The Future of Prestressed Concrete

By BEN C. GERWICK, JR.

Presented to the 25th Annual Convention of the Structural Engineers Association of California on October 13, 1956 at Reno, Nevada

When the Chairman of your Technical Program Committee, Mr. Leonard Hollister, asked me to make a presentation on prestressed concrete at this convention I was naturally very pleased and highly honored. A talk on prestressed concrete for 30-45 minutes would not be difficult.

However, when he subsequently asked that I point this presentation along the theme of this convention, "The Next Twenty-five Years in Structural Engineering," by taking a look at the next twenty-five years of prestressed concrete, I began to realize the magnitude of the task before me.

The progress made by prestressed concrete has been quite rapid. Its increasing use during the last three years, which is the period of its greatest growth, has been phenomenal. It will indeed be a most satisfying experience if the next twenty-five years in prestressed concrete are as progressive, interesting and stimulating as the last three years have been. It is truly an exciting material with unlimited possibilities for the future.

Whatever I say about the next twenty-five years of prestressed concrete I feel that the facts of 1981 will perhaps prove me to be a short-sighted prophet. However, I will attempt to comply with Mr. Hollister's request by looking as far forward as present knowledge permits.

In order to better understand the part which prestressed concrete will play in our future work, let me review some of the reasons and forces which will be the cause of its continued growth.

THE FOUNDATIONS FOR ANTICIPATED GROWTH OF PRESTRESSED CONCRETE

Actually, the development and application of linear prestressed concrete in the United States dates only from 1950. From one plant and one bridge in 1950, we now have throughout the United States close to 150 prestressed concrete plants. Prestressed concrete foundations and structures are beyond count. Most of this growth and application, as I mentioned, has taken place in the last three years.

The greatest period of growth of any industry will, of course, normally take place during the early stages of its development. Measured in terms of years, as compared to structural steel, reinforced concrete and timber, prestressed concrete is still in the early development stage. If we project this tremendous early growth over the next twenty-five years it becomes evident that prestressed concrete is destined to become a major structural material in building toward the fabulous future which business economists, labor leaders and politicians have predicted for us.

As engineers, we accept and use materials for one or both of two reasons — the material is either a better product structurally for a particular job, or it is more economical. In our economic system any manufacturing industry must stand or fall on meeting either or both of the above criteria. Based upon proven experience throughout the country prestressed concrete will, when properly used, meet these criteria. Exactly how and to what extent I will cover later on.

However. there are certain forces, economic and sociological, which we must consider if we are to gain the proper perspective of the future of the prestressed concrete industry and the part it will play in the construction industry.

The key to the goals of 1980 which have been established for us by planners and visionaries is the increased productivity of the individual worker. If we are to have more goods, both as individuals and as a nation, then we must be able to produce more as individuals. However, in your thinking and planning for the future do not overlook the fact that, while we must have increased productivity, labor and business is thinking and planning for the 35-hour, then the 30-hour week.

Therefore, the challenge which we, as engineers, must meet in the future is this: We must not only turn out more work than we are doing today, in 12% to 25% less time, but we must design projects which can be constructed with a corresponding savings in time. Such demands on our abilities must be satisfied if we are to keep pace with the great changes taking place in our country today. The course before us is dictated by necessity, not by choice.

We therefore add a new criteria for prestressed concrete — and for any material — to those of structural and economic requirements — that of time. Although the factor of time is interwoven with economics it should be considered separately in many instances. So, we must learn to do more and build more with better materials — and in less time — than we have today. There have been many notable developments in building technology in recent years which have contributed toward that end. Curtain walls, precast thin shells, lift-slabs for roof and floor, slipforms, precast panels and many other innovations indicate the trend to structures with a maximum of standard time saving products and techniques. It is true, as has been recently said, that in prefabrication we have the beginnings of the industrialization of the construction industry.

In prestressed concrete we have an extension to this trend of prefabrication. Whether the project be a bridge, building, marine project or piling, the prefabrication advantages offered by precast prestressed concrete are these: A standard product of great structural strength, of known and tested quality, manufactured to exact tolerances under close supervision for quick and efficient erection. While these advantages will always exist the economy of prestressed concrete will be determined only upon an analysis of the problem and the requirements for the particular project in question.

The prestressed concrete industry throughout the country is attempting to give you standard sections for your projects. We want you to be able to go to a catalogue of prestressed concrete products, pick out a section or sections for your project in the same manner as you do steel members, check it out and include it in your design by number, the same as you do steel.

As many of you know, we recently issued catalogues on prestressed concrete piles and building members. It is gratifying to report that our standard pile designs have been specified on numerous projects from the deep South to the West Coast, Alaska and the Philippines. Three recent local buildings have been designed using the standard sections out of our catalogue. Except in special cases there is no reason why you should have to design prestressed concrete members. As a manufactured product it is up to the prestressed concrete industry to provide you with standard designs and data for your consideration and use. Such standardization will lead to greater economy in your design costs and, from the manufacturing point of view, production costs.

Remember too, that precast prestressed concrete products will effect a savings in construction time. Instead of construction progressing chronologically, the use of precast prestressed concrete, as well as other prefabricated units, will permit several operations to be conducted simultaneously with a subsequent tying together of such units at the site.

In prefabrication of structural elements at centralized plants it is possible to increase the productivity of the individual to a considerable degree. This can be accomplished by factory line production methods with a maximum utilization of labor and time saving devices. For work which must be done at the site the answer has become mechanization. The pattern of the future is therefore established — prefabrication and / or mechanization wherever possible. It is only by an application of one or both principles to our jobs that we can meet the challenge of turning out more work in less time.

Because of this necessary trend to prefabrication in the engineering and construction industry and the ever constant search for better materials, I believe that the use application of prestressed concrete during the next twenty-five years is almost beyond prediction. I have no doubt that the prestressed concrete industry, composed of many centrally located plants, will become one of the giant industries serving the engineering and contracting professions. And, I predict that this will happen before the 50th anniversary of this Association.

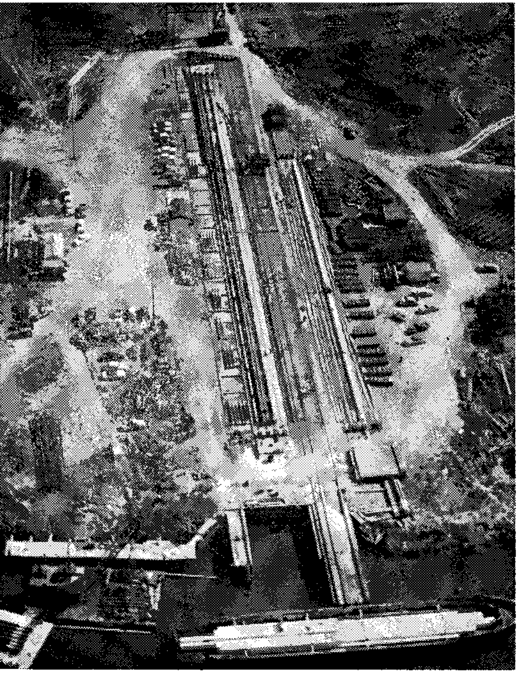
TYPES OF PRESTRESSED CONCRETE

As you know, there are two types of linear prestressed concrete; in pretensioned prestressed concrete the strands are tensioned prior to pouring of the concrete with the prestress transferred to the concrete by bond. Post-tensioned prestressed concrete may be either the bonded or unbonded type, normally the former, and it is stressed after the concrete has been poured and cured.

Generally speaking the pretensioned concrete will be more economical than the post-tensioned type, as is proven by the unmistakable trend to this type of fabrication. Though capital investment for a pretensioned concrete operation is much higher than for a post-tensioned concrete operation, the cost per unit produced is usually lower. Pretensioned prestressed concrete is not a "shoestring" operation as many have found out the hard way.

A pretensioned member will generally be of more uniform quality. The reason for this is the same as applies to any industry — factory line production of a standard product at a centrally operated plant with close supervision of quality of materials and workmanship. However, precast post-tensioned members, produced at a central plant, have been economically competitive in many instances.

Today, pretensioned concrete products are always precast in a centrally operated plant while post-tensioned products may be either



Aerial photo of Ben C. Gerwick, Inc., Petaluma plant. Barge load of 20" square pretensioned piles in foreground shipped 350 miles up Pacific Coast for bridge project. Bed on left of track is 500' long; one on right is 340' long. Another 400' long bed has just been added.

precast or cast-in-place and then post-tensioned. Pretensioning of cast-in-place concrete, in the future, is quite probable on certain types of projects. Before I analyze the present uses and possible future applications of prestressed concrete let me discuss briefly the two basic materials of prestressed concrete — concrete and steel.

MATERIALS FOR PRESTRESSED CONCRETE

The basis of prestressed concrete is the proper use of the best qualities of each material — compressive strength of concrete and tensile strength of steel. While basically the contents are the same for reinforced concrete, prestressed concrete is an entirely different material in properties and characteristics and should always be considered as such and not as a refinement of reinforced concrete.

Today we use 7 or 8 sack mix concrete, either a Type II, or a cement which meets Type II specifications, in our pretensioned concrete work. Combined with good aggregate and steam curing we obtain concrete strengths of 4000 to 5000 psi in 24 to 36 hours depending on size of members, 6500 to 7000 psi in 28 days. This is normal for pretensioned concrete.

The steel we use is a 7-wire high strength uncoated stress relieved strand made specifically for pretensioned concrete work. The ultimate strength of this 7-wire strand is guaranteed 250,000 psi. The strands are tensioned to 175,000 psi, or 70% of ultimate, with a design load of 140,000 to 150,000 psi. By combining these great strengths of concrete and steel under centrally controlled conditions, the result is a product of high structural strength. It is quite likely that during the next 25 years cement will be improved so that even greater strengths can be obtained. Too, it is possible that strand strength will be increased with the same resulting effect — greater strength per strand and per member or the same strength with less strands.

At present the industry primarily uses a ⅜" dia. strand, but 7/16" is being increasingly used in various parts of the country. In California ⅜" has been used mostly, though I feel that a change to 7/16" is warranted in the near future. ½" strand is under test and is being used on some projects.

To properly evaluate the present and future uses of prestressed concrete it would be advisable, I feel, to speak on their specific application in bridges, buildings, marine projects and piling.

BRIDGES

It is probable that in dollar volume more prestressed concrete has been used in bridges than in any other type of structure.

From the first bridge in the United States in 1950 through 1952, prestressed concrete was often chosen either because of shortage of steel or because of a desire to try this new material. Since then it has generally been chosen because of its merits structurally and economically. From 30-ft. to 300-ft. spans, prestressed concrete has competed, and often won, against steel designs in all parts of the world. The most notable example is the well publicized Lake Pontchartrain Bridge in New Orleans, 24 miles long, which was bid about 20% below a steel design and completed four months ahead of schedule.

In California the following table is indicative of the growth of the use of prestressed concrete for bridges. It is quite definite that the number and tonnage of bridges in 1957 will be greater than is shown when the new Federal Highway program projects have been included.

Year	Number of Bridges	Total C.Y. Concrete	Total Weight Tons
1954	3	6,625	13,248
1955	8	3,489	6,978
1956	43	10,764	21,528
1957	18	14,845	29,690

A very important development in the use of prestressed concrete by the State of California is the publication of standard designs for precast prestressed flat slabs from 20-ft. to 50-ft. and channel sections from 30-ft. to 60-ft. The use of such standard designs will not only shorten the design time of such structures, but will enable manufacturers to amortize their form costs over a number of jobs rather than for each job, thereby leading to lower costs per unit. In addition to their use by the Division of Highways, these standard designs have been issued to all county Road Commissioners in California, and will be of great help to them in their county bridge programs.

It is hoped that the Division of Highways will standardize sections for spans from 60-ft. to 120-ft. in the near future. Sections for such spans will probably include I, T and hollow box girders for the different situations which may be encountered.

For shorter spans our studies indicate economic advantages in flat solid slabs. Without hollow cores to place or channels to form, labor costs per unit are low. The use of flat solid slabs is controlled to a great extent by span length and distance of shipment. Their use will generally vary inversely with the length of span and shipment.

In a recent State Highway bridge project in which these flat slabs were used, there were 36 — 23′ x 5′ 10″ x 10″ units. All of them, totalling close to 5000 sq. ft., were set in one day. Trucks were using the bridge the next day, immediately after the units were transversely post-tensioned.

For long span girders and under certain loading conditions it is necessary to have the c. g. of the steel in a parabolic path, rather than straight. Up until recently it has been necessary to use the post-tensioning method of prestressing to obtain this curve. This, of course, added to the cost of the member as each one had to be tensioned individually.

The industry has recently overcome this advantage of the post-tensioned method by manufacturing bridge units with deflected or "harped" pretensioned strands with the c. g. for the steel following a parabolic path. This is an extremely important technical development toward the more economical manufacture of units which require a parabolic curve. This method of manufacture will permit better control of the tensioned elements with no friction loss or grouting problems common to post-tensioned design.

Besides the numerous prestressed concrete projects to be undertaken in the future by the California Division of Highways are two projects of considerable magnitude. The Southern Crossing of San Francisco Bay is specifically designed in pretensioned concrete. As large as this project will be, it will be dwarfed by the scope of the projected Rapid Transit System for the Bay Area. Tentative plans call for competing designs in steel and pretensioned prestressed concrete.

In prestressed concrete bridge construction the trend for the future seems to be to longer spans. We have actively studied 150-ft. spans for a railroad project and 300-ft. precast prestressed girders for an overwater highway bridge project. I have recently read of a study made in France for a 1000-ft. cast-in-place prestressed suspension span. This indicates practically no limit for cast-in-place structures.

A precast, though not wholly prestressed project which we recently completed for the Sacramento Northern-Western Pacific Railroad at Yuba City-Marysville, aptly demonstrates the time saving advantages of prefabrication. Here we designed and constructed a 1500-ft. bridge and an 80-ft. overcrossing on 40-ft. spans in about four months time. Units used were precast and prestressed concrete piles and precast concrete girders.

Most of my comments have been on highway bridges where the greatest application of prestressed concrete to date has taken place. This development will continue at a greatly accelerated rate under the impact of the recently approved Federal Highway bill. I have no doubt that prestressed concrete girders will eventually replace structural steel as the major structural material for spans up to around 100-ft. The reasons why this will happen are quite clear — prestressed concrete is available, it is economical and it is structurally equal to steel with less maintenance problems.

However, highway bridges are but one phase of the bridge field. Of great importance also are railroad bridges and trestles. Committees of the Association of American Railroads have done considerable research on the matter of prestressed concrete railroad bridges, as well as prestressed piles, building members, etc., and have approved the use of prestressed concrete in principle, with economics to be the general deciding factor in its use. All indications point to a shift from steel to precast and prestressed concrete as the basic material for railroad bridges with prestressed concrete also competing with timber trestles in many instances.

We feel that the pattern for the future of prestressed concrete bridge construction — highway and railroad — has been established. Growth will be due to availability and economic and structural competitiveness with a trend to standard sections and longer and heavier spans.

I believe this is the proper place to recognize the leader in the practical application of prestressed concrete in the State of California, the Bridge Department of the Division of Highways under Mr. F. W. Panhorst, and his two Assistants, Mr. A. L. Elliott and Mr. I. O. Jahlstrom. They have contributed immeasurably to the development and use of precast prestressed concrete piles and bridge girders in the West through their early and continuing interest in the subject.

BUILDINGS

To date the most efficient and common use of prestressed concrete in buildings has been in low level structures such as warehouses, commercial and industrial buildings, schools, etc.

Products which have been used include beams, girders, purlins, columns, roof and floor channel, and double-T sections. The majority of such items used have been of the pretensioned variety due to their greater economy than post-tensioned products.

Many all prestressed concrete structures have been built in Florida, which is perhaps the leading State in the Union in the use of prestressed concrete for buildings. Here on the West Coast the use of such products for buildings has been greatest in San Diego, Los Angeles, and in the Tacoma-Seattle area. In Northern California, prestressed concrete to date has been limited to a few roof structures and girders.

This lag in the use of prestressed concrete for buildings in this area is quite unusual since one of the areas in the U. S. in which there are two active competing prestressing plants is in Northern California. Elsewhere on the West Coast and in most other locations only one plant exists. However, I'm quite sure that such a situation will change soon. Many Northern California engineers have indicated their intentions of designing prestressed concrete structures in the immediate future, and some have them on the drawing boards now.

In speaking of prestressed concrete building structures I might point out that the preceding comments pertaining to a lack of use of prestressed concrete in Northern California does not apply to the field of prestressed lift slabs.

The California Division of Architecture, under Mr. Anson Boyd and his Supervising Engineers, Mr. C. M. Herd, Mr. C. Peterson and Mr. Alan Brownfield, has been a leader in this application and has several lift slab structures completed, utilizing prestressing forces in two directions. This is the most accepted method of prestressed lift slab construction and in some cases may prove to be desirable for other types of prestressed units. The Division is quite aware of the potentialities of prestressed concrete and, we are told, will have no hesitancy about using precast prestressed products whenever their use appears feasible. I believe they have two or three such projects under design now.

While there will be unusual and novel applications of prestressed concrete in buildings during the coming years, the main use for the future appears to be the same as for the present — low level structures with a maximum of duplication of members.

There are two possibilities in the use of precast prestressed building members. One is the all concrete structure utilizing precast or prestressed colmuns, prestressed beams, and prestressed channel or double-T roof sections. We believe channels will be used more and more in the future instead of double-T's because of better camber control and edge load transfer. Here the ideal and most competitive range is in bays from 30′ to 60′. In this range the all precast prestressed units fabricated at a plant and fastened together at the site will offer certain advantages.

In addition to the all concrete structure is the possible use of pretensioned beams and precast columns as the framework for a structure. This then permits the use of various other types of cover, such as sheathing, decking, etc., spanning between beams. Such a design would be in competition with the normal steel framework which is used so commonly. Fire resistance with prestressed concrete girders and wood sheathing would be better than with steel and wood sheathing.

We believe this latter application will be a definite trend in the future, largely because of the number of such structures as opposed to the limited number of all concrete buildings which are erected. Based on present experiences in various parts of the country, it appears that the prestressed concrete industry will be able to compete, economically and structurally, with such steel frame designs in many instances.

As I mentioned earlier, there will be unusual and novel applications of prestressed concrete in the building field in the future. For example, there is currently in the planning stage a 16 story building for Northern California which utilizes precast prestressed elements spanning 60 ft. Prestressed arches are definitely feasible. With proper design and technique, units can be prestressed on curves and angles as well as in straight lines. This applies both to pretensioned and post-tensioned members.

While the unusual and novel have, in many fields of endeavor, become the commonplace, our crystal ball for the future shows the volume use of prestressed concrete building members to be, as indicated, in low level structures which permit plant manufacture of standard units of high quality, in volume, for quick and efficient erection at the site.

MARINE PROJECTS

Wherever forming over water can be eliminated by the use of precast concrete elements, a considerable savings in time and money can be achieved. While the use of prestressed concrete elements for marine projects is merely an extension of an old idea to a new material, there are many advantages in the use of prestressed concrete over regular precast units.

To begin with prestressed concrete is a crack free material which, of course, is extremely important in any structure over water. Prestressed concrete will permit wider bent spacings without the large increase in weight and size normal to longer spans in regular precast concrete. Prestressed units will be easier to handle because of their greater inherent strength and will provide a stronger structure.

We are now working on a small marine project which is completely prestressed — piles, caps, stringers and flat slab deck units. The only cast-in-place concrete will be for connections. Such structures will become increasingly common in the future with a trend to the largest units which can be economically handled by available equipment.

Today individual units for marine projects, such as caps, stringers, and deck units, are prefabricated at a plant and assembled at the site. In the near future such units will be assembled at a plant in large sections comprising perhaps 2, 3, or 4 bents, barged to the site, set on previously driven piles and necessary connections made. Here the possibility exists of setting large flat slabs directly onto piles thereby eliminating caps and stringers. This would be very similar to the lift slab technique for buildings. Wherever water can be used as a means of transporting precast and prestressed units, the only limitation on size and shape will be the equipment available for transporting and handling the units.

Under marine projects we must also consider as a possible future field for prestressed concrete, off-shore drilling and oil storage platforms. Prestressed concrete has been successfully used on several such structures on the Gulf Coast. Its use on similar projects off California coasts is now under consideration.

Prestressed concrete development for marine projects, such as piers, wharves, platforms, etc., will, in all probability, parallel that of bridge members — larger units in standard sections. Standard designs for caps, connections and flat slab deck units are now under design study by our Engineering Department and will be published in the future.

PILES

The structural strength which is given to a member by prestressing is nowhere more apparent than in pretensioned concrete piles.

Based upon our experience and official tests, pretensioned concrete piles have been proven to be an entirely new type of pile — just as prestressed concrete is a new material.

While it has the outward appearance of a precast concrete pile, the handling, driving and strength characteristics of this pile are closer to those of a steel H-pile. Without question, it is the finest concrete pile available today and equal to steel H-piles under many conditions.

At Eureka, California, on a project for the State Division of Highways, we drove and pulled a 20″ square pretensioned concrete test pile five times with no apparent damage, driving to 100 tons indicated bearing each time.

At San Francisco, on a project for the State Harbor Board, we drove 140 20″ octagonal pretensioned piles, 132 ft. long, through 30 ft. of riprap with no apparent damage.

At Long Beach on a test project for the Port of Long Beach and the U. S. Naval Research and Evaluation Laboratory, a 14″ octagonal pretensioned pile was driven in 30 ft. of water intermittently to a final penetration of 398 blows to the inch with no damage whatsoever reported by the diver. An identical 14″ pile was driven continuously to 92 blows to the inch with no damage reported by the diver. In the same test 18″ square standard precast piles were driven to a maximum of 140 blows to the

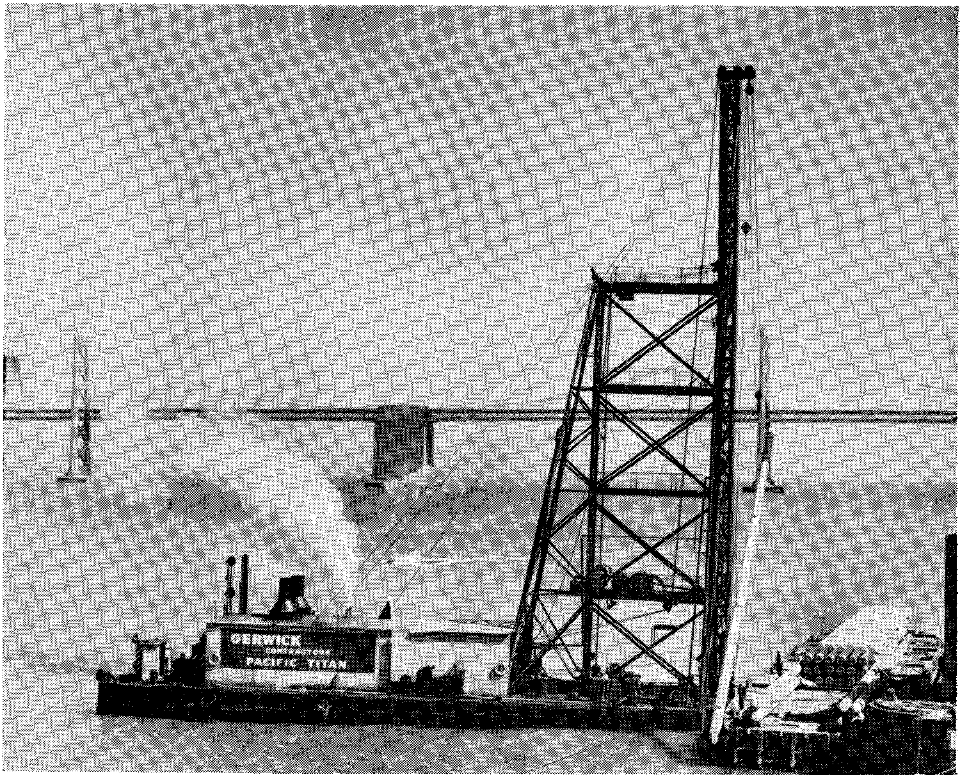


FIG. 48A. Lifting 132′ long 20″ octagonal pretensioned pile off barge, for Pier 15-17 project, San Francisco (April, 1956). Over 2,000 pretensioned piles used in this project, both 14″ octagonal and 20″ octagonal.

inch but with major structural damage.

At Richmond, California, 16″ octagonal pretensioned concrete piles are being used in lieu of 12″ BP 53# steel H-piles (with a 24″ concrete shell) to drive through a dense layer of sand gravel. Results are excellent — the savings in money was considerable.

These factual cases are rather conclusive. The question is, therefore, how can these facts be translated into usable data. These are the conclusions which we have reached, based upon use, study and analysis.

1. Pretensioned concrete piles have been, and can be, used in lieu of steel H-piles in many instances. Our study indicates a 14″ octagonal to be equivalent to a 12″ BP 53#, a 16″ octagonal equivalent to a 14″ BP 73#, and 20″ octagonal equals a 14″ BP 102#. For penetration into rock, a steel H stub has been placed in the tip of the pile in some projects, thereby gaining the structural advantages of both piles.

2. Where concrete piles are required in marine construction, there is no adequate substitute for a pretensioned pile. The crack-free, high bending strength and durability against erosion and corrosion of these piles cannot be equaled in any other type of pile.

3. Because of the great strength of pretensioned concrete piles, it is possible to reduce the section substantially as compared to regular precast piles and still have a pile which is structurally superior to a regular precast pile. This was conclusively shown at the Long Beach pile tests where a 14″ octagonal pretensioned pile proved to be far superior to an 18″ square precast pile. Of particular importance is that a 14″ pretensioned pile will compare favorably in initial cost with an 18″ precast pile and will be easier to handle and drive.

4. Pretensioned concrete piles can be efficiently and economically used for building foundations, as well as marine projects. For example, if soil conditions permit, a 12″ octagonal pretensioned pile can be used as a 54-ton pile, with safety factor of about 4 to 1. This pile is greater in volume, perimeter, point bearing area, concrete strength and reinforcing than various types of cast-in-place concrete piles with a comparable rated bearing value. Its quality is a known factor before it ever leaves the plant. Wherever they can be efficiently used on land projects the cost per ton carried will be quite low.

As with any pile, however, there are certain places where pretensioned piles are not feasible for use. For very short piles and where cut-offs are highly irregular, these piles are not as economical as other types of piles.

Future trends in the prestressed concrete pile field indicate that larger piles and greater bearing capacities for smaller, as well as larger piles, will be increasingly used wherever possible. As you may know, 54″ diameter prestressed piles were used on the Lake Pontchartrain Bridge with successful results. Other projects are under consideration for 36″ and possibly larger piles. Wider bent, or footing spacings and greater batters will be used as a result of the greater structural strength of this pile.

The use of pretensioned concrete sheet piles is also an excellent application which has been recently developed. In marine work their use as permanent bulkheads will prove economical and sound.

Another possible application of pretensioned prestressed concrete which we have studied is that of a fender pile. They have practically all of the properties which a fender pile must have.

A prestressed concrete fender pile would be trapezoidal in shape, say 12″ on top, 10″ on the bottom and 12″ deep, or similar dimensions. This would permit double bolting to resist torsion. The ability to resist longitudinal and lateral shear would be excellent. The skin friction surface available would be a maximum. Such a fender pile would have good resistance to abrasion, be impervious to marine borers, be easy to handle, drive and bolt. They would be absolutely uniform and strong in bending.

Economic studies indicate that they would definitely be competitive with creosoted timber piles because of their much greater strength and longer life.

For friction piles various shapes of pretensioned concrete piles are possible which will give a higher frictional area to volume ratio than can be obtained with the usual square, octagonal or round piles. Pretensioned friction piles in the shape of T's and Y's have been successfully used in the Far East. We have recently designed four and five pointed "star piles" which have excellent ratios of weight and volume to skin friction area, and which can be produced, handled and driven very economically.

There has been tremendous interest in pretensioned concrete piles here on the West Coast as well as elsewhere. Because they meet the structural and economic criteria previously mentioned, they are included in numerous projects now on the boards. The future use of these piles appears almost unlimited.

MISCELLANEOUS USES

These applications of prestressed concrete which I have just discussed are common and well known to most of you. Piles, bridges, buildings and marine projects are all structures which lend themselves to prefabrication.

There are other uses of prestressed concrete which have great possibilities for the future. In fact, there is hardly a place where concrete is used that prestressed concrete cannot be used. And, there are some places where cast-in-place concrete is not feasible but which will be ideally suited for prestressed concrete.

In addition to this competitive situation with reinforced concrete, prestressed concrete will often be used in place of steel or timber on many projects because of structural and economic reasons. Let me point out a few of these "miscellaneous" applications which I believe will develop in the future.

1. *Prestressed Concrete Barges:* Concrete has been used for barges before but the use of prestressed concrete will make their construction much more feasible and economical. We know they will be competitive with steel. In fact, we have made preliminary designs for a very large self-propelled freight vessel in prestressed concrete for use in the Bay Area which indicates the practicability of such construction. The manufacture of prestressed concrete barges, towed and self-propelled, would be an industry in itself.

2. *Overhead Transmission Lines:* All technicians concerned with the transfer and distribution of electric power have given and still do give attention to the important problem of "conductor supports" for transmission lines. It is essential to obtain reliable and long-lasting transmission of power with the least possible depreciation. Let me quote from an article in a recent French publication by Mr. P. Lombard, Chief Engineer of the Gas and Electricity Development Service in Algeria. After a brief discussion of wooden poles, flange metal girders, metal lattice pylons and ordinary reinforced concrete posts for transmission lines, he drew the following conclusions: "Inspection of the first (prestressed posts manufactured and erected in 1941 has incidentally revealed that they have held up perfectly with the passage of time."

"From the technical point of view, the prestressed posts are considerably superior to ordinary concrete posts since they develop no cracks, even of a capillary nature, and the reinforcement is therefore protected from any penetration of water. It is impossible for such posts to be destroyed through oxidation of the rods, and their life is therefore practically unlimited. Besides, they are lighter, less cumbersome, stand up better under transportation and handling, and finally, are more elegant in appearance."

"On the economic side, it has been shown above that they were less expensive than of either ordinary reinforced concrete, wide metal girders or metal pylons."

"Furthermore, they require no maintenance. They are therefore not only more economical in their initial cost but also cheaper to maintain." I believe the above excerpts need no further comment other than to point out that all prestressed concrete products generally have such advantages.

3. *Landing Runways and Aprons:* In the immediate future I believe we will see a trend to construction of runways of prestressed concrete. Both the Navy and Army have test strips of prestressed concrete in operation today. You may have read of prestressed runways in France and Algiers which were built of unreinforced concrete, longitudinally compressed with flat jacks and transversely post-tensioned. In this country, I believe the greater ultimate strengths obtained with strands will lead to the use of longitudinal pretensioning with transverse post-tensioning. Abutments will be constructed at intervals from 1000 to 5000 ft., strands will be pulled and stressed, and the concrete slab poured. Such methods will result in structurally stronger runways with a considerable savings in concrete over the 18″-24″ slabs which are being used today.

In view of the increasing size of today's aircraft and the loads which the runways must carry, this will be an exceedingly important development. It is quite conceivable, also, that this development will extend to concrete highways, as it has in England.

These are but a few of the fringe area developments today in prestressed concrete which will become common practice tomorrow. If you, as engineers, have ideas on other applications, any leading manufacturer will be glad to furnish you information and data.

CONNECTIONS AND CONTINUITY

Connections which tie prefabricated units together at the site are as important a part of the design as the units themselves. While such connections are a vital part of any structure, they become doubly important here in the West where seismic conditions exist.

Generally speaking, connections for prestressed units fall into four categories: (1) welding, (2) bolting, (3) mild steel with cast-in-place concrete and (4) post-tensioning. Each type of connection will have application in different types of structures both for simple spans and continuity development. The right connection will be dependent on the type of member and the conditions involved.

The greatest progress in the matter of connections remains to be made in the field of continuity. In order to make full use of the material continuity should be developed, where possible, to achieve maximum efficiency. While various methods of developing continuity have been used for prestressed concrete units it is still a field which demands further study and research.

Past experience has shown that simple spans of prestressed concrete can be competitive with other materials used as continuous members. This competitive position will improve as further advances are made in development of continuity of prestressed concrete units.

TRANSPORTATION AND ERECTION

Hauling of precast prestressed concrete has different limitations depending upon the means of transportation. Truck transportation limits the length of members which can be transported to about 80 ft. Members up to 150 ft. could be transported by rail whereas practically no limitation exists on water transportation.

The distance which it is possible to ship economically is difficult to specify since it will vary from product to product, different destinations and depend on competition which may be present at that point.

We have quoted competitively on piles for shipment to midwest, south and to Alaska. On bridge and building members as well as piles, we have quoted competitively on projects throughout California.

I have been informed that prestressed concrete building units will soon be shipped from Napa to Seattle for a large project covering close to 500,000 square feet. This project probably seems large enough to set up for at the site. However, shipping costs to distant points will often be offset by the more economical and efficient operation and productivity which can be attained in a central plant. This proved to be the case in this project. The ability of the prestressed concrete industry to economically ship considerable distances should not, therefore, be underestimated.

Many contractors penalize prestressed concrete erection quotations because of unfamiliarity with it. While this is natural with any new material, it is expected that such "penalties" will diminish as experience is gained in handling such units. This, of course, can only come with time. Whenever that experience has been gained, erection has become a simple problem, as indeed it is. For example, on three recent jobs on which we furnished prestressed concrete units the contractors underestimated their ability to erect by scheduling shipments over twice as long a period as was necessary.

CONCLUSION

Before closing I would like to clarify a few points which may be possible of misinterpretation.

My comments to you today have been made, not only as a fellow member of the Structural Engineers Association, but as a manufacturer of prestressed concrete and as an officer of the Prestressed Concrete Institute.

I have attempted to briefly describe what the industry has done, what it is doing in the development of manufacturing techniques, and some of the trends and possibilities which we, as manufacturers, see in the future.

While we may plan, predict and hope about the future of prestressed concrete, we recognize that it will be up to the design engineer to give form to these ideas. Therefore, our goal will be to make it as easy as possible for you to consider, accept, and use prestressed concrete in your projects whenever structurally or economically feasible.

The prestressed concrete industry is naturally quite enthusiastic about its products. Properly used they will be the ideal solution to many of your problems.

The industry recognizes that its products must be economically competitive and structurally sound to be acceptable. However, we ask that you recognize this fact — prestressed concrete is a high quality product produced under close supervision of materials and workmanship. As such it may well be worth the additional cost, as a better product, in those instances where another material is apparently more economical.

We hope that you do not feel we are infringing upon your design integrity when we propose various standard designs. Our purpose is two-fold in doing so — to achieve an economy in manufacturing through standardization and to save you design time. We will, of course, make any type of prestressed concrete product of your own design if our standard sections are not adaptable to your project.

At the present, standard design products vary to some extent from company to company. It is hoped that in the near future— it may be one year or five years — the Prestressed Concrete Institute, as the voice of the industry, will be able to publish a national standard handbook on different members, codes and specifications. Until that time any manufacturer of prestressed concrete will be glad to discuss with you possible prestressed concrete projects without obligation.

It is a pleasure to tell you that next July 29th through August 3rd the Prestressed Concrete Institute will hold its 3rd annual meeting in San Francisco in conjunction with a World Conference on Prestressed Concrete sponsored by the University of California. We sincerely hope you will be able to attend as the program will, I am sure, be most interesting to you.