# Social and Environmental Benefits of Precast Concrete Technology

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The author, a PCI Medal of Honor Award winner, has, during the last 40 years, designed and constructed hundreds of precast/prestressed concrete structures along the Pacific Rim which have successfully withstood severe earthquakes.

*For the past half century, precast/prestressed concrete construction has been marketed on the basis of savings in materials and labor, improved quality of product and workmanship, and speed in construction. For purely economic reasons, contractors knowledgeable in precast technology have frequently relied on this method of construction with a high degree of success. In recent years, however, precast concrete technology has taken an important new perspective in terms of its impact on social and environmental issues.*

Contractors have long recognized that conventional in situ construction in large cities has resulted in excessive labor costs due to time lost in transporting workers to and from the project site through congested vehicular traffic. This loss of time is further compounded by the accompanying need to transport materials, equipment, tools, and other items to the construction site, all of which add vehicular traffic to an already congested roadway situation.

Due to high land values, construction sites in large cities are relatively small in comparison to the working space of the project. This extremely high development of the land area results in very restricted space for storage of materials and maneuvering of equipment, thus requiring more frequent trips to the site for incremental deliveries of material and equipment as well as the removal of construction debris.

Intense activity at the construction site (due to the nature of conventional in situ works) results in untidiness, dust, noise, air pollution, traffic congestion, and other inconveniences, all of which present constant nuisances to the people living in nearby buildings, as well as aggravations to motorists driving through the area.

In some instances, sophisticated land developers have expressed embarrassment over the untidiness of building sites amidst a multitude of complaints by their neighboring occupants. Frequently, owners are reluctant to plan site visits with their financial investors, although this activity is an essential part of sound business relations, project marketing and community support.

Presently, 50 percent of the world's population of six billion people lives in large cities. By the year 2050, it is estimated that 67 percent will be living in big cities. This trend not only means more construction in large cities but also more congestion and pollution. Government officials are gradually beginning to recognize the growing complaints of their citizenry on traffic congestion and air quality.

In the case of precast concrete construction, prefabrication of structural and architectural concrete products is performed at more accessible sites away from crowded city centers. Wall panels, beams, columns, slabs, stairways, architectural façades, and other components are fabricated under controlled conditions in areas with adequate operational and storage space. Workers, materials, equipment, and other items are easily transported to and from these prefabrication sites.

The precast components are formed with high strength, durable steel and high quality concrete in steel or fiberglass molds, which provide for extensive repetitive and economic re-use. In the early years of the precast concrete industry, timber molds were used which would not have been very durable by today's standards.

When these structural and architectural components are completed, they are temporarily stored and then transported directly to the project site for erection. These finished components make only one trip to the construction site through the congested city traffic. On the other hand, were these components fabricated at the project site, repeated trips to the site during working hours would have been required to transport workers, materials, and equipment as well as the removal of debris, to accomplish the same results.

Furthermore, the precast components can be transported during off-peak hours, such as in the middle of the night, when vehicular traffic is at its lowest volume. Exterior façade units can be pre-painted at the precasting plant to offset the need for exterior gondola or scaffolding and painting at the job site.

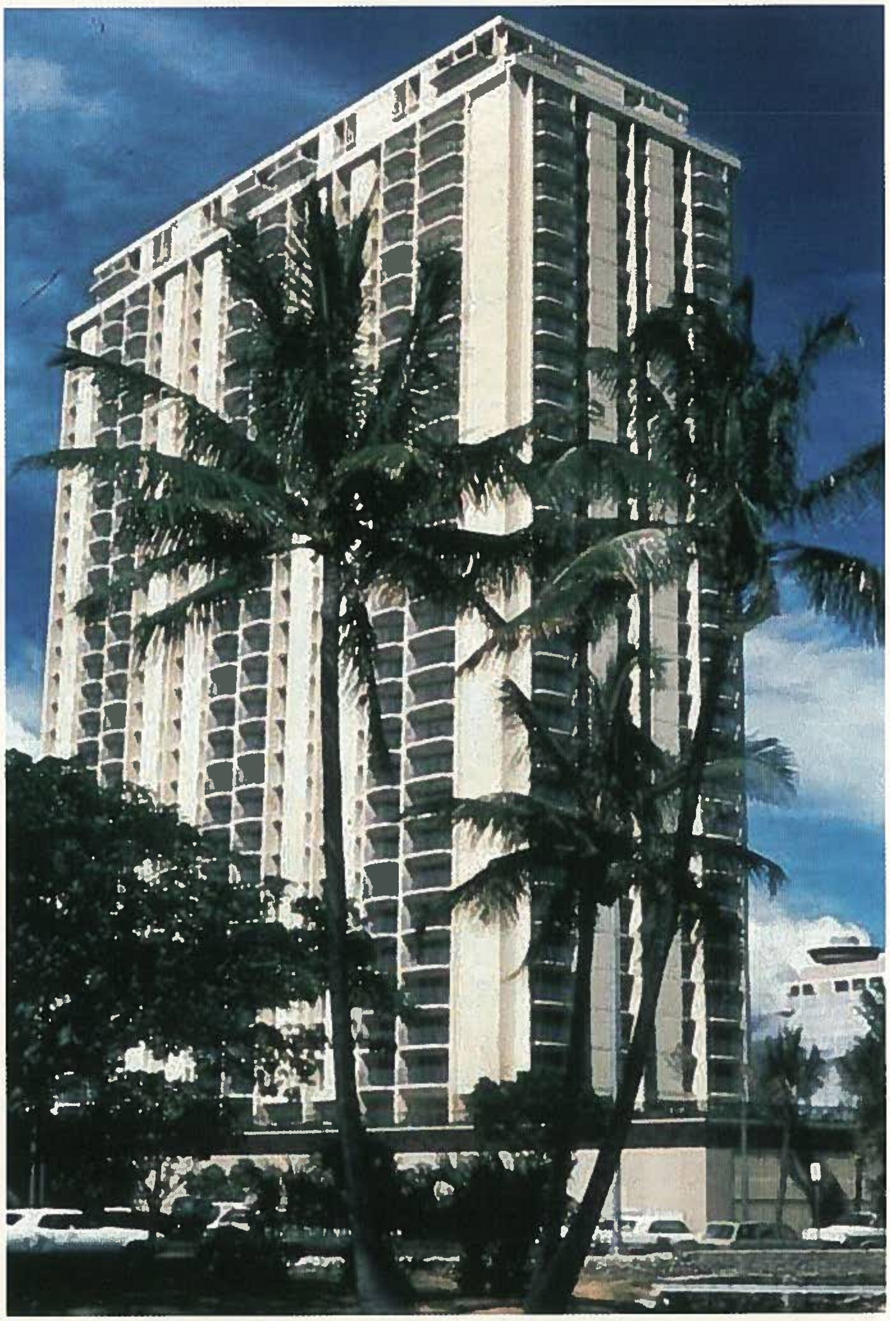


Fig. 1. Ala Moana Apartments, Honolulu, Hawaii (built in 1966). The framing of this 33-story building consists of precast, prestressed concrete floor slabs $3^1/_2$ in. (89 mm) thick, with an in situ composite topping $2^1/_2$ in. (63 mm) thick, for a total slab thickness of 6 in. (152 mm). For the floor loads and spans required, a conventional floor slab would need to have a total thickness of 9 in. (229 mm). Total savings in concrete for the floor slabs alone on this building would be equivalent to a block of concrete 8.34 ft (2.54 m) thick, covering the entire footprint of a typical floor. Not only would this result in considerable savings in material and costs required for the column, beam, bearing wall and foundation support system but with the height restrictions in this area, one extra floor of saleable apartments can be realized within the cumulative void area due to reductions in floor slab thicknesses.

Precast concrete construction technology presents economic opportunities and physical advantages because it allows convenient pretensioning of concrete structural members in the precast manufacturing process. This concept greatly reduces the material and labor requirements for equivalent structural adequacy by other construction methods.

The 33-story Ala Moana Building in Honolulu, Hawaii, has proven the test

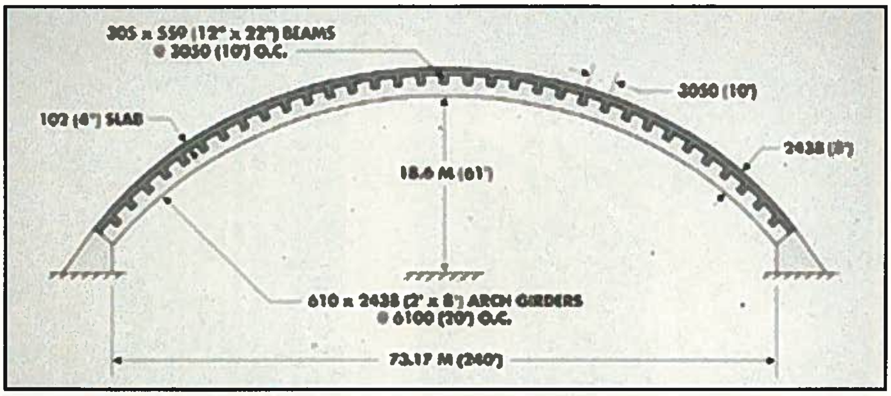



Fig. 2. Typical cross section of an aircraft hangar designed for Seismic Zone 3 and a wind velocity of 155 miles per hour (250 km/hr). The contractor who was awarded the bid for this project requested a value engineering design involving precast concrete construction in order to save costs and increase construction speed.

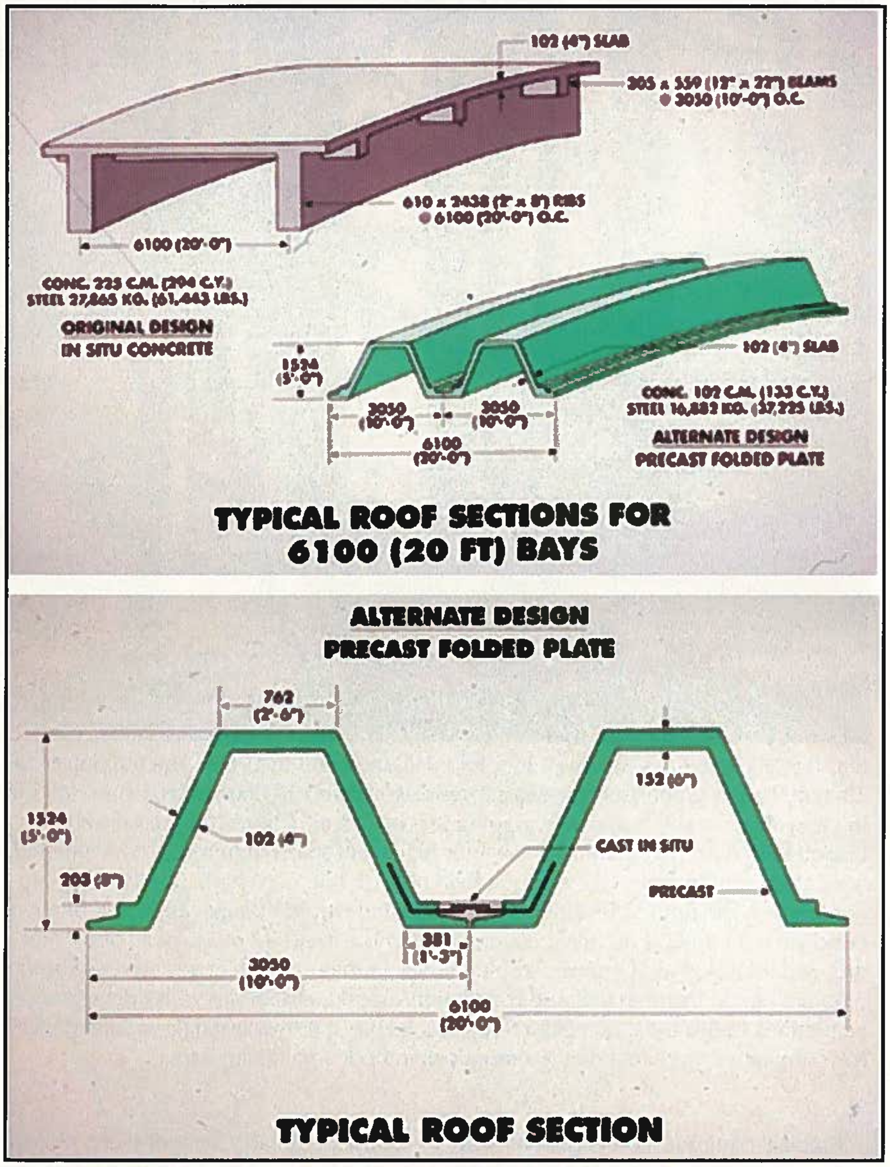



Fig. 3. In the value engineering process, an alternate design utilizing a precast segmental folded plate framing system resulted in substantial savings in materials. For instance, concrete quantities were reduced by 55 percent and reinforcing steel by 40 percent. Formwork costs were virtually eliminated by precasting at ground level with a short, fixed, folded-plate mold capable of casting various incremental sizes.

of time. An all-precast, prestressed concrete building, it was built in 1966 when the precast concrete industry was growing strong (see Fig. 1).

In some instances, the substitution of alternative precast designs for conventional in situ construction has resulted in savings of as much as 55 percent of the concrete quantities and 40 percent of the reinforcing steel requirements (see Figs. 2 through 4).

In the case of typical floor slabs, the combination of precast, pretensioned slab soffits and a composite in situ topping can result in savings over conventional in situ construction of about 28 percent in concrete quantities and about 45 percent in steel requirements (see Fig. 5a).

In the case of conventional in situ beams, savings of 60 percent in concrete quantities and 65 percent in steel requirements can be realized by the use of precast, prestressed concrete technology (see Fig. 5b).

The above savings vary according to span lengths and loading requirements. In general, longer spans and higher live loads result in larger material savings when precast/prestressed components are employed. Other examples of material savings in actual high-rise buildings constructed are shown in Figs. 6 and 7.

This reduction in the use of materials such as cement, stone, sand, steel, timber, formwork, and other ingredients results not only in a significant reduction in energy employed in the mining, manufacturing and processing of these materials but also a reduction in the air pollution accompanying the use of this energy. For instance, in the manufacture of one ton of cement, approximately one ton of $CO_2$ is emitted into the atmosphere (see Ref. 6).

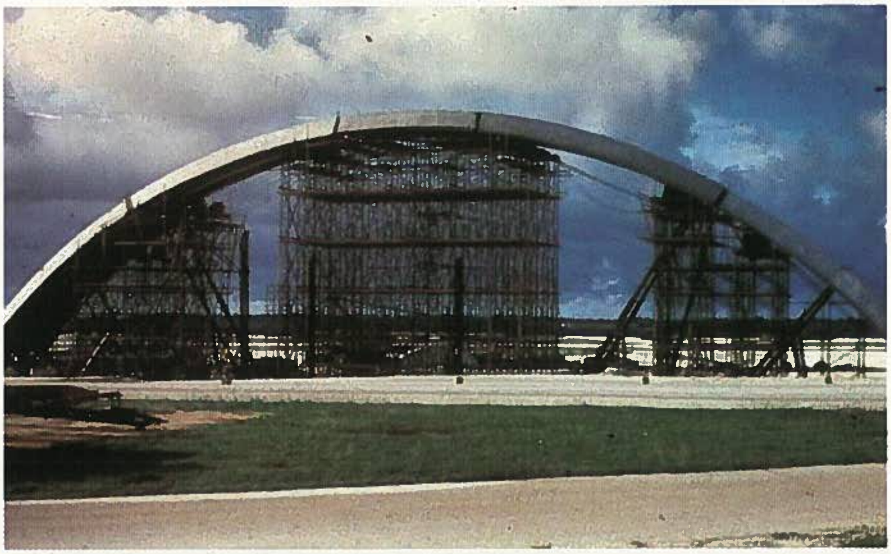
In addition, savings in construction materials will result not only in savings of our natural resources from which these materials are derived, but also savings in the energy resources such as fossil fuels, nuclear and hydroelectric facilities, all used in the mining, manufacture, transportation and installation of construction materials. The need for timber, largely consumable in the conventional in situ construction process for temporary bracing, shuttering, forming, dunnage, and other devices, will be reduced substantially and thus contribute to the preservation of our forests and wildlife.

Using less construction materials will lessen building dead loads, reduce earthquake forces impacting the structures and, thus, save structural framing and foundation support materials as well as costs. Material reductions will also result in less traffic impact on the highways during the construction process, thus reducing highway maintenance costs and the associated materials and energy required for repairs. Road repairs not only expend more energy but also cause more traffic congestion, air pollution and social frustration.

Recent international concerns over the subject of greenhouse gases and consequent earth warming have been seriously discussed at the Kobe Protocol in Japan and the United Nations Congress in Shanghai, China. At these events, world-renowned scientists have stressed the dangers of environmental pollution and have warned of the imminent catastrophic impact of weather changes due to greenhouse gases causing the melting of polar ice caps, rising sea levels, atmospheric storms, floods, droughts and other adverse consequences. Many world leaders are alarmed by these dire predictions and, today, concerted efforts are being discussed to resist this serious deterioration of the environment on an international scale.

While these environmental theories may be controversial to some, precast concrete construction, nevertheless, will definitely result in less greenhouse gases than in the case of conventional in situ construction and will provide sufficient economic advantages to serve as an incentive for wider use. Although many other basic activities in mining, agriculture, manufacturing, transportation and the consumption of goods impose a substantial impact on the state of our environment, the construction segment of the world economy can play an important role in the mitigation of environmental deterioration.

This process can begin with an awareness of our fragile ecosystem and the need to utilize already avail-



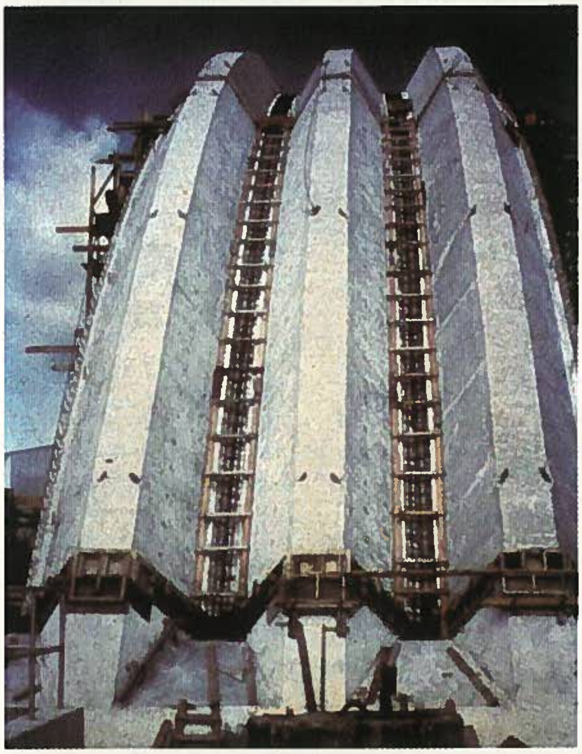


Fig. 4. This aircraft hangar was completed on schedule at a considerable cost savings. Over the years, this structure has successfully withstood several severe hurricanes of wind velocities exceeding 155 miles per hour (250 km/hr) and seismic occurrences of magnitudes as high as 8.1 on the Richter Scale without damage.

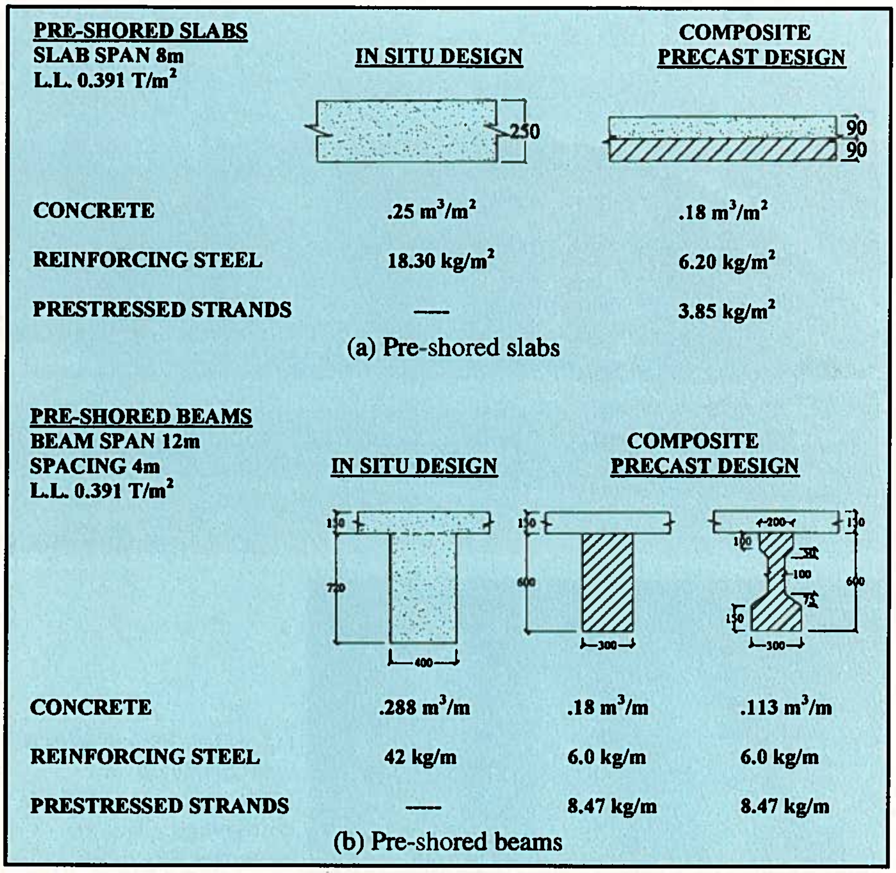



Fig. 5. Materials savings using precast/prestressed concrete.

able existing engineering knowledge and construction technology as well as the experience to develop more economical means of safe construction practices that consume less natural resources, energy and labor.

The skillful and efficient use of construction materials will result in lighter, stronger, more earthquake-resistant structures. It is bad enough that catastrophic earthquakes cause building collapses, heavy loss of life and multiple injuries. However, it also puts an added burden on our ecosystem in terms of further depletion of natural resources as well as the addition of greenhouse gases generated in rescue operations, demolition, clean-up of debris and the reconstruction that follows.

In the last 40 years, precast concrete structures of both low- and high-rise buildings have proven their capacity to withstand major earthquake occurrences in Manila, Philippines; Kobe, Japan; Guam (United States); and other regions throughout the world with minimal or no damage.

In Tokyo, Japan, where the world's severest seismic design criteria exist, nearly 40 precast concrete high-rise buildings ranging from 35 to 43 stories have been constructed. Currently, plans are in progress to build a 54-story precast concrete building in the city. In Dalian City, China, a 43-story high-rise office building designed for seismic activity was recently completed (see Fig. 6).

Presently, a 39-story precast, prestressed concrete building, designed for Seismic Zone 4, is nearing completion in San Francisco, California (see Fig. 7).

In recent years, major advances have been made in the development of reliable mechanical connection devices, especially the so-called "fail safe" connections for precast members which provide monolithic and full continuity in structures. In addition to extensive engineering research and laboratory testing, many precast concrete structures situated on the Pacific Rim have successfully withstood very severe earthquakes. As a result of these experiences, a large body of knowledge has been gathered on the behavior and design of precast/prestressed concrete structures in seismic areas.

For background information on precast concrete technology and its applications, see References 1 through 7.

Today, some world leaders are aware of the social inequalities in overcrowded cities. For example, because of severe labor shortages, large numbers of construction workers are frequently imported from foreign countries at lower wages. At the same time, with social pressures mounting, there has been a progressive tightening of the supply of foreign workers and an increasing demand for higher quality construction. As a result, there is a trend towards the adoption of more labor-efficient designs and the growing use of prefabricated products and pre-assembled units in construction.

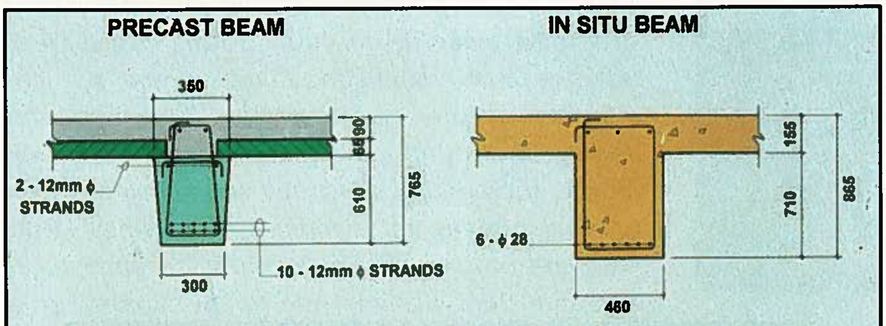
New laws have been enacted requiring that all building permit applications meet certain minimum buildability scores that are based on "principles of standardization, simplicity and single integrated elements to achieve a buildable design." Standardized factory cast concrete components erected on site with simply executed connection details in repetitive grid layouts are graded to significantly higher buildability scores.

## CONCLUDING REMARKS

In the last 50 years, a tremendous amount of knowledge has been accumulated from research, design and construction of precast/prestressed concrete structures. Over the years these structures have performed very well and have shown excellent durability even when subjected to severe earthquakes. With advancements in the quality of materials, workmanship and new technologies, precast concrete has become a very modern, high tech industry.

Until now, the success of the precast concrete industry has been based on economic advantages, namely, a high quality product and speed of construction. Today, however, there is an additional motive for using precast construction. With heightened awareness of traffic congestion, environmental pollution, natural resource depletion

Fig. 6. Dalian Xiwang Building, Dalian City, China. The table below shows substantial savings in concrete and steel quantities by using precast/prestressed concrete technology. This building is located in a high seismic zone and, therefore, savings in materials will result in lower building dead weight and subsequently lower shear forces due to seismic loads.




| | PRECAST BEAM 300 x 610 | IN SITU BEAM 460 x 710 |
|---|---|---|
| REINFORCING STEEL (kg/M) | 11.4 | 42 |
| PRESTRESSING STRANDS (kg/M) | 9.5 | |
| CONCRETE ($M^3/M$) | 0.20 | 0.33 |

DALIAN XIWANG BUILDING

Fig. 7. 39-story 680 Mission Apartment Building, San Francisco, California. Photograph shows building at 40th roof level on June 5, 2001. Photo Courtesy: Charles Pankow Builders, Ltd.

and accompanying social problems, precast concrete has become a very attractive alternative to in situ construction methods, especially in large congested urban areas.

Many local, state and world leaders are gradually becoming aware of the profound environmental and economic issues emanating from rebuilding the urban infrastructure. However, these same leaders need to know the advantages and mitigating factors that precast concrete can play in overcoming these problems. This promotional effort needs to be intensified on all fronts.

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