

PERFORMANCE ASSESSMENT OF MULTI STOREY REINFORCED CONCRETE SPECIAL MOMENT RESISTING FRAMES

PULIVARTHI BHARGAVI, SINGAM SUNIL KUMAR, MARUTLA VASEEMA

ASSISTANT PROFESSOR ^{1,2,3}

pbhargaviciv9f@gmail.com, singamsunil444ever@gmail.com, vaseema2019@gmail.com

DEPT OF CIVIL ENGINEERING In Sri Venkateswara Institute of Technology,

N.H 44, Hampapuram, Rappthadu, Anantapuramu, Andhra Pradesh 515722

Abstract: Seismic performance is enhanced in the dual structural system that includes a concrete shear wall and a special moment resisting frame (SMRF) because of the enhanced lateral stiffness and strength. Buildings are far more resistant to seismic activity when their shear wall systems are well-designed. In order to determine the optimal layout of shear walls inside the structural framing system for improved seismic resistance, the seismic performance of several RC moment resistant framed building configurations with varied shear wall arrangements are evaluated. Arranging shear walls in various locations/configurations within the structural frame system allows for a comparison of structural behaviour regarding strength, stiffness, and damping characteristics. In order to assess seismic performance, analytical techniques such as response spectra and nonlinear static pushover are used. The research found that for improved seismic performance, shear walls should be provided symmetrically in the building's outermost moment resistant frames and ideally coupled in mutually perpendicular directions to create a core.

KEY WORDS: SEISMIC PERFORMANCE, SHEAR WALLS, BASE SHEAR, LATERAL DISPLACEMENTS, LATERAL STIFFNESS.

INTRODUCTION

Most individuals don't give much thought to the surface that supports their feet on a regular basis. Many of us take the idea of solid footing as a sure thing. Every day, we rely on the earth as a firm basis for our automobiles, commutes, outdoor activities, and home life. Having said that, the earth may shift, and shifts can be rather severe. Earthquakes pose a significant threat to both human life and property. It presents a one-of-a-kind challenge for engineering design. Most civil engineering projects are subject to high seismic loading.

might undergo structural degradation. When there are a lot of earthquakes, a lot of people die or get hurt. The economy and lives alike are at danger as a result of this catastrophe. The goal of engineering design is to create buildings that can withstand extreme earthquakes and continue to function normally over their service lifetimes with as little damage and casualties as possible. Research on earthquake damage yields priceless details on how real-life buildings fared during seismic tests. This is analogous to doing full-scale earthquake testing on a range of prototype constructions. Every earthquake brings to light the shortcomings of a region's prevailing building and design methods. Features of the design and construction that are based on the actual behaviour of the prototype structure during earthquakes also contribute to its high

qualities. A lot of the damage has been mitigated since structures were built with earthquake resistance in mind. The requirements of the code of practice have been evaluated and modified based on lessons learned from the damages caused by prior earthquakes, which have developed the design and construction to be more earthquake resistant. The efficiency of earthquake resistant measures is shown in several instances. Both natural and artificial factors may cause ground vibrations, which are often known as earthquakes. Earthquakes often occur as a result of movement along a crustal fault. Large landslides, which may occur as a result of earthquakes, or volcanic eruptions are two other natural disasters that might trigger this. Underground explosions or mining operations are examples of man-made earthquakes. Worldwide, around a million earthquakes are detected and reported annually. The vast majority of earthquakes are minor and pose little danger, but sometimes bigger ones may wreak havoc and even kill people. The requirements of the people who will be occupying a building are the primary considerations in its design. Therefore, providing an acceptable interior layout of buildings is one of the most important design needs. After the functional layout is defined, the next step is to create a structural system that, within the constraints of the architectural layout, meets the defined design requirements in the most cost-effective and efficient way feasible. An acceptable failure reserve, sufficient lateral stiffness, and efficient performance throughout the structures' service lives are the crucial structural requirements.

Numerical Example Considered:

The research takes into account numerical examples of moment-resistant RC-framed buildings with six, twelve, twenty-four, and thirty-six stories, with plan dimensions of 30 x 20 metres, bay lengths of 5 metres in both directions, and floor heights of 3 metres.

Figure 1a and Figure 1b show the structural configurations that were taken into account, which show the placement of the shear walls. Table 1 shows that the total length of the shear walls for all models is 40 metres for models 2, 3, and 4, and 80 metres for models 5, 6, 7, and 8. This length is applicable in both directions. Concrete Characteristics: 28500 MPa Modulus of Elasticity, 0.2 Poisson's Ratio, 0.125 m Thickness of Slab, respectively. The masonry has a modulus of 3500 MPa, a Poisson's ratio of 0.2, and a wall thickness of 0.23 m, whereas the reinforcement steel has a modulus of elasticity of 210000 MPa and a Poisson's ratio of 0.3. Shear wall characteristics: the reinforced concrete shear wall has a thickness of 0.23 metres. Buildings are shown as three-dimensional models. We have eight models of six-story, twelve-story, twenty-four-story, and thirty-six-story RC framed buildings ready.

MODELLING AND ANALYSIS OF BUILDING STRUCTURE:

Elements of the frame are represented by beams in the model. The brick infill is represented by a uniformly thick 0.23 mm quadrilateral shell element with in-plane stiffness. It is presumed that the nonlinear features of columns are a plastic P-M-M hinge, whereas those of beams are plastic moment hinges. When it comes to the intended rebar distribution, the plastic hinges are established according to FEMA 356, as well. Elements of the Mid-Pier frame with P-M-M interaction hinge are used to represent the shear walls. In terms of the overall behaviour of the structural systems, the findings of several models are compared. The slab is represented as a stiff

diaphragm that is in one plane. The computer models' load deformation responses were tracked all the way to collapse using the capacity curve. These nonlinear static Buildings with RC frames, masonry infill, and shear walls undergo pushover analysis. For the elastic analysis utilising the response spectrum technique and to conduct pushover analysis, the programme ETABS [CSI, 2004] 8 was used.

A. **MOMENT RESISTING FRAMES**

Buildings designed to withstand earthquakes sometimes use reinforced concrete special moment frames within their seismic force-resisting systems. Moment frames are designed to withstand the flexural, axial, and shearing motions that occur when a structure sways through many displacement cycles caused by intense earthquake ground shaking. This includes beams, columns, and beam-column connections. A frame that can withstand substantial earthquake shaking without significantly weakening or losing rigidity is the product of careful proportioning and attention to detail. When a frame's parts and joints may flexure to withstand forces, we say that the frame is moment-resistant. A moment-resisting frame that does not match the specific detailed requirements for ductile behaviour is called an Ordinary Moment-Resisting Frame (OMRF). This is a moment-resisting frame that has been meticulously designed to exhibit ductile behaviour and meet the standards outlined in IS 4326 or IS 13920. When it comes to responding to stresses caused by earthquakes, not all structural

systems are created equal. Structure, symmetry, mass distribution, and vertical regularity are all important factors to think about. Appreciating the significance of ductility, stiffness, and strength in relation to appropriate reaction is also crucial. There are a plethora of structural possibilities that arise when thinking about systems that resist lateral forces, such as bearing wall systems, moment resistant frames, lateral bracing systems, and the possibility of using IMRF, OMRF, or SMRF when building concrete frame structures that resist moments. While conceptual design begins with determining the optimal framing system and lateral load resisting mechanism, engineers often encounter difficulties when designing structures for field use when deciding on the Response Modification Factor R, a metric for the structure's ductility and over-strength. The base shear, which is dispersed across many storeys, may be determined using this method.

B. **CONFIGURATION**

Buildings' seismic performance is greatly affected by their configuration. In terms of seismic design, the three most crucial factors are building geometry, structural systems, and load pathways. In this part, we will go over a number of topics concerning seismic setup. Aspect Ratio of the Plan A big plan aspect ratio is bad for structures, and so are buildings with enormous projections. In the event of an earthquake, the building's inertia force is more readily applied on the upper stories, due to the higher mass of those areas. Lateral load resisting structures, such as structural walls and columns, are subsequently assigned the inertia force. Distribution of this lateral inertia force to

different lateral load resisting systems according to their lateral load resisting capacity is the recommended method. This is accomplished by ensuring that the floor slabs do not undergo excessive deformation in their own horizontal plane. In this case, the floor slab is acting as a rigid diaphragm, which helps distribute the inertia force to various lateral load resisting systems according to their stiffness. When floor slabs flex in their plane, the inertia force is distributed according to the tributary area. Because of this, members with less capability are overloaded, which in turn causes structures to sustain unnecessary damage. Rigid diaphragm action may not be provided by floor slabs in structures with a high plan aspect ratio (>4).

C. PUSHOVER ANALYSIS

Seismic performance assessment of new and existing buildings is increasingly being done using the static pushover technique. Assuming the design ground motion imposes sufficient seismic stresses on the structural system and its components, the pushover analysis is expected to yield sufficient information. The paper's goals are to (1) provide a concise overview of the foundational ideas behind pushover analysis and (2) evaluate the reliability of pushover predictions. It will also seek to determine when pushover will yield sufficient information and, more importantly, when it will fall short or even mislead. An example of a static non-linear analysis is the pushover test, which subjects a building to constant vertical loads and progressively increasing lateral stresses. Static lateral loads that are equal to earthquake forces are a good approximation. This study would reveal any early failure or weakness

in a structure by plotting the total base shear against top displacement. The collapse load and ductility capability may be determined by doing the study up to failure. Analytical computations of the full structure's lateral inelastic forces vs displacement response are made by monitoring plastic rotation on a building frame. Weak spots in the structure may be identified using this kind of investigation. In such research, the choice to retrofit may be made.

D. PERFORMANCE POINT

The capacity spectrum approach (ATC 40) may be used to measure the degree of building performance by displacing targets. A graphical comparison of the structure's capacity to seismic demand may be achieved using the capacity spectrum approach. The lateral resisting capability is shown by the pushover curve, while the seismic demand is shown by the response spectrum curve. When it comes to a structure's seismic performance, pushover analysis might reveal its weak spots. The ideal building condition as a function of spectral displacement amplitude or roof-top displacement amplitude is often used as the performance metric for pushover analysis. In order to get the results design base shear is used to determine the safety of the building frame at a certain position in relation to base shear. The structure's performance point is where the demand spectrum and capacity spectrum meet. A safe structure is one whose base shear at performance point is higher than its design base shear. Standard IS: 1893:2002 is used for the calculation of the design base shear. The next step, at the performance phase, is to verify the building's reactions using certain acceptable criteria. After obtaining the Performance Point via pushover analysis, it is compared with the goal displacement that was determined.

RESULTS AND DISCUSSION:

The structure is analyzed for the seismic loads and load combinations as per the Indian standards, IS-1893(Part-1)-2002, for Seismic zone = Zone V, Importance factor = 1, Soil type = II, Live load = 3.5KN/m² and designed as per IS-456-2000. Full dead load (self weight) and 50% of live (Imposed) load constitute the seismic weight. The “Seismic Analysis” using “Response Spectrum Method” and “Nonlinear Static Pushover Analysis” are performed on all the thirty two models namely, the eight models of 6 stories, eight models of 12 stories, eight models of 24 stories and eight models of 36. The results

Table 1 Details of numerical models

Model No.	Structural details
1	RC moment resisting frame with full masonry infill without shear walls
2	RC moment resisting frame with replacement of masonry infill by shear walls at all corners with the total length of shear wall as 40m in the plan.
3	RC moment resisting frame with replacement of masonry infill by shear walls symmetrically placed on all sides with the total length of shear wall as 40m in the plan.

of the elastic analysis using “Response Spectrum Method”, namely the lateral displacements in mm ,are presented in figs.2-5. The natural period and the base shear are presented in the Tables 2. The results of the in-elastic analysis using the “Nonlinear Static Pushover Analysis” namely, the displacement ratio ($d_i/d_1 = \text{top displacement of model-i} / \text{top displacement of model-1}$), the base shear ratio ($V_{Bi}/V_{B1} = \text{base shear of model-i} / \text{base shear of model-1}$), the effective damping and effective period at performance point are presented in the Figures 6-9.

4	RC moment resisting frame with replacement of masonry infill by shear walls symmetrically placed in the central core with the total length of shear wall as 40m in the plan.
5	RC moment resisting frame with replacement of masonry infill by shear walls symmetrically placed at all corners and central core with the total length of shear wall as 80m in the plan.
6	RC moment resisting frame with replacement of masonry infill by shear walls symmetrically placed on all sides and central core with the total length of shear wall as 80m in the plan.
7	RC moment resisting frame with replacement of masonry infill by shear walls symmetrically placed on all sides with the total length of shear wall as 80m in the plan.
8	RC moment resisting frame with replacement of masonry infill by shear walls symmetrically placed in the form of a core with the total length of shear wall as 80m in the plan.

Table 2. Results of "Response Spectrum Analysis" for 6, 12, 24 & 36 models

Model No.	Natural Period In, sec			
	6	12	24	36
1.	0.242	0.513	1.08	1.69
2.	0.195	0.446	0.957	1.54
3.	0.182	0.423	0.911	1.49
4.	0.175	0.419	0.923	1.48
5.	0.155	0.378	0.828	1.36
6.	0.151	0.372	0.832	1.37
7.	0.141	0.344	0.744	1.24
8.	0.136	0.342	0.745	1.24
Model No.	Base Shear in kN			
	6	12	24	36
1.	7026	14707	15393	18609
2.	7013	14638	17585	20538

3.	7082	14685	18376	21521
4.	7148	14629	18081	21776
5.	7295	14763	20492	23276
6.	7306	14706	20278	23397
7.	7455	14934	23063	25177
8.	7525	14913	22877	25528

OBSERVATIONS ON THE RESULTS OF ELASTIC ANALYSIS USING "RESPONSE SPECTRUM"

PROCEDURE:

The 6- and 12-story structures exhibit shear behaviour, as seen in the storey displacement graphs (fig. 2–5), due to the fact that their height is either equal to or less than their lateral dimension. The flexural behaviour of 24- and 36-story structures is due to the fact that their height is much bigger than their lateral dimension.

2. In the x-direction, the top lateral displacement for models-3 (side shear wall) and -4 (core + side shear wall) is almost identical; models-5 (core + corner shear wall) and models-6 (core) are similarly shaped.

+ side shear wall) are quite similar, as are models 7-8 (core shear wall) and 7 (side shear

wall). This is true for buildings with 12 or 24 stories. The y-direction shows similar tendencies to the x-direction, although the top displacements are often larger in the y-direction. This is because there is less lateral stiffness in the y-direction as a result of the smaller plan size.

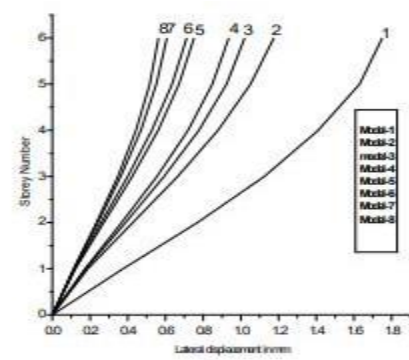
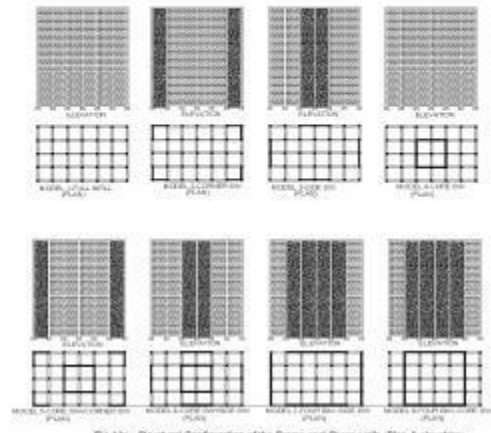
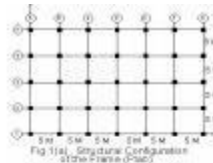


Fig.2 Lateral displacement in x-direction

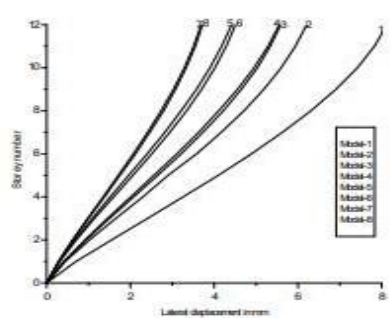


Fig.3 Lateral displacement in x-direction

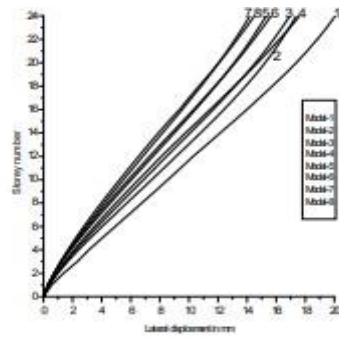


Fig.4 Lateral displacement in x-direction

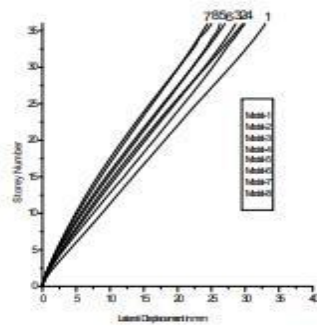


Fig.5 Lateral displacement in x-direction

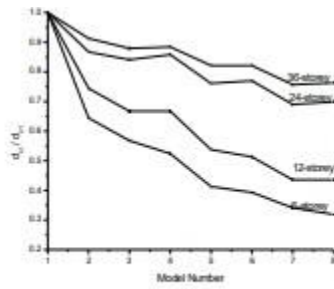


Fig.6 Displacement ratio in x-direction

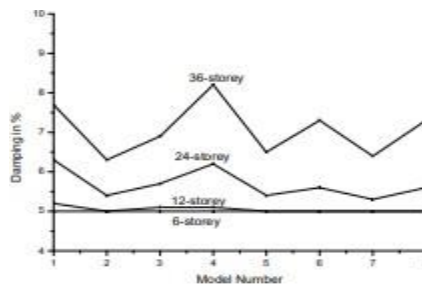


Fig.8 Damping in x-direction

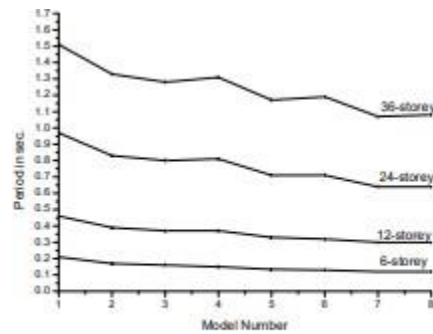


Fig.9 Period in x-direction

1. Out of the four models (1, 2, 3, and 4), model 4 has the smallest top lateral displacement for 6 and 12-story structures, whereas model 3 has the smallest top lateral displacement for 24 and 36-story buildings. To be noticed, model-3 has a larger moment of inertia. Hence, the greater moment of inertia is mainly relevant for higher structures, since they primarily display flexural behaviour. Notably, for a 36-story structure, the top displacement of model-3 is 87% of that of model-1 (without shear wall), but for a 6-story building, it is 58%. 4 Out of the five, six, seven, and eight models, model 8 has the smallest top lateral

displacement in the x-direction for 6-story structures, model 7 has a top lateral displacement that is equivalent to 12 stories and the lowest for 24-and 36-story buildings. Keep in mind that the model-7's moment of inertia is greatest along the y-axis. Due to the preponderance of flexural behaviour in tall buildings, this behaviour suggests that the higher moment of inertia is solely relevant to these structures. It should be mentioned that for a 36-story structure, the top displacement of model-7 is 74% of that of model-1 (without shear wall), but for a 6-story building, it is 35%.

Observations on the results of in-elastic analysis using “Nonlinear Static Pushover Analysis” procedure:

1. The relationship between lateral stiffness and lateral displacement is well-established. Figure 6 suggests that, at performance point, the displacement ratios, d_{xi}/d_{x1} and d_{yi}/d_{y1} , are quite modest for models 7 and 8, suggesting that these models are somewhat stiffer than model-1, which does not have a shear wall. The displacement ratios, d_{xi}/d_{x1} and d_{yi}/d_{y1} , are very modest for models 7 and 8, respectively, at the performance point.

The impact of the shear wall is much larger for shorter structures compared to taller ones,

since the displacement ratios, d_{xi}/d_{x1} and d_{yi}/d_{y1} , are very small for 6-story buildings (about 0.3) and rather big for 36-story buildings (approximately 0.8), respectively. Model 8, with its Four-Bay Core shear wall, has the lowest lateral displacement at the roof level at the performance point when compared to other shear wall frames. The results show that the configuration with the most lateral stiffness and the least amount of roof-level displacement at the performance point is the one in which the outermost frames have shear walls placed symmetrically (models 7 and 8), ideally interconnected in mutually perpendicular directions to form the core (model 8).

Fig. 7 clearly shows that, when it comes to

tall structures, frames with shear walls have a much higher lateral load resistance capability (base shear at performance point) than masonry infill frames. At the performance point, the base shear ratio is much higher for taller structures and significantly closer to 1 for shorter ones. As a result, it's clear that shear walls significantly affect the strength of higher structures. The lateral load resistance capacity (lateral load resistance at performance point) is highest among models 5, 6, 7, and 8 (Four-Bay Core shear wall) among the frames with shear walls. While models 7 and 8 both have similar y-direction lateral load resisting capacities (base shear), model 8 has a slightly higher value. In models 7 and 8, the shear walls are arranged symmetrically in the outermost frames; in model 8, they are ideally joined in a mutually perpendicular manner to create the core, which will result in higher lateral load resistance. From the analysis of the stiffness and strength characteristics, it can be shown that in the Y-direction, there is greater lateral displacement and less lateral load resistance

CONCLUSIONS:

As a rule, shear wall provision has a larger impact on lateral strength and a smaller impact on lateral stiffness in higher structures. In structures with a lower height, the addition of a shear wall has a less impact on lateral strength but a larger one on lateral stiffness. Shear walls have a major impact on the damping properties and performance point period of tall structures. To date, model-8's structural design has shown to be the most effective in terms of stiffness and strength throughout the elastic and nonlinear domains, right up to the point of performance. On the other hand, the model-7 is structurally comparable to the model-8 up to the performance point, with respect to both elastic and nonlinear stiffness and strength. As a result, the structural arrangements of models 7 and 8 enhanced the lateral stiffness and lateral load resistance capability. Both the stiffness and the strength of the structural performance were negatively affected by the frame that did not have shear walls but had masonry infill. For optimal seismic performance,

capacity (base shear) compared to the X-direction. This is due to the fact that the Y-axis has a very small lateral dimension and, by extension, a relatively weak lateral stiffness in the frame.

3. As seen in figure 8, shear walls have a significant impact on the damping characteristics at the performance point, however this is only true for tall structures.

4. The periods of the higher structures are clearly longer. Figure 9 shows that when comparing building models of the same height, shear walls have a much larger impact on taller structures, whereas the durations at the performance point are almost identical for shorter buildings.

Out of all the models, the ones with the shortest durations at the performance point are models 7 and 8. indicates that models 7 and 8 have somewhat greater lateral stiffness, regardless of the building's height.

shear walls should be symmetrically provided in the outermost moment-resisting frames and ideally coupled in mutually perpendicular directions to create the core.

REFERENCES:

1. Dolsek M. (2010) "Development of computing environment for the seismic performance assessment of reinforced concrete frames by using simplified nonlinear models" Bull Earthquake Eng 8:1309–1329
2. Wallace J.W. (2007) "Modelling Issues for Tall Reinforced concrete Core wall Buildings" The Structural Design of Tall and Special Buildings Structures, 16, 615–632.

3. Fahjan Y.M., Kubin J. and Tan M.T. (2010) “ Nonlinear Analysis Methods for Reinforced Concrete Buildings with Shear walls” 14th econference in Earthquake Engineering.

4. Bozdogan K.B.(2011) “A method for lateral static and dynamic analyses of wall-frame buildings using one dimensional finite element” Scientific Research and Essays Vol. 6(3), pp. 616-626, 4

5. Kubin J., Fahjan Y.M. and Tan M. T (2008) “Comparison of practical approaches for modeling shear walls in structural analyses of buildings” , The 14th World Conference on Earthquake Engineering October 12-17, Beijing, China

6. Mohan R., Prabha C. (2011), “Dynamic Analysis of RCC Buildings with Shear Wall” International Journal of Earth Sciences and Engineering ISSN 0974-5904, Volume 04, No 06 SPL,pp 659-662

7. Deierlein, Gregory G., Reinhorn, Andrei M., and Willford, Michael R. (2010). “Nonlinear structural analysis for seismic design,” NEHRP Seismic Design Technical Brief No. 4, produced by the NEHRP Consultants Joint Venture, a partnership of the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering, for the National Institute of Standards and Technology,

Gaithersburg, MD, NIST GCR 10-917-5.

8. CSI (2004) CSI Analysis Reference Manual for SAP2000, ETABS and SAFE, Computers and Structures Inc., Berkeley CA.