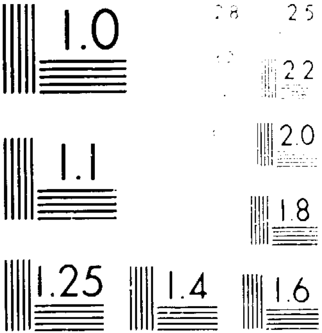

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5

10821

Distr.
LIMITED

ID/WG.347/18
29 September 1981

ENGLISH

United Nations Industrial Development Organization

Workshop on Cement and Concrete Products
Brisbane, Australia, 18 -29 May 1981

# POST-TENSIONED BUILDING STRUCTURES. ECONOMIC TRENDS AND THE INFLUENCE OF CONSTRUCTION TIME *

by
G.F. Pash **

* The views expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

** Managing Director, VSL Prestressing PTY. Ltd.

V.81-30242

# CONTENTS

## 1.0 INTRODUCTION.

In complex building applications the economics and rate of construction of the post-tensioned areas are not always critical because of the magnitude of the unusual loading or framing conditions to be solved. This paper is confined to post-tensioning as applied to the more conventional structural floor systems where the selection of structure type is heavily influenced by direct material and labour costs and the speed with which the building is to be constructed. Construction time has become of the utmost importance under today's prevailing high interest charges and potentially escalating costs.

Two distinct building types are reviewed, namely, multi storey projects involving office, hotel and apartment structures and also multi linear jobs incorporating medium level structures, as used in shopping centres and industrial complexes, sometimes with relatively large plan dimensions.

The areas of maximum direct and indirect cost influence are highlighted and the balance between these costs is reviewed.

Examples of the relative cost of various post-tensioned structural solutions are given, compared with alternative solutions using other materials in two typical building spans and loadings. The examples and cost data provided, cover the United States of America, the United Kingdom, South East Asia and Australia and therefore incorporate unit labour rates with a ratio of approximately 40 :1 between the U.S.A., and certain regions of South East Asia. The relative importance of the major structural cost items varies among many of the countries studied and the particular trends evolving in Australia are explained, together with a projection on future developments. A typical construction programme for a multi linear structure is discussed and the significance of the formwork and post-tensioning interaction is emphasised.

Availability of constructional plant must seriously influence the choice of structural solution. The major differences between on-site construction equipment in the United States, Europe and other-less industrialised countries, are highlighted.

The various advantages and disadvantages of post-tensioned building structures are discussed and compared with alternative methods, from the point of view of the owner and contractor.

## 2.0 THE BASIC AIM OF THE PROJECT

Sometimes the basic project aims can be obscured in the maze of Architectural and Engineering gymnastics which form part of a package. We must remember that these professional skills are only means to an end and must be viewed in their true perspective. The building incorporating the highest level of structural engineering achievement can be a failure unless it satisfies the basic client, community and functional objectives.

What do we mean by a successfully completed project? There are a number of possible motives behind the original decision of the client to undertake a particular project. Remember that it is the client who, in nearly all cases, initially determines the need to construct a project and it is clear that his needs must be the prime consideration in the minds of the constructors and designers of that project. Depending on whether the project is an office building, industrial complex, retail store or public works project or indeed any of the other variety, the basic aims of the project would normally be one or more of the following :

- the client's personal occupancy needs
- investment return, to the client, by way of rental
- development and future sales for profit, on completion
- in the case of public works, additional or improved community services.

The economic viability of the project is not a by-product of the project teams endeavours, it is normally the prime reason for the project's existence. Economic viability, demands that the project construction team produce a building which must be :-

a) competitive in costs

b) constructed to a planned time schedule

These sub-divisions describe operations which are also the Contractor's primary goals of 'Economy and Speed'. Technical, functional planning and aesthetic soundness are implied. Post-tensioning of conventional building structures can produce several important by-products, eg., early formwork removal, deflection control, durability and crack control. These are secondary affects only. The process is clearly worth while, if it is - less expensive and faster than alternative methods. We will confine ourselves to the tangible basic cost comparisons.

## 3.0 DIRECT PROJECT COSTS.

Materials and labour : In the current world political and financial climate, no paper is complete without a discussion on the effects of inflation. Material and labour costs have escalated alarmingly and have aborted many formerly viable projects. Contractors have been forced to re-think many of their former values. Materials and methods, which have been standard in the building and civil engineering industry for the last 20 years are becoming obsolete, as on-site labour prices itself out of the market, in so many areas.

The availability and standardisation on building materials must be carefully considered by the designer when completing his detail drawings. There are innumerable somewhat equivalent materials which can be selected to do a particular job. It is absolutely essential for the designer to be familiar with the full range of materials and to understand their relative costs and availability. It is pointless and costly, if the designer proceeds through sophisticated mathematical analysis and transforms the data into impractical or unobtainable physical elements.

In my experience, I have not seen many Design Engineers who have made a great success as contractors, nor have I seen the reverse take place. This is a sad trend, brought about by today's requirements of premature specialisation. I have seen spectacular reciprocal improvements in the designer and the contractor in cases where the designer has been commissioned to design a particular project for the contracting wing of the client. The close co-operation or interaction, thus created, tends to produce team members with a broad outlook as regards the projects aim.

By these remarks, I am not endorsing the principle of 'design and construct', I am merely trying to point out that the parties require a sound working knowledge of the functions of their team members to permit balanced interaction. The opening of tenders, too often. proves a bitter disappointment for the client. This could be minimised by regular progressive cost planning, by the project team, during the design process and before tenders are called. Many major decisions affecting the building price are taken between the two traditional estimating times - at the feasibility stage and at the conclusion of the documentation, immediately prior to tender. By a regular and formal series of cost plans, the design team should be in a position to take the necessary design decisions with sound knowledge of the effect on the project budget. The designer must know :-

(a) how the structure is to be built

(b) what the various elements are costing and how these costs are effected by each adjustment in planning.

## 4.0 INDIRECT PROJECT COSTS - THE COST OF MONEY!

The extremely high interest rates prevailing now, in many countries can mean that interest charges alone can account for 15% to 20% of the total project costs, including land. This factor is uppermost in the client's mind and must be considered very carefully by the project team. There are very few owners or clients who are investing the total cash sum for any project from their own resources. Even if they were, the loss of market interest on the client's employed funds is an indirect project cost.

The speed of construction is now more vital than ever before and this can benefit enormously from interaction between the design team and the contractor.

There has been a tendency in some countries for "Fast Track" construction of the concrete frame which proceeds as the Architectural and other planning is in progress. My theme relates more to the thorough planning of all the concrete trades to achieve a structural frame economically in the minimum effective time.

## 5.0 THE AREAS OF MAXIMUM TOTAL COST INFLUENCE.

In most parts of the world, concrete has become clearly our most common basic material for the construction of building and civil engineering projects. For this reason, and also to conform with the basic theme of the Symposia, most of my specific remarks and examples will be directed to examples of effective cost planning relating to post-tensioned concrete structures. The principles highlighted, naturally apply to other structural media.

Figure 1 has been prepared from information received from a number of sources in each of the areas listed. The rates cover average conditions for normal post-tensioned structure types. The rates are meant to be current at January 1976 and embrace material and labour costs including placing materials into their final position. The rates quoted are sub-contract prices and do not include prime contractors overheads and profit. The factory and site labour rates include all statutory loadings and an allowance for superintendence overheads.

UNIT COST FOR CONSTRUCTION OF CONCRETE FRAMED POST-TENSIONED BUILDINGS :

All figures in Australian dollars.

One Australian dollar equals approx. US$1.25 (May, 1976)

| | Formwork per $m^2$ | Concrete per $m^3$ | Reinf. per tonne | P.T. Substr. per tonne | Average Labour cost per hour | |
|---|---|---|---|---|---|---|
| | | | | | Factory | On-site |
| Australia | 12 | 50 | 450 | 1800* | 5.00 | 7.00 |
| U.S.A. | 8 | 36 | 500 | 2000 | 8.00 | 11.00 |
| United Kingdom | 16 | 31 | 240 | 1200 | 3.00 | 3.50 |
| Singapore | 3 | 24 | 365 | 1300 | 1.30 | 1.30 |
| Malaysia | 3 | 24 | 365 | 1300 | 1.30 | 1.30 |
| HongKong | 7 | 38 | 253 | 1200 | 0.60 | 1.00 |
| Indonesia | 3 | 47 | 400 | 1800* | 0.25 | 0.25 |
| Average S.E.Asia | 4 | 33 | 346 | 1400 | 0.86 | 0.96 |

Note : * Certain anomalies arise from the basic domestic steel price and also particular tariff and duty imposition on imported material.

FIGURE 1.

Let us consider two alternative structure types and apply the above unit costs to determine the areas of maximum cost influence.

## 6.0 COST COMPARISONS.

### 6.1 Structure Type A

Typical High Rise multi-storey structure :
Column Grid 10m x 10m
Live Load (including finishes etc.) 5 kPa.

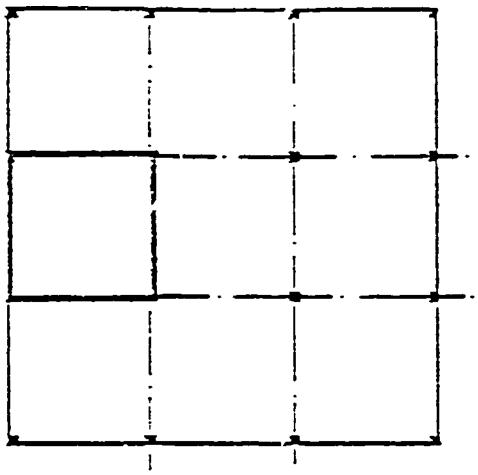


FIGURE 2.

**Scheme A.1**
**Reinforced Concrete Flat Plate**
Slab depth 320mm
Span/depth ratio 31
Concrete quantity $0.320 m^3/m^2$
Reinf. quantity 43 $kg/m^2$

**Scheme A.2**
**Prestressed Concrete Flat Plate**
Slab depth 240mm
Span/depth ratio 42
Concrete quantity $0.240\ m^3/m^2$
Reinf. quantity 4 $kg/m^2$
Prestress quantity 7.5 $kg/m^2$

## 6.2 Cost Comparison

Scheme A.1 Reinforced Concrete

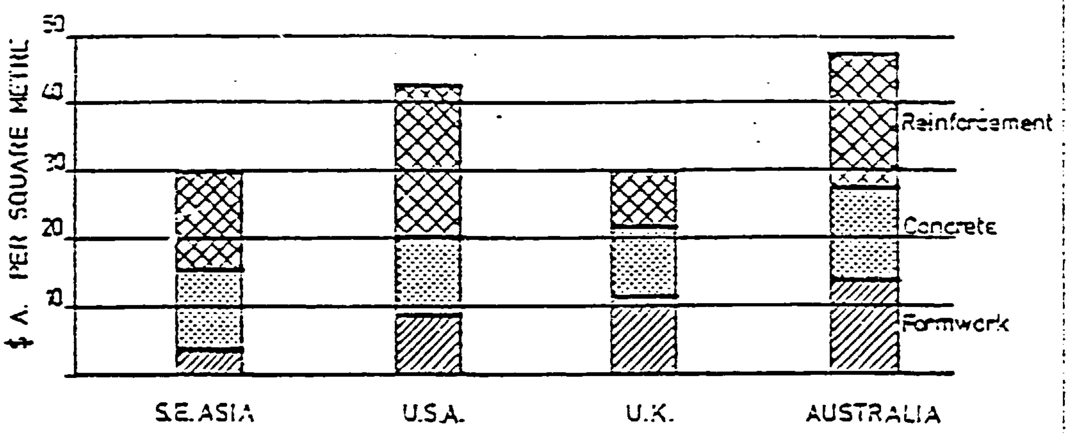



FIGURE 3.

Scheme A.2 Post-tensioned Concrete

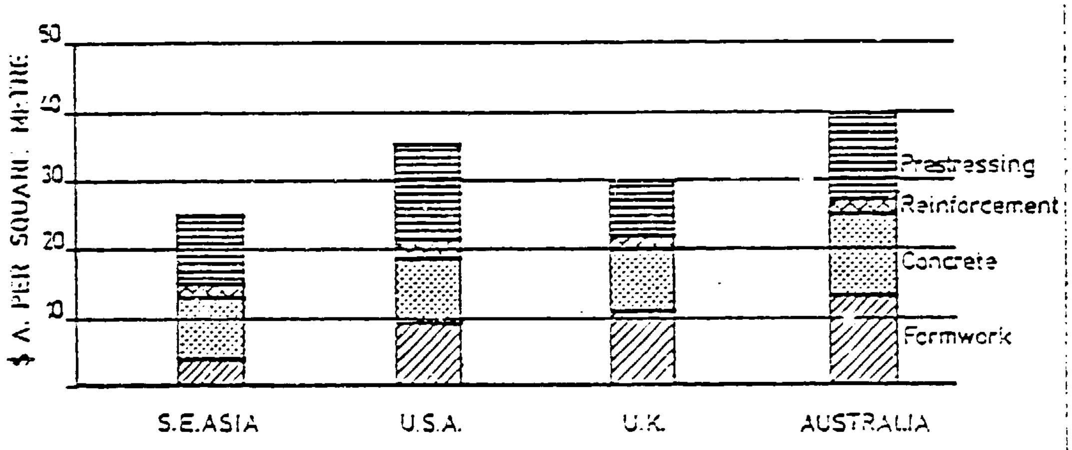



FIGURE 4.

Considerable material saving could be made by incorporating a post-tensioned beam slab solution to replace Scheme A.2 in the high rise application. It is often the case that flat plate slabs are preferred in high rise structures because of planning requirements concerning the building height and the costs of architectural facade finishes. It is also more difficult to incorporate heavy table forms unless the handling equipment is sophisticated.

6.3 Structure Type B.

Typical Multi-linear (Shopping Centre) structure.

Column Grid 8.4m x 8.4m - Live load 5 kPa.

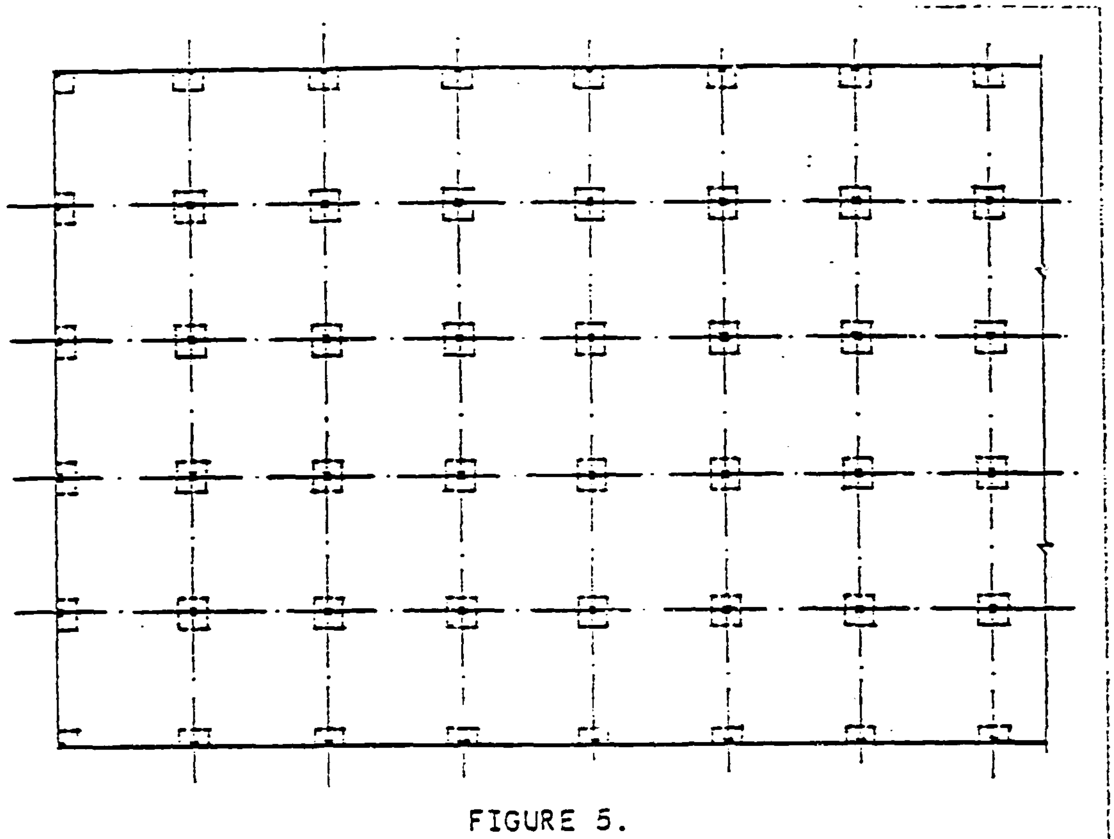


FIGURE 5.

Scheme B.1
Reinforced Concrete Flat Plate
Slab depth 250mm x 150mm drop panels
Span/depth ratio - 33
Concrete quantity $0.270 m^3/m^2$
Reinf. quantity $31 kg/m^2$

Scheme B.2

Prestressed One Way Wide Beams and One Way Slab.

Beam depth 350mm

Slab depth 175mm

Span/depth ratio 24 beam

Span/depth ratio 39 slab

Concrete quantity 0.215 $m^3/m^2$

Reinf. quantity $3kg/m^2$

Prestress quantity - bar 4.5 $kg/m^2$

- strand 2.6 $kg/m^2$

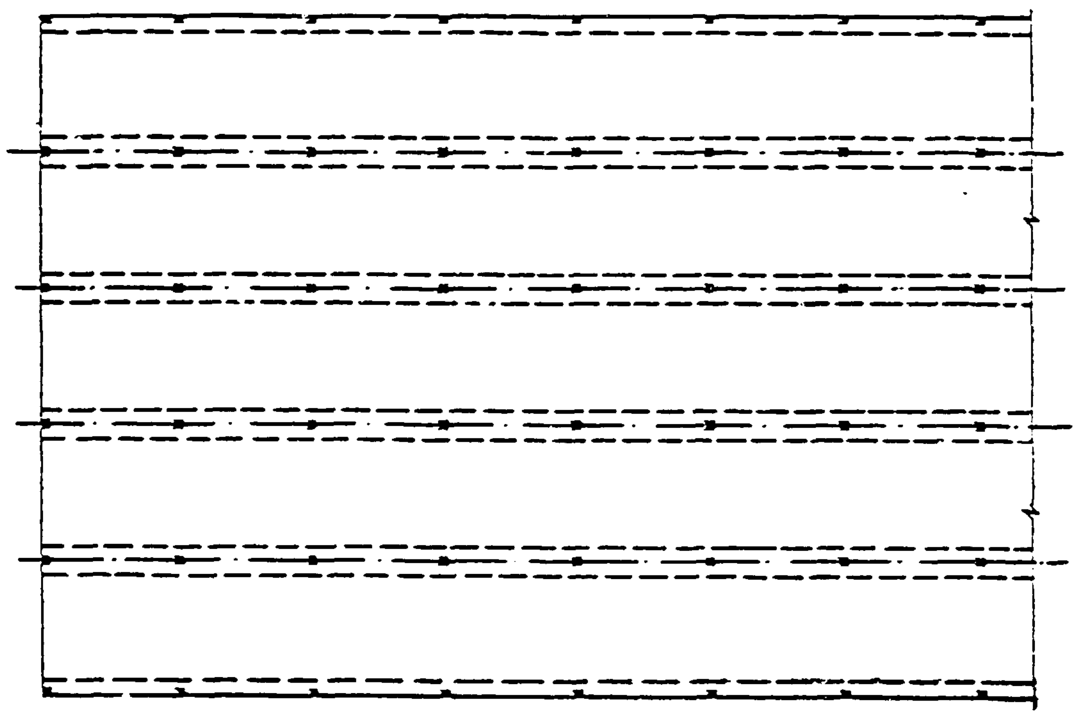


FIGURE 5(a).

6.4 Cost Comparison

Scheme B.1 Reinforced Concrete

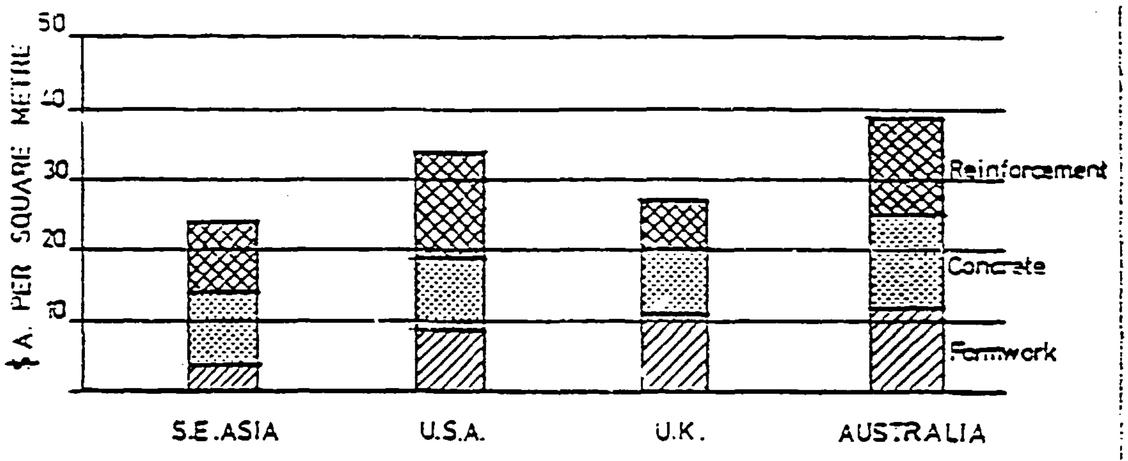



FIGURE 6.

Scheme B.2 Post-tensioned Concrete

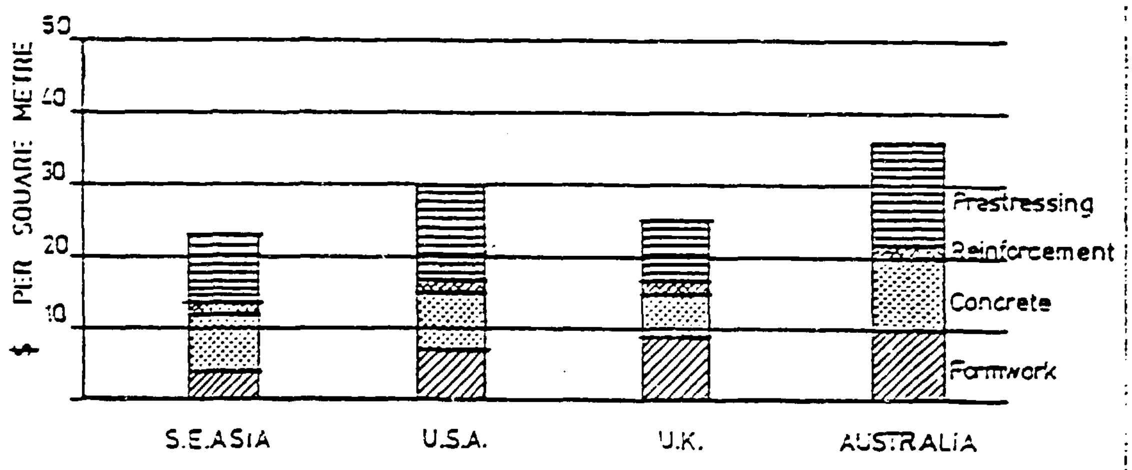



FIGURE 7.

## 7.0 COST COMPARISON LESSONS.

There are several important lessons to be learnt from these comparisons.

### 7.1 Formwork Costs :

In Australia the in-place costs of concrete, post-tensioning and to a similar extent reinforcement, have not increased at the same rapid rate as installed formwork costs. The basic formwork material costs have increased significantly but extremely high labour costs and low productivity are the major factors accounting for the total escalation. The structural designer and architect control the shaping and profiling of the structural concrete members. By experience and thoughtful planning, the designer should be competent to detail shapes that can be moulded simply and effectively combining simplicity, repetition, easy stripping, transporting and re-usability of form sections. Mechanisation for movement and ease of relocation can lead to use of large pre-assembled 'table or fly-forms', which are extremely economical in time and money, provided there is sufficient repetition.

Having emphasised the major role that formwork plays, in the cost of concrete structures, I must comment that interaction, in regard to formwork; is far more difficult for the design team than other factors. To my mind, speaking frankly, I consider that the construction industry is in need of sub-contract groups who design, supply and erect well planned formwork systems and who could become specialist sub-contractors, providing the equivalent service to that often supplied by organisations such as piling or post-tensioning companies.

The significance of formwork costs varies greatly from country to country. In the United States of America they have lived with high unit labour costs for many years and this accounts for the developed and mechanised nature of their formwork contractors. In most instances in the U.S.A., the formworker becomes the principal sub-contractor and often controls the reinforcement, post-tensioning and concrete placing.

Of the main material items which have been studied, formwork looms as a major direct and indirect project cost influence. The speed of construction of a building project is more seriously affected by formwork practice than by any other trade. It is possible to greatly facilitate the formwork construction rate by planned interaction between formwork, concreting sequence and post-tensioning. Refer to Figure 13 which depicts a typical construction programme for a retail shopping outlet.

It is difficult for structural designers to take account of the various methods which are proposed by particular contractors especially when the tender list is likely to contain a vast spread of contractors, each wishing to employ his own methods and equipment inventory. The problem can be extended to sub-contract formworkers, who have vast stocks of traditional formwork hardware. We are all reluctant to write off plant and equipment, but unless formworkers do this in future years, the labour costs will become prohibitive.

The formwork lessons for Australia and other countries in a similar state of development must naturally tend to come from the U.S.A. There were initial moves towards precast flooring systems in the U.S.A., because of the ready availability of high capacity handling equipment on-site. The developed transportation system in the U.S.A., has also been of assistance to the precast industry. In Australia and South East Asia, the sites are generally not well equipped with cranes and other handling equipment. The problem of cranage is made more complex as a result of industrial disruption surrounding the crane operator. The road systems in Australia and South East Asia do not tend to permit efficient transport of precast structural members.

7.2 Post-tensioning site costs.

In the late 1960's it was possible to construct a typical post-tensioned floor using a post-tensioning labour content of approximately 45 man hours per tonne with each man hour costing approximately A$2.20. This produced a trade labour cost of approximately A$100 per tonne of prestressing steel installed.

During 1974/75 when the building industry in Australia and elsewhere was at peak activity with a resulting abundance of serious industrial unrest, equivalent recorded labour times rose to 110 man hours per tonne at an average man hour cost of A$7.00 producing a comparable trade labour cost of A$770 per tonne, an increase of 670% in approximately 5 years.

To combat this wild escalation there has been a strong move to mechanisation of the post-tensioning labour activities. Far more financial resources have been allocated to on-site handling and hydraulic equipment.

The four major developments have been :

(a) The strand pushing-cutting machine which has reduced cable installation (excluding stressing and grouting) from a peak of around 30 man hours per tonne in difficult projects, down to a figure closer to 10 man hours per tonne.

(b) Improved stressing and grouting equipment which is fast acting, reliable and extremely portable.

(c) A strong accent on formal operational training and instruction of site personnel. When your man hour is likely to cost A$7.00, it is a sound investment to spend A$1,000 on a formal training programme with a reliable artisan.

(d) The level of office pre-planning of the future site activities has increased by a significant amount, resulting in far more effective application of the priceless commodity - site labour.

## 7.3 Post-tensioning design and construction methods.

In many countries of the world, vigorous use is made of unbonded, factory produced tendons. There have been a number of reasons for the retardation of unbonded applications in Australia, notably :

(a) More frequent use of post-tensioning in shopping and industrial complexes incorporating the higher range of live loading. In these cases there is often little economic advantage in unbonded construction.

(b) The widespread geographic nature of Australia with inherent transportation costs and problems with factory produced tendons. The Australian strand manufacturers deliver the coiled strand to site or to factory for the same basic price.

(c) Reluctance on the part of Consulting Engineers to permit unbonded tendons for reasons of

- safety
- corrosion resistance
- reduced ultimate characteristics

(d) Limitations imposed by the Australian Prestressed Concrete Code AS1481, which negate any major savings in unbonded designs in many applications.

We should now look at the better examples of recent construction and look for some trend for the future.

## 8. RECENT EXAMPLE OF EFFICIENT CONCRETE CONSTRUCTION

### 8.1 Economic Review

There are several specific Australian examples of merit worthy of mention, but I will confine my comments to the details of a shopping centre recently constructed in Australia. The structural layout of this project has been described earlier in paragraph 6.3 Structure Type B.

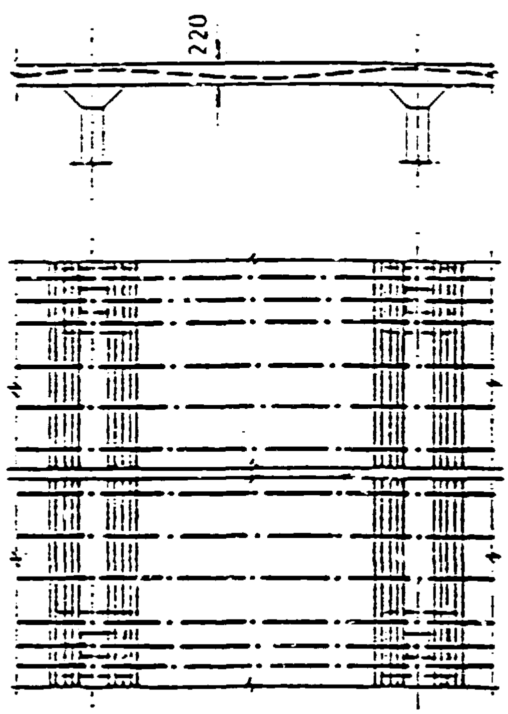
In this case escalation in building materials and labour costs had taken place during the design process without a tangible increase in the expected rental returns. The project team were then thrown the problem of re-designing their various elements of the building to attempt to offset the increase in price. Ideally of course, the optimum solution should have been achieved in the first place, but all of the costing data was not known accurately or able to be forecast.

When we are forced to re-think, it is amazing how many new ideas can develop. In the case of the shopping centre, my knowledge is limited to the structural aspects. The prices for concrete and post-tensioning had risen approximately 10% since the original estimate whereas the price of formwork has risen by 35%. The original structure was a solid flat plate slab spanning 10.0mx10.0m carrying a superimposed live load of 5.0 kPa per sq. metre. As we all know, a flat plate is not the most desirable section from the point of view of stiffness or concrete volume, but is normally considered cheaper for formwork.

The obvious solution to save concrete and post-tensioning costs was to create a beam system in one direction and a ribbed slab transversely. Without a detailed investigation, this proposal could easily be dismissed because of the apparent formwork complexity.

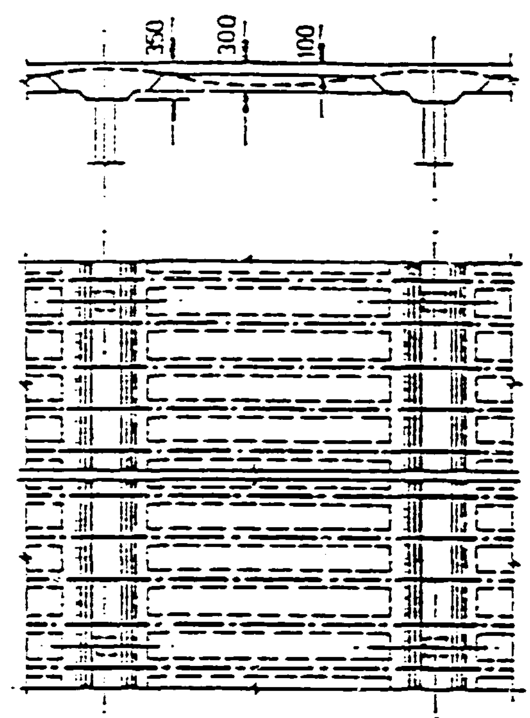
### 8.2 Alternative proposals.

Figures 8, 9 and 10 show respectively the original post-tensioned structural scheme, a second proposal and the finally adopted scheme. I have chosen to show the second unsuccessful proposal as I believe this method has major advantages in cases where the transverse span exceeds 9 metres and for total floor areas in excess of 10,000 square metres. The reinforced concrete proposal has been described in paragraph 6.3 Scheme B.1. The reinforcement concrete proposal proved to be the most expensive of these four alternative structure types.



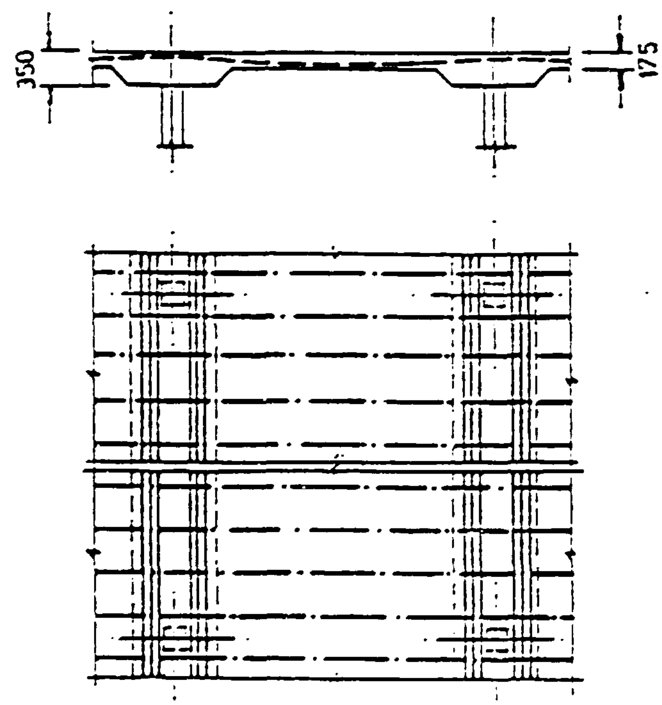

SCHEME 1.

FIGURE 8.




SCHEME 2.

FIGURE 9.




FINAL SCHEME

FIGURE 10.

The increased depth in the beam column strips produces an obvious reduction in post-tensioning costs longitudinally. In the transverse direction, the increased stiffness in the column zones considerably assists the bending and deflection characteristics of the slab.

With the dead/live load ratio typical of retail stores, it is normal that post-tensioning is designed to counter balance the self-weight of the slab and therefore the self weight saving in this direction as a "per cent" represents approximately the post-tensioning percentage cost savings in the transverse direction.

SUMMARY OF MATERIAL QUANTITIES PER SQUARE METRE

| | Concrete cu. metres | Reinforcing steel kg. | Post-tensioning steel kg. |
|---|---|---|---|
| RC Scheme | 0.270 | 31.0 | 0 |
| Scheme 1 | 0.220 | 1.5 | 7.7 |
| Scheme 2 | 0.200 | 5.5 | 5.9 |
| Scheme 3 | 0.215 | 3.0 | 6.3 |

FIGURE 11.

The above material comparisons are important, but the main issue for my discussion relates to the effective construction of such structures now that the saving in materials has been achieved, that is converting the theoretical saving into a practical reality.

## 8.3 Construction Methods

### 8.3.1 Tendon arrangement

The price per unit length of standard post-tensioning cables varies inversely as the cable length.

This is understandable when you consider that you have to amortise, in the price per unit length of the cables, the cost of anchorages and associated labour to stress and grout. How can we therefore create longer cables without asking the contractor and his formworker to provide extremely large areas of formwork with the subsequent increase in cost and delay to the construction cycle?

It is highly desirable to reduce large expanses of slab into practical areas to provide a concrete volume that can be readily placed and finished in a working day.

The following system was evolved which involved the co-operation and planning of the designer, formworker, concretor and post-tensioner.

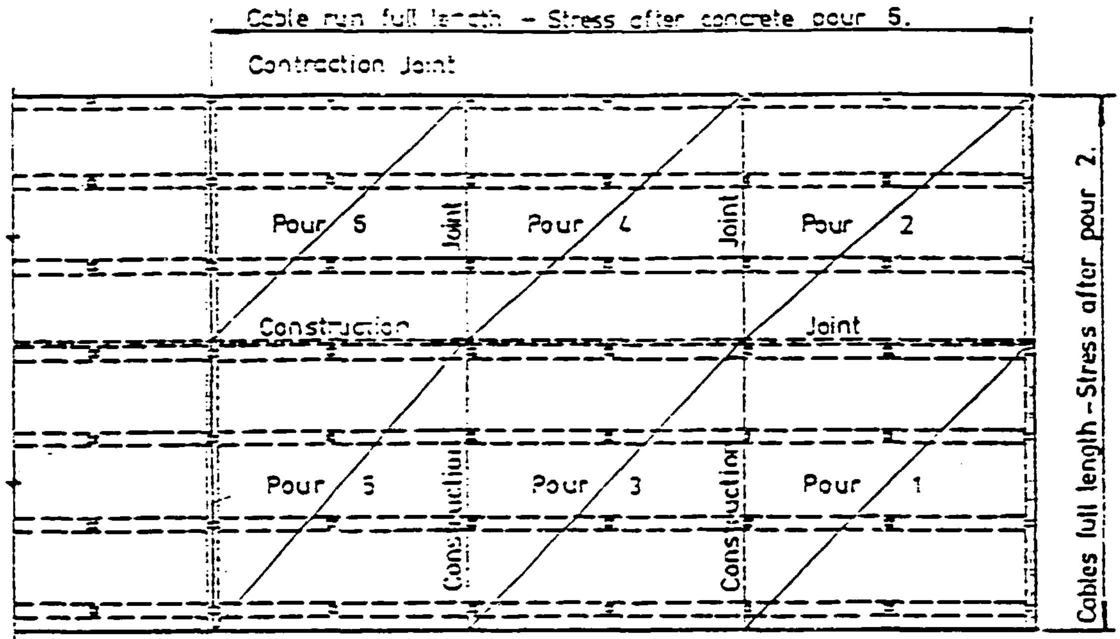



FIGURE 12.

Figure 12 shows the layout of construction joints indicating a large panel broken into 6 separate concrete pours.

The formwork and post-tensioning cables complete with the minor amount of ancillary reinforcement were prepared in panel 1 and concreted.

Simultaneously on the adjoining pour Section 2, formwork and post-tensioning cables were being assembled. This allowed good continuity of on-site labour as the progress of their work was not interrupted by the concreting days. Section 2 was concreted some 4 days after Section 1 and incorporated a band of higher strength concrete along the exterior edge. 48 hours after concreting of Section 2 the transverse slab tendons were stressed to 75% of the final jacking load by stressing 3 of the 4 stands in each tendon. Since prestressed losses had not taken place, this prestress uplift balanced the slab load, so that formwork between the beams could be removed and re-positioned in the direction of the band beams. In what we will call the longitudinal direction, we have of course not completed the post-tensioning, but a number of cables per beam were stressed to provide shrinkage control. These cables are later coupled at the adjoining construction joints. After final concreting of Sections 5 and 6 respectively, the major cables in the band beams were reeved into position and longitudinal stressing completed. The transverse stressing of Sections 3 and 4 and 5 and 6 take place in the same manner as Sections 1 and 2. Figure 13 shows a typical construction programme achieved regularly and conveniently during the construction.

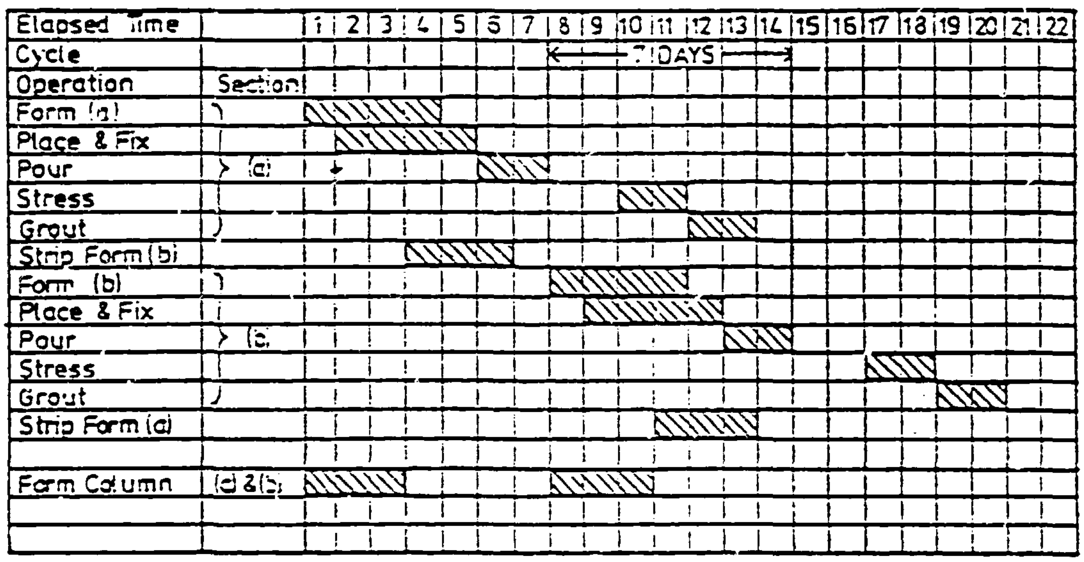



FIGURE 13.

### 8.3.2 Formwork details

Figure 14 shows the arrangement of formwork under the soffit of the slab and indicates the forms which are left in position under the band beams until longitudinal stressing is complete. The arrangement of the formwork is quite simple as it provides exactly the desired concrete shape, at no appreciable expense when compared with normal flat plate formwork.

Several similar jobs have incorporated ribs in the transverse direction formed using polystyrene wrapped in P.V.C. bags for ease of removal and re-use. The initial capital cost of the styrene void former equals approximately the cost of the concrete volume saved in the first pour, but it has been possible to achieve up to 5 re-uses of the styrene and the labour to place and finally strip the styrene, is extremely low. It is desirable to introduce ribs where the transverse span is 9 metres or more and where the total floor area to be formed exceeds 10,000 sq. metres.

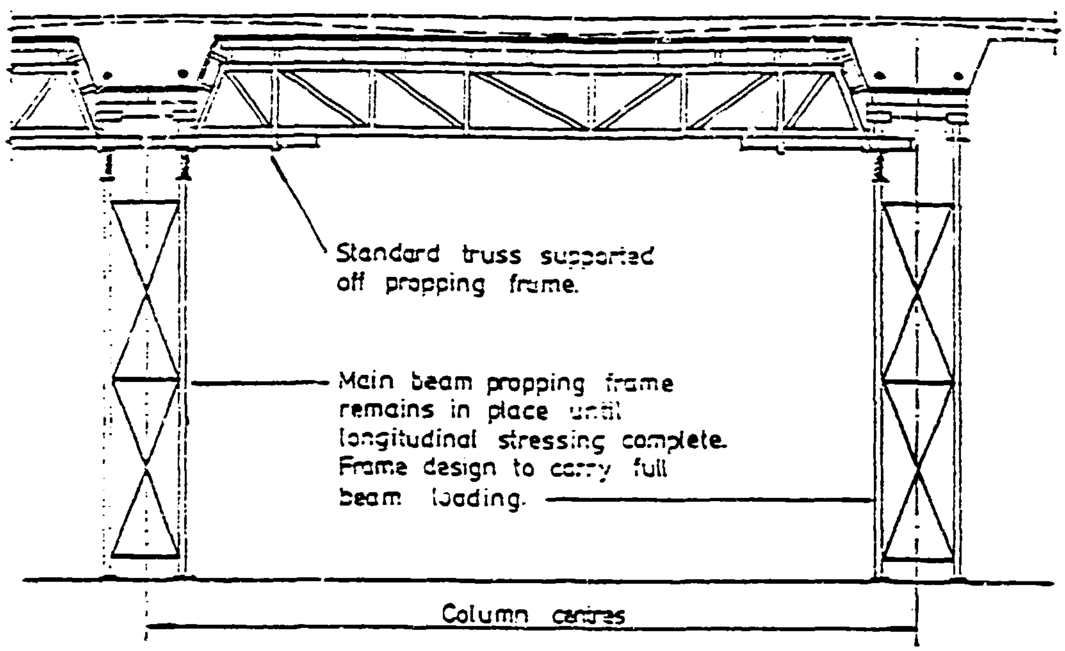



FIGURE 14.

The formwork panels have been constructed in such a manner that they can be easily modified to cover a range of column grids from 8 metres to 12 metres. The fabrication of the form panels was carried out in a factory away from the site and the panels delivered complete to the site with a minimum of final assembly work to be done.

A major problem can occur in many projects as a result of the late construction of the ground level slab after completion of drainage and other services. It is highly desirable to construct a working slab either of concrete or road base to simplify the movement of the large table forms. If this cannot be achieved a system of formwork tracks needs to be constructed to allow level and straight movement of the form panels.

A typical form panel weighs 1500 kg and has a side clearance of only 400 mm so it is necessary to use sophisticated handling equipment if the terrain is rough.

Figure 15 illustrates an earlier project incorporating transverse ribs formed by styrene. You will notice that the formwork soffit tables are constructed in two halves with a central secondary slab prop. This arrangement is more costly in labour and the use of the larger panels shown in Figure 14 is preferred because of the lower labour cost and speed of erection and relocation.

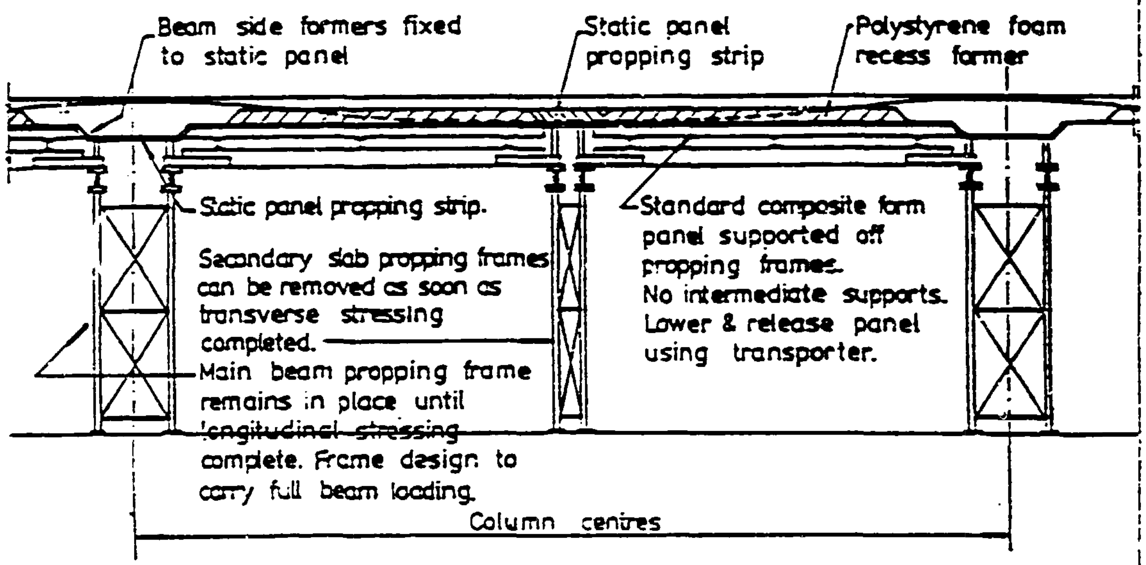



FIGURE 15.

## 9.0 FUTURE TRENDS

The major lessons from the U.S.A., which are directly applicable in Australia and South East Asia relates to <u>insitu</u> concrete construction. Precast flooring systems are unlikely to develop in popularity, if U.S.A., trends are an indication.

In the U.S.A., there are specialist firms who often construct the concrete building frame as a package sub-contract and these firms are in nearly all cases, from a formwork origin. Formwork is their basic skill and it was learnt very early in their life that this is the prime cost influe ce in a concrete structure.

The trend in Australia has not been that way and in my opinion is more likely to follow a slight deviation along the following lines :

9.1 As mentioned in my introduction, I am speaking mainly about traditional multi-level and multi-linear buildings of significant floor area. The column spacing for many of the sites and occupancy requirements are strongly standardised in the 8 metre to 12 metre range.

It is becoming increasingly common for structural consultants to contact specialist organisations at an early stage when they are conferring with the architect and project team on alternative structural systems. In an average case the Consultant may have 6 alternative structural framing schemes, of which, say three are post-tensioned concrete solutions. Since the specialists are concentrating particularly in this aspect of the work, they are able to review the three post-tensioned schemes and make relevant comments regarding the design, budget costs of the schemes and also their practicability.

During the review, one or two alternative methods may be suggested which may be unfamiliar to the particular consultant.

Since most of the specialists are working on a wide range of projects throughout Australia and South East Asia and by affiliation with others in related groups in Europe and the U.S.A., an appropriate solution to this particular problem may come to light. In this way informal pre-consultative meetings develop and the consultant may become more aware of :

a) recent innovations and trends

b) practical suggestions from the sub-contractor's point of view

c) budget prices with which he can review far more realistically his alternative structural framing systems.

This particular method of consultation is highly desirable. It is done purely as a technical service to clients in consultation with the project consultant and orientated to fit in with his basic thinking. The timing of the advice is ideal as it allows the consultant to incorporate the latest practical details on his drawing and thus avoid the need for possible on-site detailing difficulties.

In future years, I believe that Consulting Engineers will confer more formally with specialist contracting companies to prepare :

- feasibility design schemes based on specialist experience and availability of sophisticated formwork systems linked with post-tensioning services.

- formwork design and layout including construction, programme details

Tenders or offers will be submitted for nominated packaged sub-contracts covering :

- supply and erection of main formwork elements

- supply and installation of post-tensioning tendons and associated reinforcement.

The general contractor will continue in his customary project management role and will arrange for the sub-contract concreting and finishing trades.

This method will succeed because it does not undermine the traditional general contractor role and does not prejudice the Architect, Consulting Engineer or Client in any way. Too many schemes founder because they require over-much change and disruption to established procedures. In formulating the above trends, I have tried to take into account these personal and tradition based established methods. There are numerous other examples in which the successful interaction amongst the project team has developed mainly because the project costs have risen to a stage that the project became only marginally viable. In future we will see this interaction as a standard approach.

9.2 The immediate future years will see the application of unbonded tendons for the following structure types.

- Apartment and office buildings with spans in the range 6 metres to 8 metres in which range they will compete favourably with reinforced concrete.

- Industrial floors on grade.

The bonded slab tendons in flat ducting have reached a sophisticated stage and under prevailing tendencies it seems highly unlikely that unbonded tendons will become popular in retail shopping centres and industrial complexes which have been the major source of usage of post-tensioning in buildings in Australia.

The role of specialist post-tensioning organisation has changed dramatically in recent years as have other specialist organisations. It is no longer sufficient for a group to provide materials, equipment on hire and leave the work to the contractor. For optimum results it is essential that specialised groups be exactly that - specialists, with strong design engineering support and to participate as an integral part of a planning team co-ordinating formwork and post-tensioning construction activities.

It will be interesting to observe the future movement and tendencies in the building industry and it is extremely convenient to have opportunities such as these to review and consider the methods and results being achieved in such a geographically wide spread group that we have assembled here.

* * *