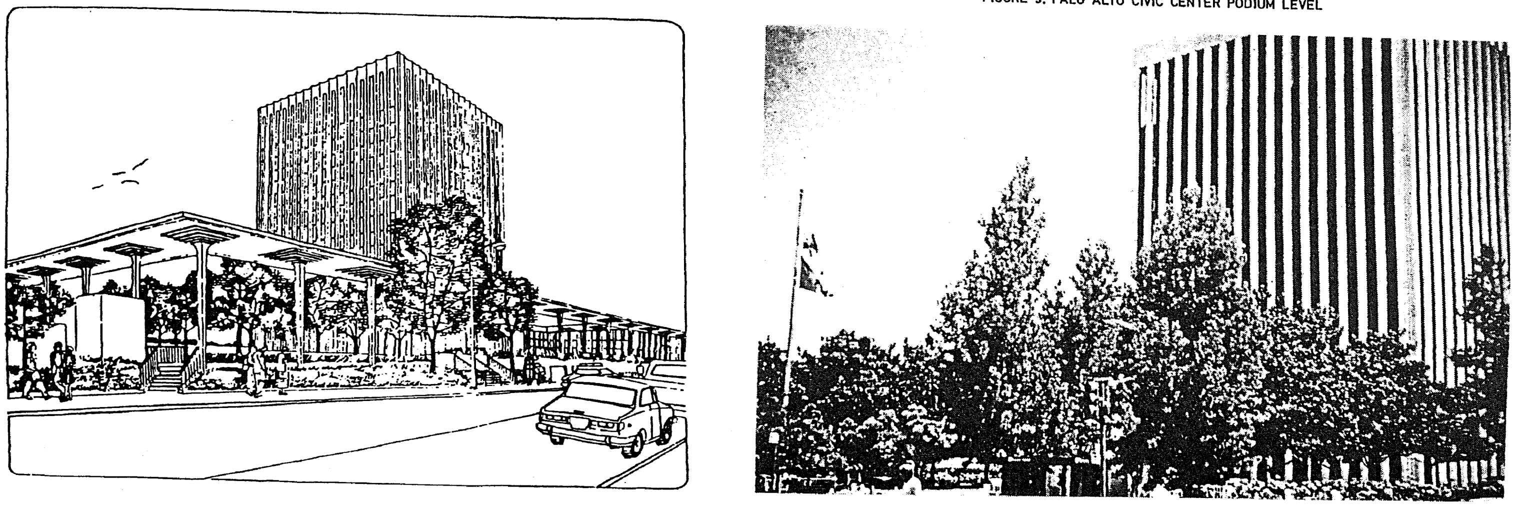

FIGURE 2. PALO ALTO CIVIC CENTER BEFORE / AFTER RETROFIT

## SCHEDULE OF EVENTS

The building was five years old when the first problems appeared. Recommendations to carefully review the structure and reanalyze seismic forces were resisted because of the building's age.

1980-81 Extensive cracking appeared in the garage floor slabs and walls because of differential creep and shrinkage between the poststressed slab floor and the normally reinforced exterior walls. The stressed tendons were repaired to prevent corrosion from the environment.

1982-83 EDAC conducted a detailed seismic risk study of the PACC including a structural assessment and made the following recommendations:

1. Strengthen elevator shaft walls with steel plates on the elevator side plus required architectural, mechanical and electrical work.
2. Strengthen the eighth story by adding two north south shear walls and steel bracing in the east-west direction.
3. Add new reinforced concrete shear walls at garage levels B and C.
4. Strengthen tower perimeter columns on lines 10 and 14 at levels B and C.
5. Strengthen connections of precast facade columns to tower structure.
6. Strengthen 34 columns supporting umbrella walkway at Podium level.
7. Provide support extension at expansion joints for Podium, and garage levels A and B.
8. Provide seismic restraints for mechanical equipment at level A and the eighth floor.
9. Add wire bracing and hangers for the suspended ceiling and light fixtures on all levels.
10. Upgrade tower restrooms and access to meet California Handicapped Requirements.

Major problems arose because of the cost and potential impact on City operations. Schematic design documents, construction plan and cost estimate were prepared to mitigate the impact on City operations.

Meanwhile the City announced plans to float a bond issue. Objections from some residents about the legality of a bond issue forced the City to develop an innovative approach. The City transferred the PACC to a non-profit corporation for twenty years and agreed to pay rent to the corporation. The corporation in turn issued Certificates of Participation bearing interest for twenty years. The funds were deposited in a local bank with authority for the City to request periodic reimbursement for design and construction expenses. Design and construction documents were prepared.

The question of whether to evacuate the PACC during construction was studied at length. Inconvenience to the public, lack of adequate close-by office space, expense of moving the staff, and difficulty of moving the Emergency Communications Center which served Palo Alto, Mountain View and Stanford University precluded moving. The fourth floor had been left unfinished when originally constructed. It was decided to finish this space including restrooms and then move occupants from a floor to the new floor while construction was completed on their floor.

Another problem was construction noise, dust and debris. Acoustical studies were made to assess the impact of core drilling versus rotary impact drilling. Because the poststressed construction of the tower created a sound chamber, the intensity of noise was a serious concern. The Emergency Communications Center operates on a 24-hour basis and thus special acoustical sealing, insulation and procedures were adopted. A bell was installed where the drillers were working, which could ring when an emergency call was received and the drillers would stop work until the call was completed. Many emergency callers are difficult to understand because of their panic or injuries, hence low ambient noise levels are essential when the operator is receiving a call.

The coordination of construction activities with daytime City operations and night time Council and Committee sessions was also critical. Noisy work during the day and during evening meetings was prohibited. Therefore, to minimize impact on City operations, whenever feasible, noisy work was conducted from 5:00 pm to 7:00 am.

It was decided to bid the work in three packages: architectural-type including cast-in-place concrete, structural steel, and demolition and concrete drilling. The three contract packages were used so close control of scheduling, access to construction areas, use of elevators during working hours, noisy operations, etc. could be maintained.

<u>1984</u> Bids were taken during the spring and work started in June 1984. Initially only two elevators had been installed, so steel plate could be installed in the empty shaft. Meanwhile the fourth floor was completed with restrooms, ceilings, HVAC, telephone systems, and moveable partitions. Work was also started on the construction of new concrete shear walls in the garage.

In general construction activities progressed quite well. However, changed conditions were encountered such as electrical conduits in the ceiling slab rather than in the floor slab; the conduit was inadvertently severed on a Saturday. Unbeknownst to the workmen, this cut power to a sump pump draining a lower portion of the garage and caused flooding which severely damaged control equipment for an exit elevator. Fortunately no cars were in the flooded area. In other areas reinforcing steel was not in locations as shown on the building drawings.

Despite careful precautions and detailed procedures, numerous false fire alarms were caused by smoke from welders. Each alarm caused complete evacuation of the building with about forty five minutes lost time for each City employee.

The City Project Manager worked closely with the city employee unions before and during construction to help them understand the need for the strengthening and to answer their complaints. This planning materially reduced the number of complaints. The City staff endured the inconveniences remarkably well.

<u>1986</u> Construction work on all floors was completed in the fall of 1985. The installation of steel plates in the elevator shafts and steel plate bracing of the exterior concrete walls in the stairways were not completed until August 1986 because of labor and access problems.

## STRENGTHENING DESIGN

The 1982 seismic risk study showed that the lateral force resisting system for the tower was inadequate. Shear walls were missing from the eighth story and in the garage levels below the tower, shear resistance of walls on other floors was inadequate, concrete columns supporting the perimeter walls were overstressed in the lower levels, and connections of the precast facade columns to the structure were overstressed.

Initially it was planned to thicken the concrete walls of the elevator shaft on the exterior. However, careful inspection of running clearances in the shaft revealed that there was enough clear space (2.5") to install steel plates against the concrete walls. It was decided to strengthen the walls with 0.5" and 0.63" thick steel plates anchored with bolts through the walls and epoxy injected between the plates and the wall (see Fig. 5). This solution minimized impact on adjacent office spaces and did not reduce usable office space which was at a premium.

New concrete shear walls were added in the two lower garage levels to resist torsional forces from the tower and transmit shear to the foundations (see Fig. 6). Shear walls were also added to the eighth floor.

The precast facade columns were anchored to the floor slab with steel angles. Where this could not be done, bolts were installed from the exterior by drilling through the precast prestressed columns into the poststressed perimeter floor beams. Careful measurements and good workmanship avoided cutting any tendons, although over 400 bolts were installed in this manner.

When the strengthening of the umbrella columns supporting the exterior canopy was started by stripping some of the concrete cover, it was found that the structural steel and reinforcing were so misplaced, that the required reinforcing would be architecturally unacceptable. After careful study the City decided to remove the canopy and columns. The work was accomplished in January 1985 without difficulty despite the tight space around the plaza and streets adjacent to it.

## CONCLUSION

The use of probabilistic response spectra was helpful in demonstrating the needs for seismic design levels greater than the building code. The dynamic analysis program clearly pointed out the weak areas in the lateral force resisting system. Careful study of existing details and construction methods used also indicated serious deficiencies in the building. The strengthening measures installed should enable the building to survive a major earthquake albeit with some damage.

Research is needed in the area of strengthening concrete walls with steel plates and/or bracing. During the design, the literature was surveyed in detail to find applicable research; little was available. Thus experienced engineering judgement based on detailed calculations was relied upon for the design.

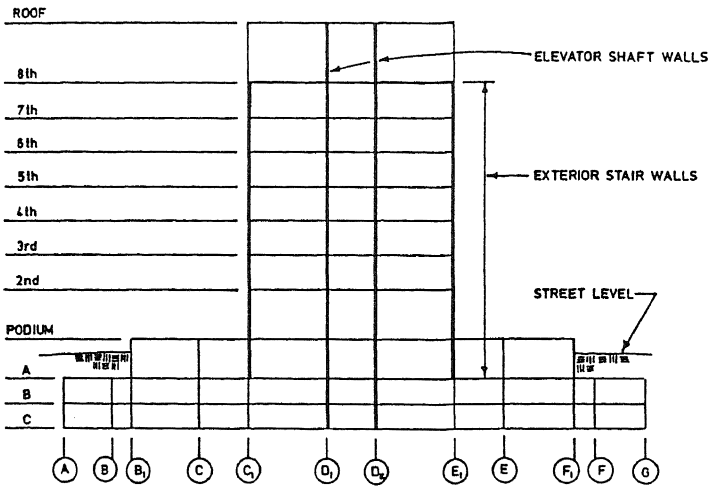


FIGURE 4. SCHEMATIC SECTION LOOKING NORTH

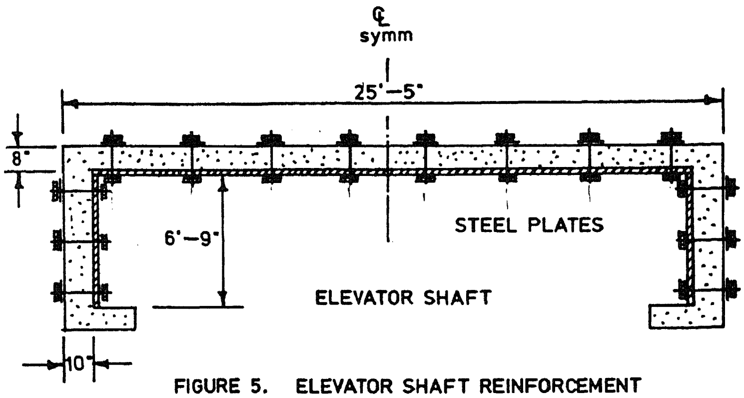


FIGURE 5. ELEVATOR SHAFT REINFORCEMENT

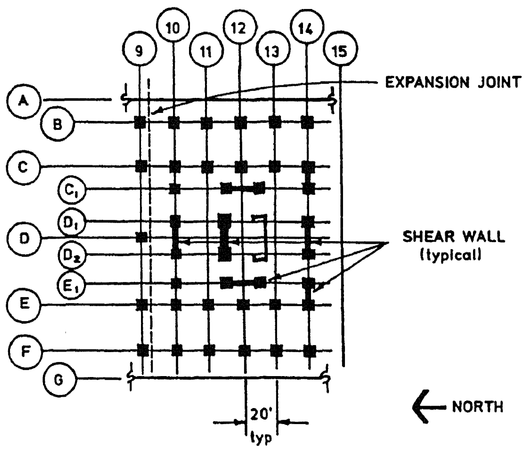


FIGURE 6. NEW SHEAR WALLS AT GARAGE LEVELS