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HEAVY MOVABLE STRUCTURES
MOVABLE BRIDGES AFFILIATE

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SESSION
WORKSHOP NOTES

Session (6-6)
"The Shop Print Process: Who is Communicating with Whom?", Alan J. Moreton, Fla. Dept of Transp. Tall, Fl.

"The Shop Print Process: Who is communicating with whom?"

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Florida D.O.T., August 1990

Contents

1. Introduction

"Shop Drawings; who is communicating with whom?" - this question was raised in a slightly different context in a recent paper on segmental bridge construction in Florida (ref.1). Segmental construction, though a widely understood engineering technique, has been a relatively recent introduction in the United States (i.e. mostly in the last decade.). We are only now seeing the benefits and pitfalls. Unfortunately, as with all bad news, the latter has attracted much attention within the industry, State and Federal governments. However, when the causes of the difficulties are examined, one finds much culpability on the part of all organisations. It would be unfair and improper to cite specific examples, suffice to say that most could be categorised as "inexperience" or "unpreparedness" - not entirely unexpected with something new! One of the areas most often criticized has been "Shop Drawings" or as the previous paper termed it "Administration Processes" since it is a broarder ranging issue than simply one of the drawings themselves or even of segmental bridges.

2. Illustrations from Segmental Bridge Construction

Perhaps it would help to briefly review the segmental industry. Over the last ten years, many precast segmental bridges have been built nationwide and Florida, with over 30, has more than most states. (Table 1) Most applications in Florida are on curved balanced cantilever viaducts at complex interchanges and long span-by-span bridges over water. In all segmental construction, the emphasis is on factory style precast production and rapid, versatile, erection systems tailored to the needs of the site. It is a true mix of design and construction.

2.1 Types of Segmental Bridges

Precast segmental bridges are so called because they are made of individual precast units or "segments" carefully manufactured in a precast concrete plant, either on or off the site. (Fig.1). The segments are later erected and secured together by longitudinal post-tensioning to form each span or cantilever. (ref.2)

They are categorized according to their method of construction:

(a) Span-by-Span - where all the segments of one span between piers are erected on a special supporting truss or gantry and then longitudinally post-tensioned together. (Fig.2) (Examples; Long Key, Channel Five and Seven Mile.)

(b) Balanced Cantilever - where segments are erected sequentially in cantilever on each side of an initial segment placed on top of the pier using an overhead gantry or cranes. (Figs. 3 and 4) Usually, stability is provided by the gantry or by temporary towers at the permanent piers. Cantilevers are joined by cast-in-place midspan closures. (Examples: Ramp-I and I75/I595 interchange.)

(c) Progressive Cantilever - where segments are erected in cantilever in one direction, starting at one end of the bridge and progressing over all the piers in sequence. Additional intermediate temporary piers or towers with cable stays are needed to facilitate construction. (Fig. 5) (Example; the Linn Cove Viaduct in North Carolina.)

Since the majority of segmental bridges are continuous structures, the method of construction, particularly the sequence of achieving continuity from one span to another, influences the statical scheme and the finally induced moments and forces. This is why construction is such an integral part of the design process.

2.2 Segment casting and erection

Precast segments are usually made in a special form or "casting cell" (Fig. 6) where a new segment is cast against its older neighbour to achieve a perfectly mating or "match cast" joint.

During erection, temporary post-tensioning bars are used to secure each segment to its neighbor prior to installing and stressing the permanent longitudinal post-tensioning tendons which provide the structural capacity and continuity of the superstructure. Longitudinal post-tensioning tendons are typically external to the concrete in span-by-span and internal in cantilever construction. Joints between segments are usually sealed with epoxy in cantilever construction or left dry in span-by-span.

In Florida, various erection systems have been used, (Table 2); mostly ground based crane for cantilever erection at interchange sites and truss or gantry for span-by-span erection over water. Beam and winch devices were used for the main spans of the Sunsine Skyway Bridge and an overhead gantry for the span-by-span approaches (Fig. 7). Various gantries and trusses have been used elsewhere; some examples are shown in figures 11 and 12.

2.3 Time and Costs

Rates of erection have been geared to the project size and contract duration. After a few weeks learning period, span-by-span construction typically achieved 3 spans per week and balanced cantilever four to six segments per day per cantilever. Despite delays on a few early cantilever projects, 11 segmental cantilever bridges on two major interchanges were recently completed nine months ahead of schedule.

For comparison purposes, construction costs based on bid prices from survey of 75 bridges built in Florida over three years up to F.Y. 86-87 are summarised in table 3. Despite occasional difficulties, delays and claims, segmental bridges have proven their worth and remain competitive in the major bridge category.

3. Issues Arising from "Shop Drawings" for Segmental Bridges

It should be clear from the above that segmental construction has involved the preparation and review of many shop drawings for special items such as, casting machines and erection systems, falsework, temporary stability towers, trusses, gantries, lifting devices and so forth. Frequently, detailed shop drawings for all the concrete segments were required although the effort needed depended upon the extent of detail provided on the original plans. In all cases casting curves (camber), detailed geometry control and step-by-step erection manuals have been required.

In addition, in recognition of the "State of the Art" nature of segmental construction and that the design is linked to the construction method, contractors have been allowed to propose changes to better suit their chosen erection methods. In turn, this has required the submittal of supporting calculations and re-analysis of the structure itself (permanent works) to verify that it remains within the prescribed design limits. (This is particularly so, if it is built in a different sequence to that designed as it changes the statical scheme, inducing different internal moments and forces in the final continuous structure.)

To some extent, this dichotomy led to confusion over roles and responsibilities and greatly increased the overall shop drawing effort. Questions arose such as;

- How detailed should the original design plans be?
- If the bridge design is dependant upon the construction method, what assumptions should a designer make and what should be shown on the plans?
- Who is the designer if the bridge is changed to suit the erection system?
- What role does the original designer play in reviewing and approving changes to suit the contractors erection methods?
- What is the contractor responsible for?
- Who carries the liability for the final as-built structure?
- How much detailed review should the original designer give to temporary erection equipment or falsework (temporary works)?
- How much detailed review should the original designer give to minor changes to segment details (i.e. moving rebar, adjusting dimensions etc.)?

- What review does the Department provide since no shop drawing can be used for construction without the Departments stamp of approval?

- Who is responsible for delays and claims as a consequence of any changes, no matter how major or minor?

- What role does the Construction Engineering and Inspection agency play?

.....and so on.

Also, shop drawing preparation and reviews influenced time on some segmental projects. This, and similar cases on many other bridges nationwide, stimulated improvements in processes and procedures within Florida and, to some extent, nationally through Federal Highway Administration directives and the implementation of the new AASHTO Guide Specification for Segmental Bridges. The latter is new and not very specific on the question of shop drawing information, reviews or dispositions. Some specific suggestions for segmental bridges are offered in Appendix A below.

Basically, the above are questions of defining roles, responsibilities, the nature of the work under review, paper flow, liabilities and so on. Summarised, this is "administration" and it is not confined to segmental bridges but applies to all types.

4. Shop Drawing Issues within the General Construction Industry

General claims, litigation and rising insurance costs due to a series of accidents in the early 1980's focussed attention on shop drawing issues and prompted an investigation and report in the private sector. (ref. 3) The conclusions and recommendations of this report were very similar to an earlier report of 1976. (ref. 4). (This begs the question as to whether the profession or industry as a whole can ever settle this issue? Perhaps it needs some stimulus from federal or state legislation such as outlined herein to implement improvements.)

The conclusions of these reports are essentially as follows;

- Courts do not understand the technical issues involved in the design and construction of a project or the complex relationships that exist between the parties.

- There is not enough law to establish a precise list of what must and may not be done as regards the design professionals' responsibilities.

- Each case taken to trial involves a lot of testimony to educate and explain technical issues to those who decide the case. This requires many experts and costly presentations.

- Courts look skeptically on contract language or other efforts to reduce the responsibilities of design professionals below that required for the public good.

- Courts and arbiters rely upon standard documents prepared by objectively and fairly by industry professionals to establish appropriate practices and responsibilities.

- All parties should understand their responsibilities and adhere to procedures set forth in standard documents (such as the "Engineers Joint Contracts Document Committee's Standard Documents") to minimise mistakes and misunderstandings.

The recommendations in these reports are summarised;

- All parties should be reminded of the significance of shop drawings to a contract and their obligations.

- Adhere to established procedures.

- Specifications should only call for shop drawings to cover those submittals essential to the project and pertaining to its' design aspects and the Engineer's professional functions.

- Owners should appreciate the importance, time and costs needed for a professional review.

- The Engineer should confine his review .. "for conformance with the design concept....and compliance with the information given in the contract documents."

- The Engineer must not do the Contractors' job and should insist on proper submittals prepared and reviewed by the contractor.

- Adhere to submittal timings and keep a log.

- Given reasons for non-approvals.

- Resubmittals should be carefully checked against the original submittal.

- Submittals should be reviewed by professional peers and adequate time allowed.

- Engineers' stamp of approval should indicate its' limited purpose according to the Contract Documents.

- Engineers must recognized that approval of an item indicates acceptance to the same extent as an item in the Drawings, Specifications and Contract Documents.

- Engineers should recognize that shop drawing reviews are one of their professional functions and not evade responsibilities.

5. The Development of Policies and Practices within Government

Construction practices were questioned in a 1984 report by the U.S. House of Representatives committee on Science and Technology entitled "Structural Failures in Public Facilities". It cited many concerns; some of the prominent ones are paraphrased from a summary (ref.5) prepared for the Florida Department of Transportation as;

- Communications between participants in construction projects is lacking.
- Structural engineers should inspect construction.
- Design quality is falsely sacrificed to speed and costs.
- Structural connections are sometimes left to unqualified detailers.
- Low bid fee competion.
- Failure to disseminate information on mistakes.
- No overall designated accountability for structural integrity.
- Deliberate low bidding followed by claims.
- ...and so on.

The Federal Highway Administration issued a directive on June 28 1984 requiring that States;

- Introduce special bid conferences for major projects
- In contract special provisions, define responsibilities for erection procedures
- States shall independantly verify a contractors' construction calculations on major and unusual structures.
- Assign a qualified publicly employed engineer to be in responsible charge.
- Introduce longer bidding periods for major projects
- Hold regular meetings during construction to communicate and solve problems.

It did not specifically address the self adequacy of erection equipment and falsework. Subsequent clarification added erection equipment to the required checks and emphasised the need to avoid conflicts of interest by not allowing engineers to work for the contractor and the client.

Nevertheless, there is a distinct difference between erection equipment (gantries, towers, falsework) and the erection of the structure (sequence of adding segments, post-tensioning and making continuity between spans). The former are specific items only the contractor can control, the latter affects the final structural regime of the permanent structure which is of interest to the designer and state.

For example, during construction of the segmental bridges on the I-595 projects in South Florida, one contractor proposed several relatively minor changes to the design to facilitate his prefered erection sequence and methods. These changes affected the statical regime of the permanent structure and therefore required the review and approval of the Department, the Engineer of Record (consultant designer) and the Federal Highway Administration. Appropriate terms were agreed and the Contractor was allowed to proceed. For the revisions to the design, the flow of submittals followed the path shown in fig. 10. Normal shop drawings on this and other similar projects followed the path shown in Fig. 11. In view of the FHWA policy at the time, temporary erection equipment was reviewed in detail for self-adequacy by the Engineer of Record.

The Department has traditionally held the view that the structural integrity (self-adequacy) of temporary erection equipment, falsework and similar devices is the sole responsibility of the contractor regardless of the type of structure under construction. It should be reviewed for its' effect upon the permanent structure but not for its own self-adequacy. The reasons cited for this view center upon the facts that:

1) the design engineer is not privy to the fabrication, construction or assembly of the equipment,

2) he does not have input into the material selection or detailing,

3) he has no evidence to verify that the materials shown on the drawings were in fact used,

4) industry wide liabilities and insurance requirements which most design consultants are unwilling or unable to accept.

However, the latest Federal directions of March 1989 require a detailed analysis and review of those parts of the temporary equipment or falsework which directly affect the safety of the travelling public. On most major urban interchange sites this is almost everything!

6. Florida Rule governing Public Sector Employees.

In 1987, a new rule was introduced by the Florida State Board of Professional Engineers (21H-26.001, F.A.C., "Standards for Supervision of Governmental Employees by Professional Engineers") which prohibits non-professional public sector employees over-ruling the engineering judgement of professional engineers unless a registered professional engineer within the agency takes responsibility for the decision. This was an important step which in raising standards and professional accountability within the State Government.

This rule was discussed at the American Society of Mechanical Engineers meeting in St. Petersburg in November 1987 with representatives of the Board of Professional Engineers present. They recommended that;

- Policy makers must be made to understand the need for the organization to permit a Professional Engineer to be "In Responsible Charge"

- That individual engineering responsibilities be clearly scoped out to protect their individual positions and define their roles to outsiders.

- Professional Engineers within the Department should present any concerns to the Secretary.

7. Current Practice of the Florida Department of Transportation

7.1 Departments Role and Position

The Department executes a two-party contract with a general contractor to construct a facility defined by design drawings and accompanying specifications. Upon favorable disposition of a shop drawing, as signified by the Department's stamp of approval, it becomes a binding contractual document. The Department may contract with a consultant to perform reviews and make recommendations as to disposition, but it is only the Department's stamp which makes the drawing an official contract document.

7.2 Structures Design Guidelines

Current policy for Shop and Erection Drawings is contained in the Department's "Structures Design Guidelines", Chapter 19. (ref.6)

Summarising, shop drawings are a means of permitting a contractor to propose, under certain specification guides, ways of accomplishing the work. They include all drawings, diagrams, catalogue material, procedure manuals, calculations and the like pertinent to the project. Certain miscellaneous and previously certified items do not necessarily require shop drawings (e.g. light poles).

Generally, shop drawings are required for any structural component of steel or concrete, fabricated off site. This chapter also sets out the format and standards of submittals and requires that prime contractors certify that they have reviewed the submittal and that it meets the contract requirements. They are also required to specifically point out variations from the contract so that the Department can determine if a Supplemental Agreement or Value Engineering is required.

Since the "Guidelines" are not a construction contract document, definitions and specific shop drawing requirements are often repeated in the Specifications or Special Provisions. Alternatively, these may refer directly to the "Guidelines" and require that submittals comply with it.

The "Guidelines" also define the "Engineer of Record" and the "Specialty Engineer". For example; the former is the original project designer engaged by the Department and the latter the qualified engineer engaged by the Contractor. A qualified "Specialty Engineer" is required if the shop drawings introduce engineering input. This is usually case with fabricated structural components and special erection equipment or falsework. He is required to sign and seal the those drawings and calculations which he prepared. Erection equipment drawings must carry the seal of the Specialty Engineer.

A schedule of submittals is strongly recommended for major projects. Figure 12, (reproduced from the "Guidelines") illustrates the directions for copies and paperflow for the review of all structural shop drawings. The "Guidelines" also contain instructions for the disposition of shop drawings as either "approved", "approved as noted", "resubmit" or "not approved" for all items pertaining to the permanent structure.

For erection equipment and falsework, the disposition is either "not approved" or "approved as noted" where the latter contains a disclaimer that the equipment or falsework has been reviewed only for its effects on the structure and not for self-adequacy. The question of detailed verification of equipment and falsework over public routes is still open as regards the general situation but resolved on a case-by-case basis to the mutual satisfaction of all parties whenever necessary.

7.3 Contractor's Form Letter

Beginning with the bid award packages of December 1987, a document and cover letter was introduced which is loosely called the "Contractor's From Letter". While not a contract document, the letter and it's enclosures describe the shop drawing preparation, submittal, review, disposition and distribution procedure of the Deparment. It generally parallels Chapter 19 of the Structures Design Guidelines but is tailored more to the Contractor's role and to questions on the shop drawing submittal process he might have. It basically expounds putting into practice the idea that "If you do your part, then we will do our part and we'll both be better off for the effort!" The shop drawing flow diagram of figure 9 and a similar one for non-structural shop drawings (light poles, attenuators, traffic devices etc.) are included with the letter.

7.4 Construction Procedures

A shop drawing and erection drawing approval procedure was officially implemented in May 1989 by the Department's Office of Construction. (ref.7) This parallels Chapter 19 of the Structures Design Guidelines, repeating the requirements in the construction area.

7.5 Construction Specifications.

Definitions and requirements are set out in the General Specifications, Section 5 "Control of the Work". Specific shop drawing requirements for structures such as segmental bridges are usually provided in Special Provisions pertinent to the project.

7.6 Out of Specification or Change of Conditions Situations

This was the subject of a lively panel discussion at the ASME meeting in November 1987 and many concerns were raised. No specific conclusions or recommendations ensued except that each parties' roles and responsibilities need clearly defining and that contracting procedures, bidding processes, pre-qualifications, communications, specifications, legislation, etc. needed clarifying or changing.

In the area of precast concrete, the Department has introduced a "Procedure for Proposing Acceptance of Deficient Prestressed Components" (No. 700-030-010a, Jan 1990). This clearly sets out the conditions under which non-complying members may be categorized as to severity, repairs or other proposals presented, reviewed and dispositions made. It addresses the roles of the Engineer (Departments District Construction Engineer), Engineer of Record (designer), Specialty Engineer (producers' engineer), Resident Engineer and Yard Inspector. Any structural repair proposals must be prepared by the Specialty Engineer and reviewed by the Engineer who may enlist the assistance of the Engineer of Record and Federal Highway Administration as deemed appropriate.

(A similar procedure is being prepared for structural steelwork. Also, in each case, appropriate specification requirements regarding implementation of the procedures are being developed.)

8.0 Discussion and Conclusions

A shop drawing may cover any conceivable item for the construction of the project. At one end of the spectrum there are non-structural, "off the shelf" commercial components (i.e. light poles); at the other perhaps a re-design of the permanent structure itself. This is a broard and diverse range.

- Do we know who should see what?
- Is it possible to ensure that the right drawings are reviewed by the right people?
- Can the Clients interests be protected?

Possibly; providing items can be clearly defined and the extent of a professional's interest and responsibilities defined to match.

- How can the Client (State and FHWA) be assured that all appropriate reviews are made?

Either, they must perform the reviews themselves or engage a consultant. Usually, they prefer to retain the Designer (Engineer of Record) to perform "shop drawing" reviews and rely on the project Specifications to identify items that need submittals.

- But, does this mean they expect the Designer to receive and review "everything"?

Clearly, the Designer has an interest in anything which brings "engineering" into his project - especially items which, to a greater or lesser extent, modify his design. Anything that the Contractor uses for his own purposes, providing it does not affect the final structure is of lesser interest to the Designer; in fact, the Designer may not wish to know anything about some items in order to protect his own liability. So, the Designer cannot review everything.

- Should the Client (State) be in the review loop?

As far as State of Florida contracts are concerned, the State must be "in the loop" because a shop drawing cannot become a legal contract document without its' stamp of approval - so all shop drawings must finally pass through the State. The reason is because of a clear contractual demarcation. The State has a contract with the Designer for the design plans and a separate contract with the Contractor for construction; consequently, there must be no instructional communication between the Designer and Contractor. This is also Federal policy.

- So, who should decide on what is to be reviewed?

Clients usually have qualified personnel and resources for routine project administration, but not for large or complex jobs where they normally engage a Construction Engineering and Inspection (CEI) agency. In Florida, the "CEI" is the primary point of contact between the State and the Contractor for contract administration; in a sense the CEI is an "extension" of the State. However, current State policy places the CEI at the end of the shop drawing loop; to be only a recipient and enforcer of approved shop drawings (as is the case with the States' own contract administration personnel).

- Could the CEI decide on what is to be reviewed?

One objective of employing a CEI is to obtain "technical expertise" which is not readily available within the State. In fact, Federal policy often requires the State employ a CEI with very specific expertise. So, if selected properly, the CEI should be technically qualified and able to judge the degree of "design engineering" or "construction engineering" elements in any submitted item.

- If so, might he act as a "clearing house" for submittals?
- Would this protect the Clients interests?

Perhaps. But, in Florida, it is not allowed by established policies and contractual requirements. This means that in most cases, the practical solution is to submit all shop drawings to the Designer and let him decide what he can and cannot review.

- If a change is required to the Designers' services contract to perform extra work as a result of a construction change who makes the change and is the CEI involved?

There is no established policy or procedures for this in Florida at present and it is difficult to see how this could be established given current overall State and Federal attitudes which are that "...the design is O.K. so why should it be changed?" Of course, there can be any number of reasons. These usually come under "contract administration"; which is the CEI's field. In practice, a design change resulting from a construction change, for any reason, will require the involvement of both the Designer and CEI. To date cases have been dealt with as-needed.

- Is it possible to establish rules and procedures in advance to cover all eventualities?

Routine projects may be controlled this way but certainly not large and complex ones. The mis-application of rules designed for the "routine" quickly leads to trouble. In practice, for complex projects, flexibility is needed. But it should be within broardly defined guidelines.

- Who should establish the "guidelines"?

In conjunction with professional and industry bodies, State and Federal agencies should establish broard guidelines. However, on any particular project, communications, paper-flow and reviews will depend on the project and should be tailored to suit. Each party, the Client, Designer, CEI, Contractor has his own interests and these should be satisfied by mutual agreement within the project management structure.

- What of communications?

A vital key is clear and effective communications between all parties. Regular meetings with key personnel to openly discuss issues, resolve them and plan ahead are essential, especially on major projects. It is helpful to have an "informal" network via telephone and fax to address matters in a preliminary form before committing to official submittals.

- Policy developments; who needs to know?

All parties should be aware of policies and developments. This places some responsibility upon Clients (States and FHWA) to keep Designers, CEI's and Contractors appraised through circulars, meetings and up-dated guidelines. If any organisation doubts their instructions they should always seek clarification.

- What can we conclude?

Perhaps the only conclusions that can be drawn are that the issues surrounding shop drawings and all the attendant questions of liabilities, responsibilities and consequences remain open although significant progress has been made through initiatives within private and public sectors. Many issues affect the industry and should be addressed through joint consultations.

(Footnote; any questions raised and views expressed are those of the authors and not necessarily of the Florida Department of Transportation, the Federal Highway Administration or any other organisation.)

9.0 References

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10.0 Acknowledgements

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Post, Buckley, Schuh & Jernigan, Inc.
Tony Gee & Quandel (Alfred Benesch)
Volker-Stevin Construction Inc.

11.0 Figures

12.0 Tables

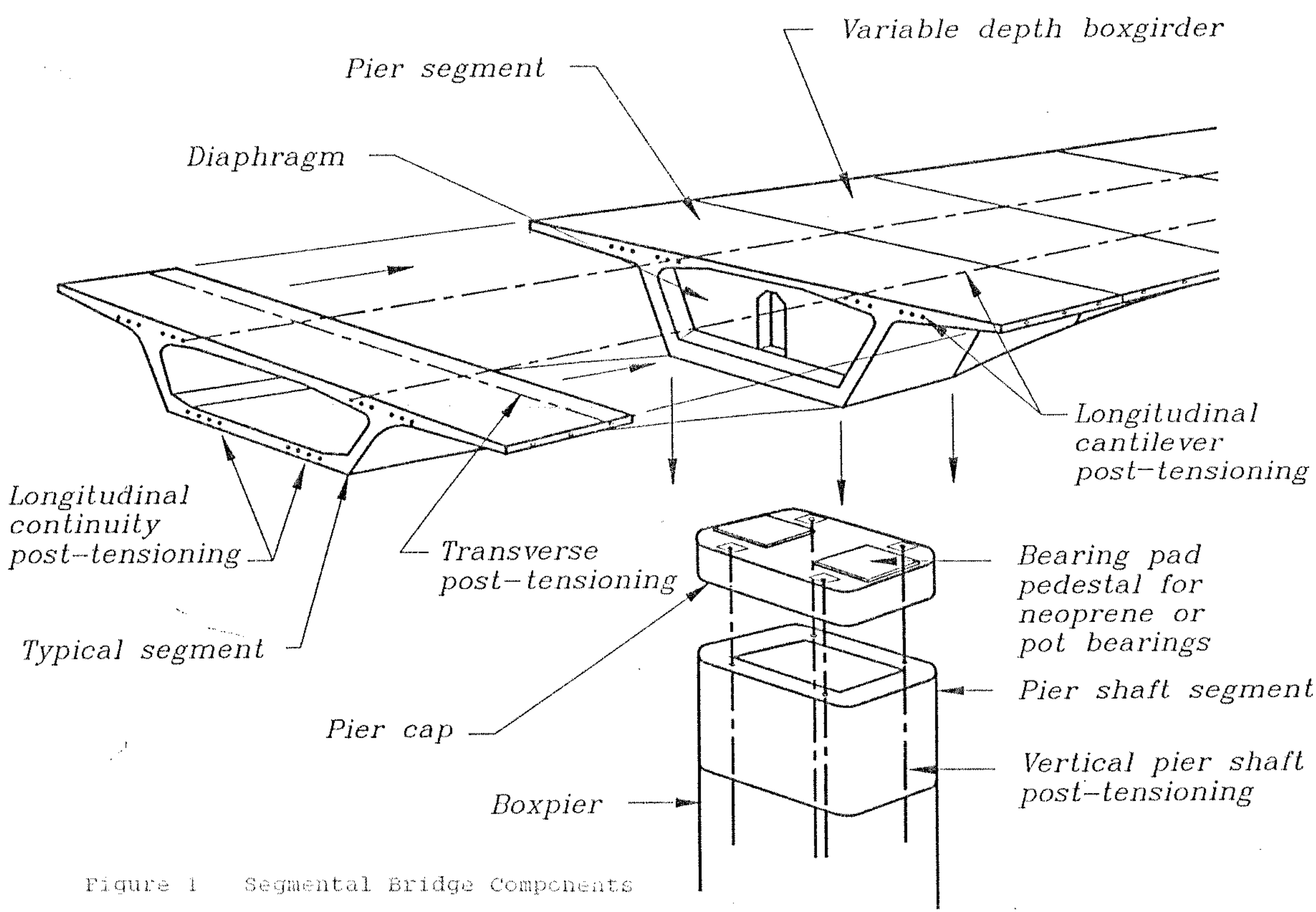


Figure 1 Segmental Bridge Components

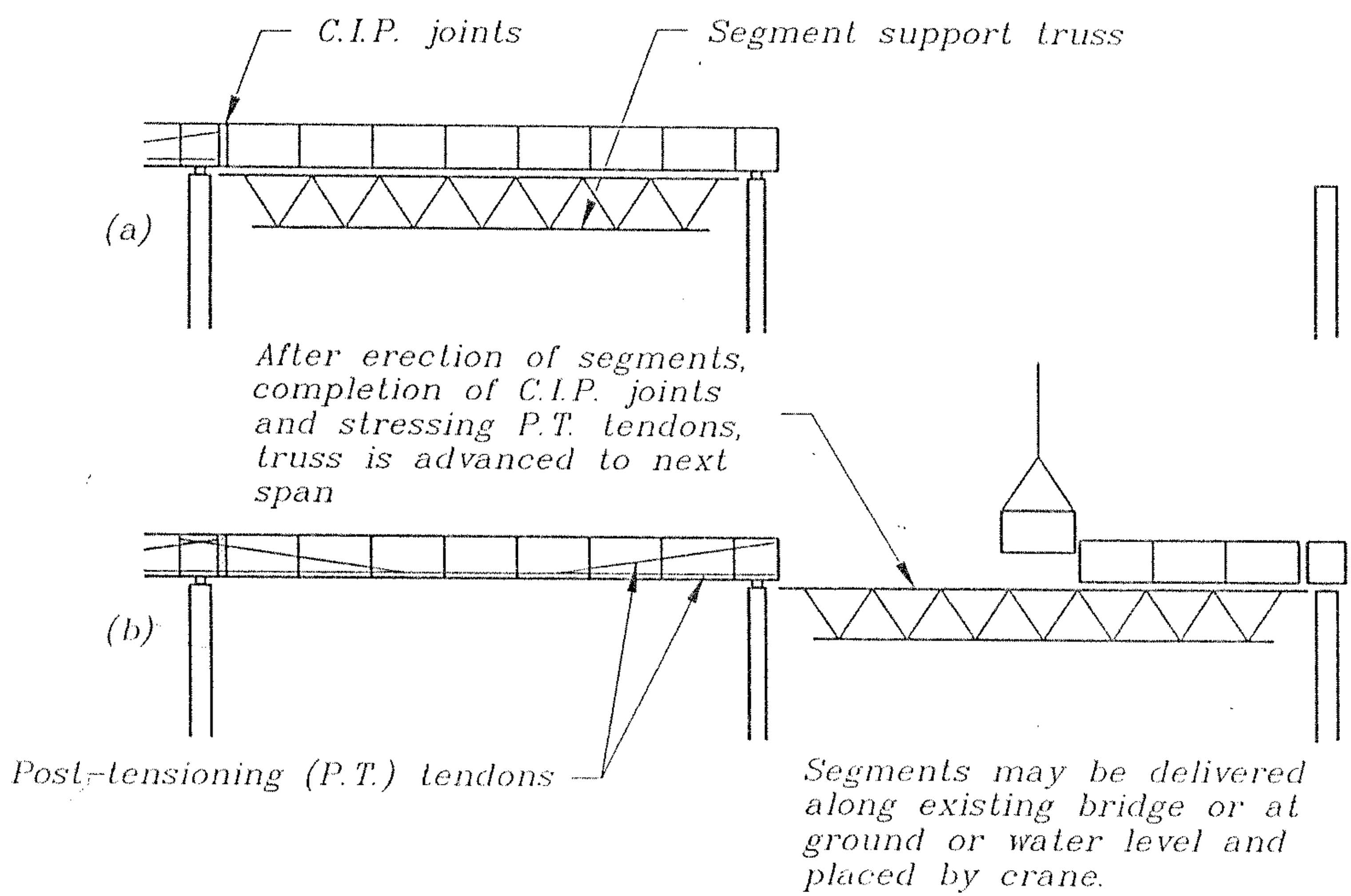


Figure 2 Span-by-Span Construction.

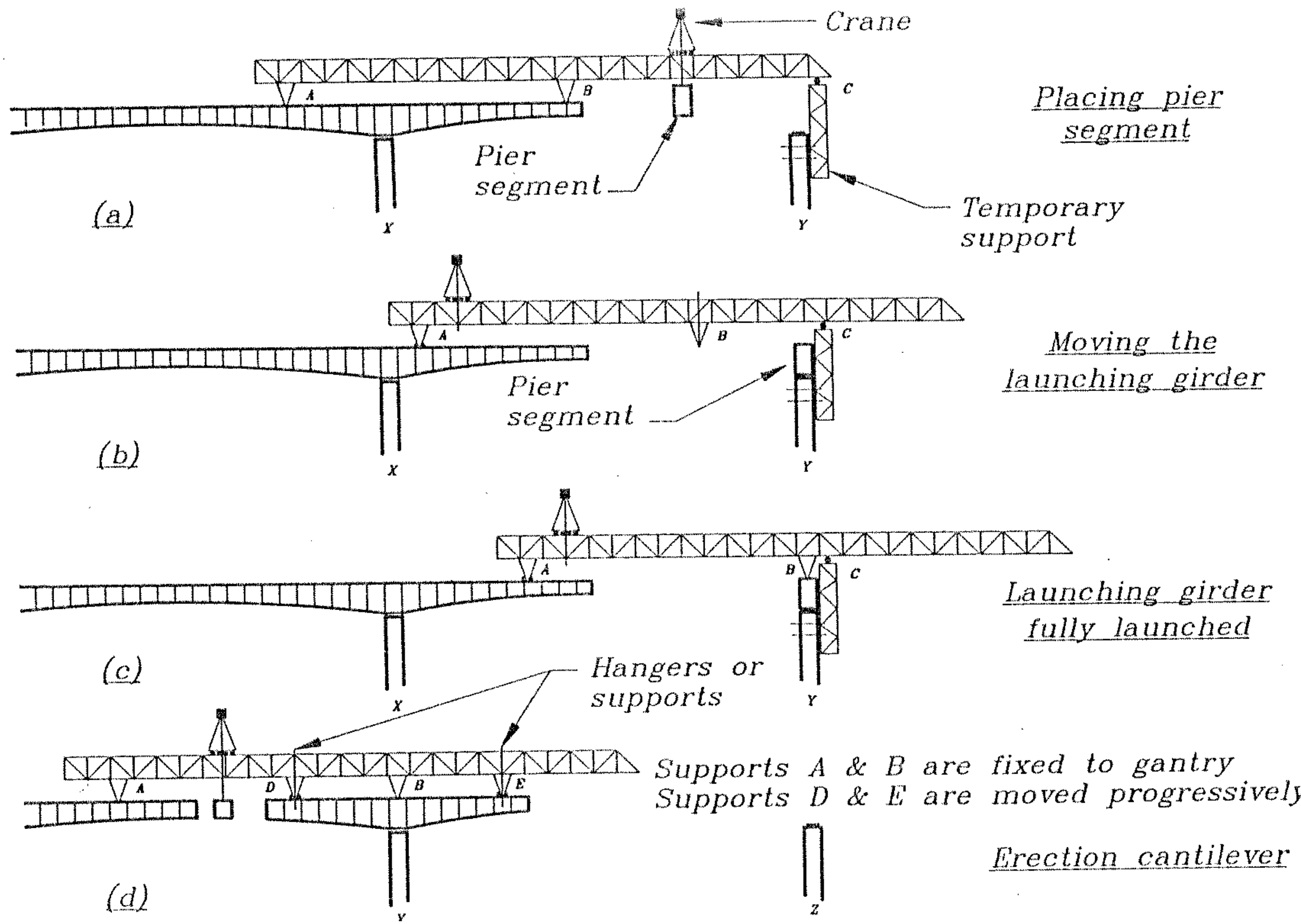


Figure 3 Launching Gantry for Overhead Cantilever Erection.

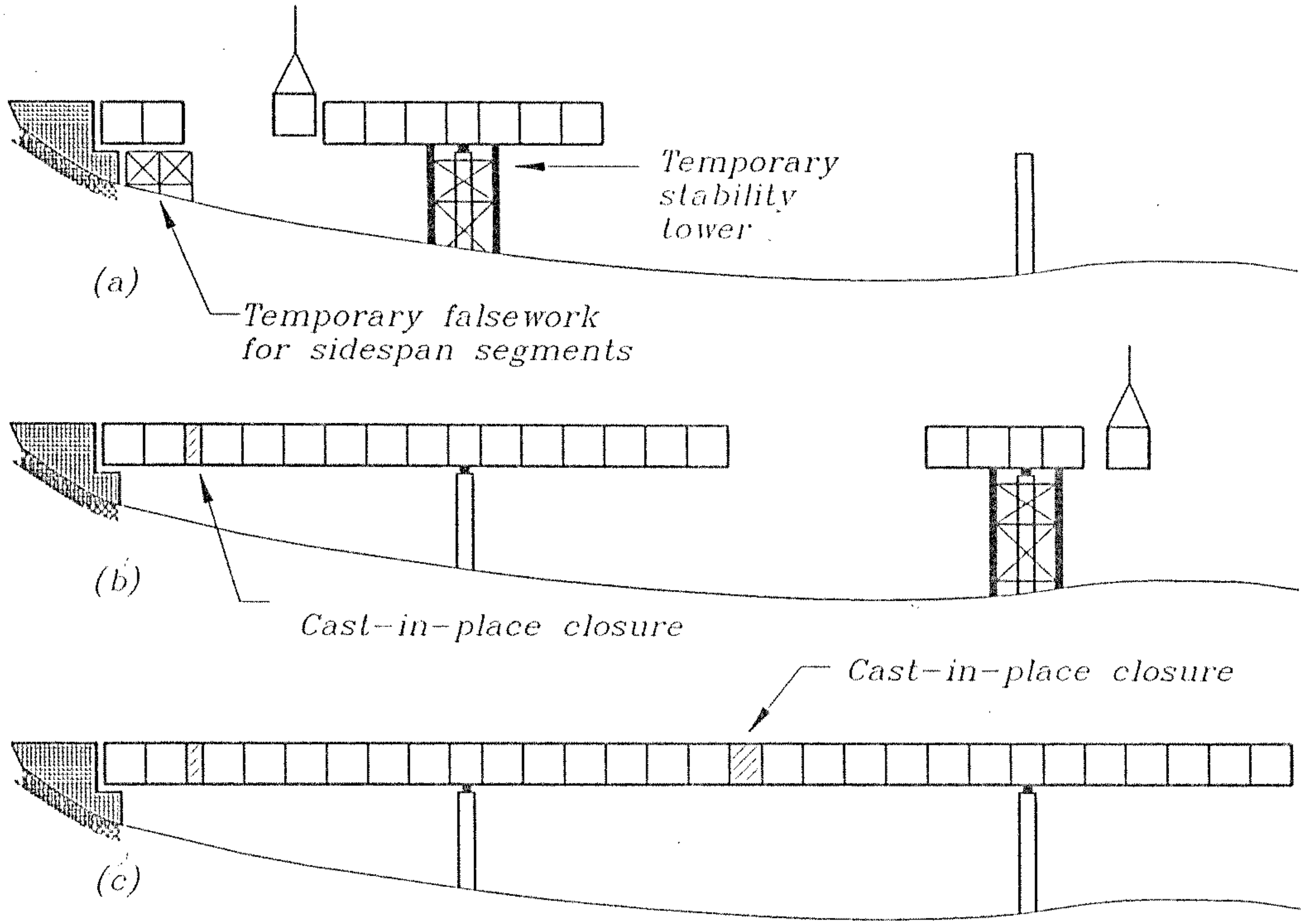


Figure 4 Balanced Cantilever Erection.

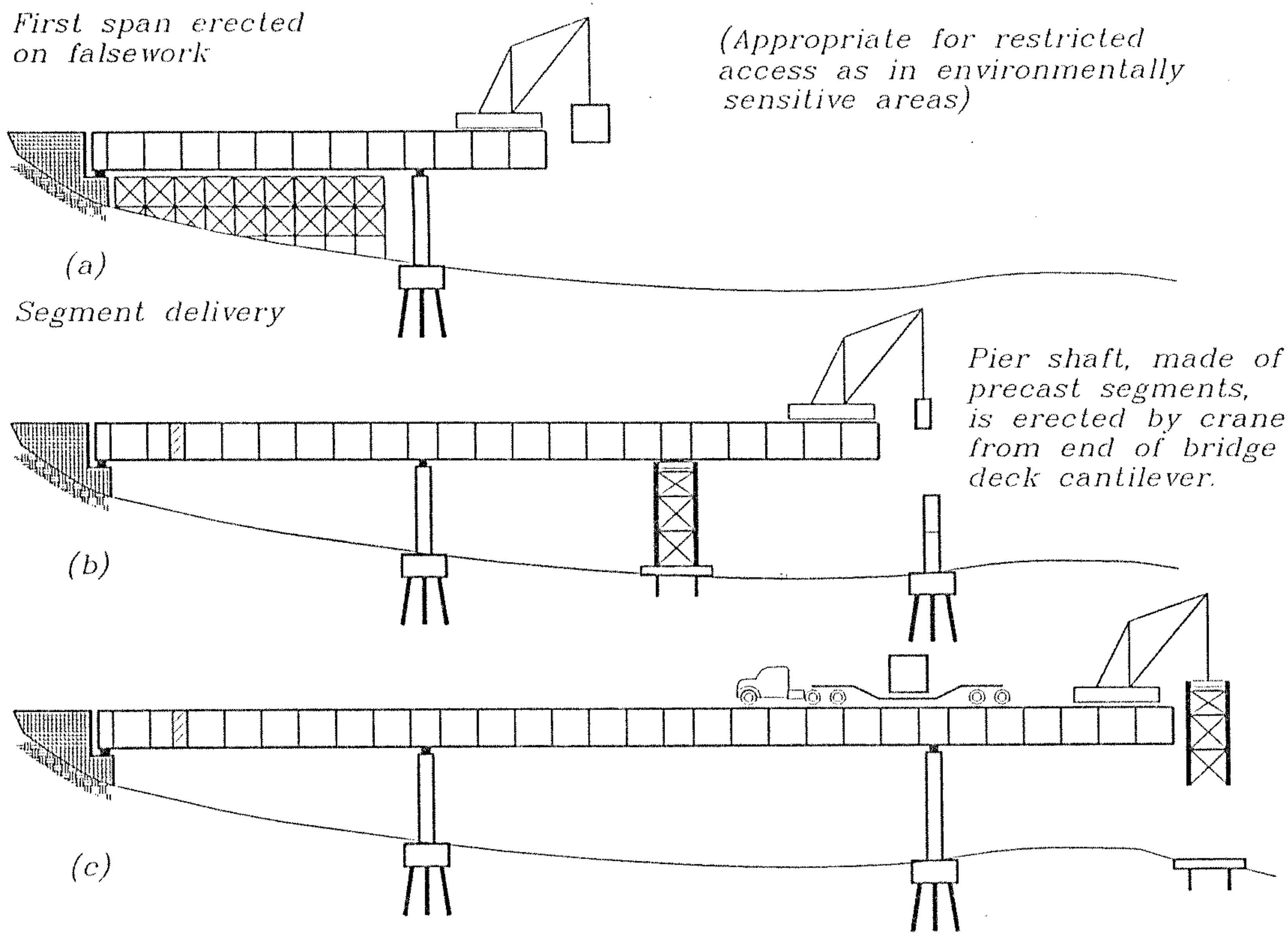


Figure 5 Progressive Cantilever Erection.

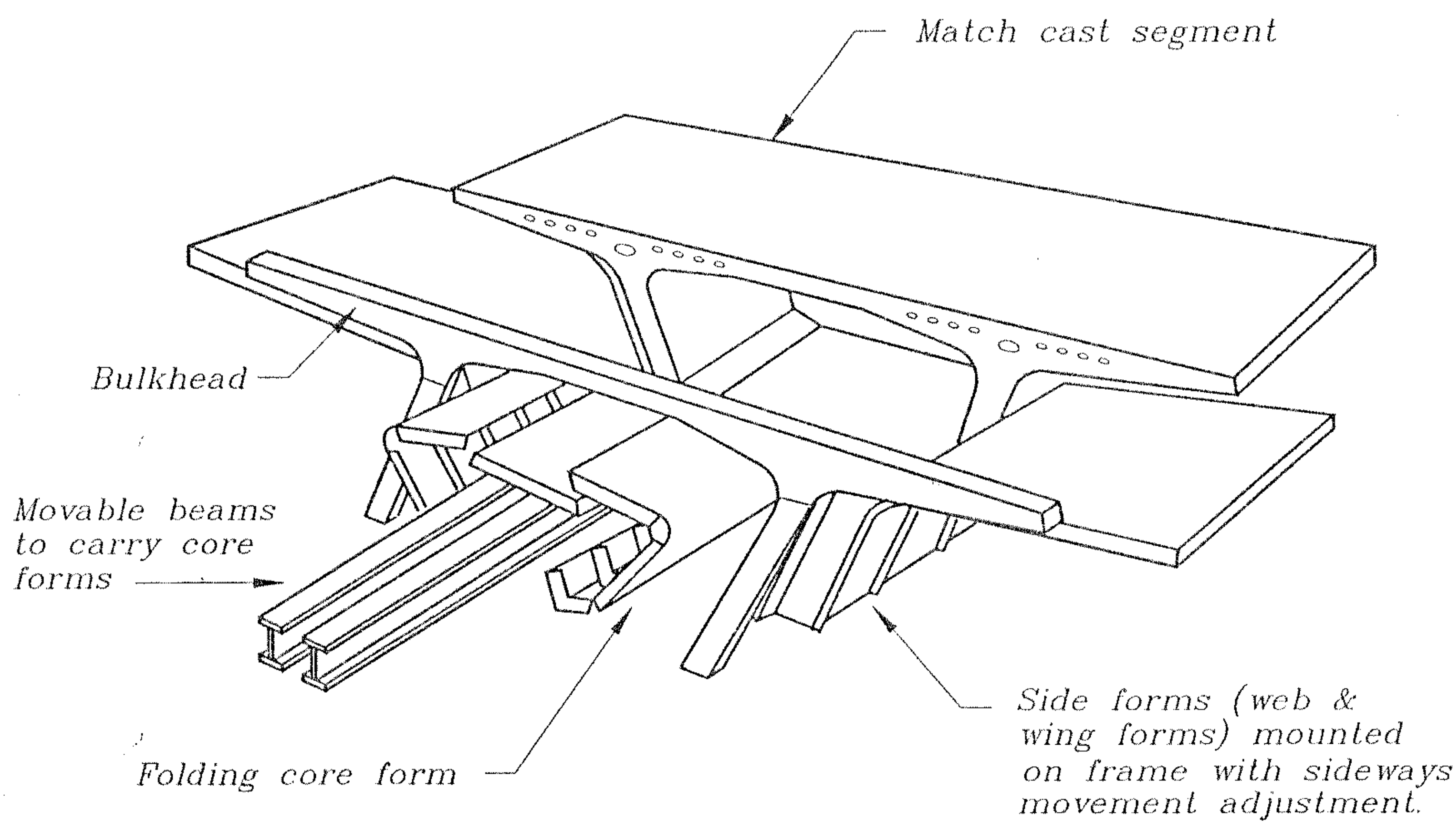


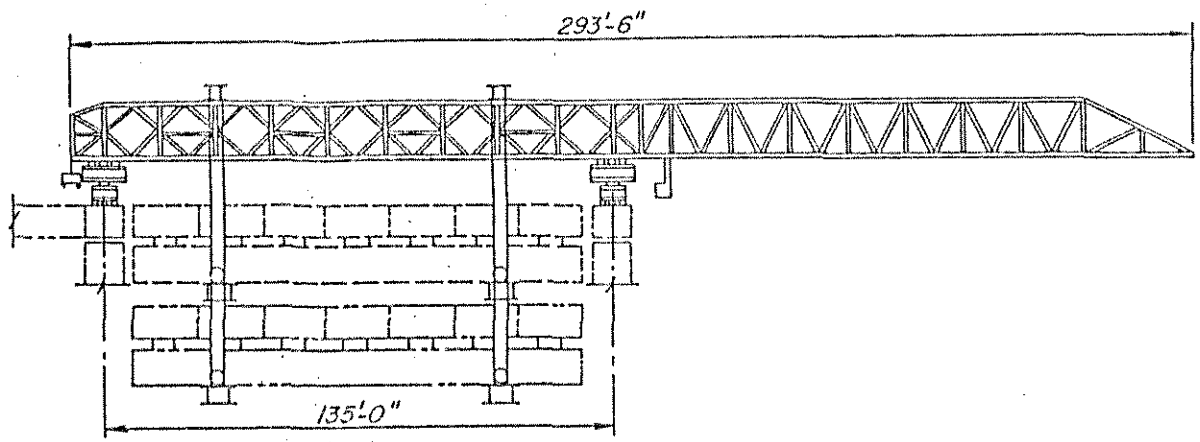
Figure 6   Casting Cell (Short Line Method).

SUNSHINE SKYWAY BRIDGE (1986)

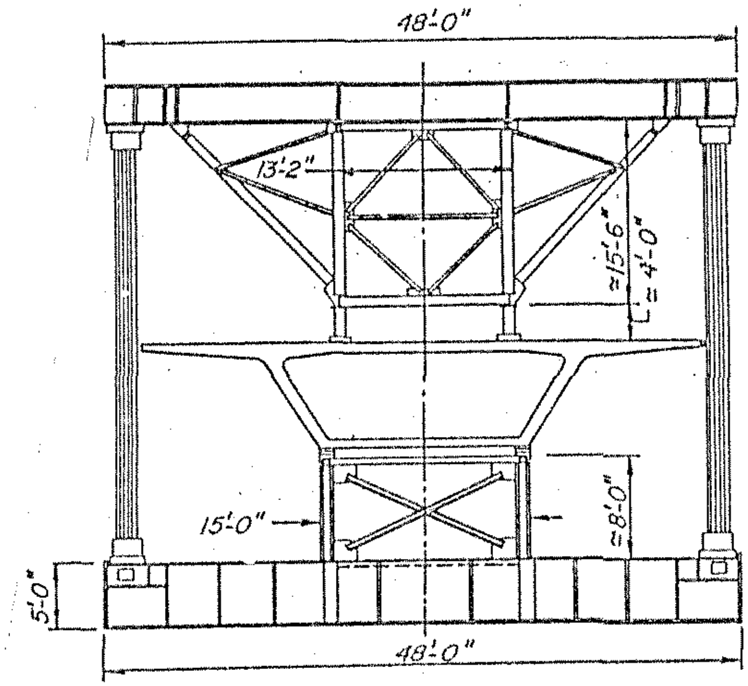
CONTRACTOR=PASCHEN CONTRACTORS, INC.

Figure 7

Span-by-Span Overhead Gantry



ELEVATION



TRANSVERSE SECTION

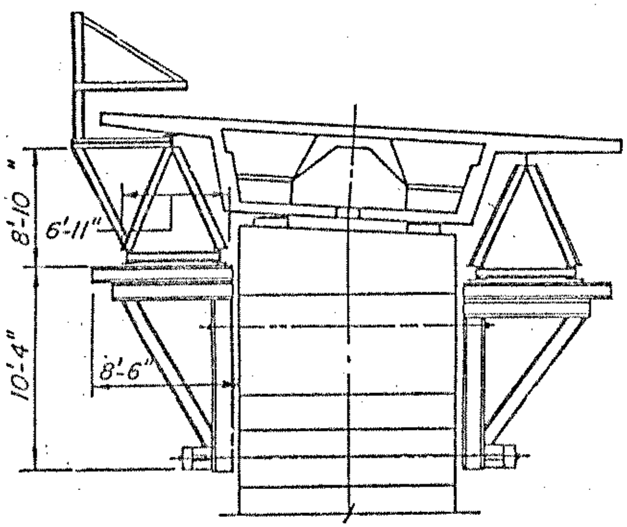
GENERAL CHARACTERISTICS		
TRUSS WEIGHT	PER SIDE	GANTRY - 500K INCLUDING COUNTER WEIGHT ON NC
	TOTAL	LIFTING FRAME - 170K
SEGMENTS WEIGHTS (KIPS/FT.)		8.5
MAXIMUM BRIDGE SLOPE		4%
SUPPORTS WEIGHT		CARRIED BY GANTRY = 20K EACH
AVERAGE TIME REQUIRED TO RESET FROM ONE SPAN TO THE NEXT		2 HOURS
DESCRIPTION OF SEGMENT SUPPORTS		SLIDING PADS ON TEFLON WITH SHIM STACKS FOR VERTICAL ADJUSTMENT AND SLIDING PLATES + SCREWS FOR HORIZONTAL ADJUSTMENT
AUXILIARY EQUIPMENT	WINCHES	FOR LIFTING AND LAUNCHING .
	P.T. PLATFORMS	HANGING FROM GANTRY IN FRONT OF PIER SEGME

GENERAL REMARKS

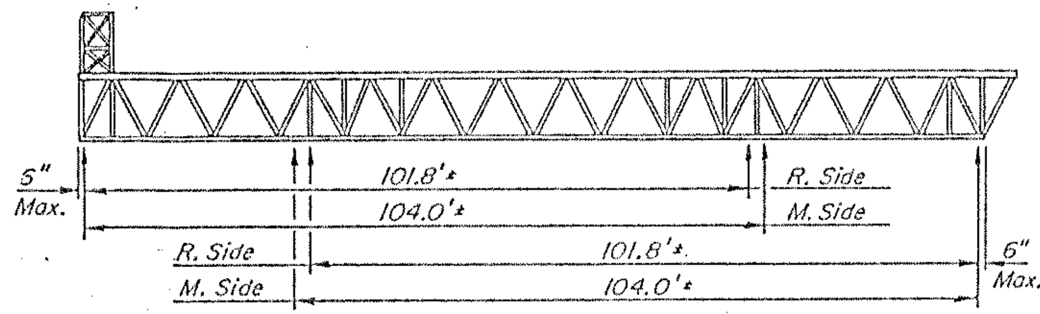
THE GANTRY WAS FIRST USED FOR THE 7-MILE BRIDGE. MODIFICATIONS INCLUDE: REMOVAL OF MAST AND STAYS, NEW LAUNCHING NOSE -- THE PIER SEGMENTS HAVE TO BE ERECTED WITH AN INDEPENDENT CRANE.

GLENWOOD CANYON BRIDGE (1985)

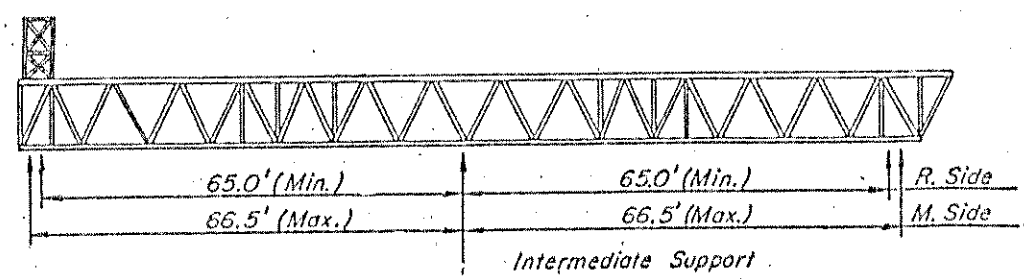
CONTRACTOR=FLATIRON STRUCTURES CO.



TRANSVERSE SECTION



ELEVATION



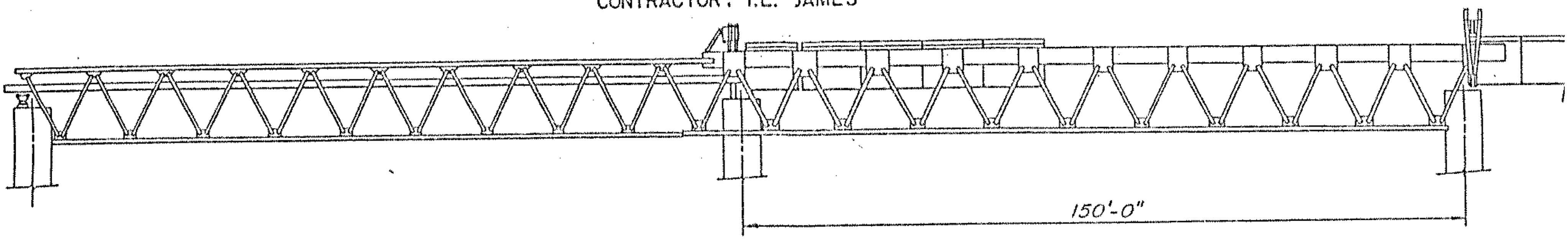
ELEVATION

GENERAL CHARACTERISTICS		
TRUSS WEIGHT	PER SIDE	0.65K/FT
	TOTAL	1.30K/FT
SEGMENTS WEIGHTS (KIPS/FT.)		8.5
MAXIMUM BRIDGE SLOPE		
SUPPORTS WEIGHT		
AVERAGE TIME REQUIRED TO RESET FROM ONE SPAN TO THE NEXT		
DESCRIPTION OF SEGMENT SUPPORTS		HILMAN ROLLERS WITH HYDRAULIC JACKS AND HORIZONTAL ADJUSTMENT SYSTEM
AUXILIARY EQUIPMENT	WINCHES	
	P.T. PLATFORMS	
GENERAL REMARKS		
TRUSSES WERE FIRST USED FOR THE MARTA PROJECT		

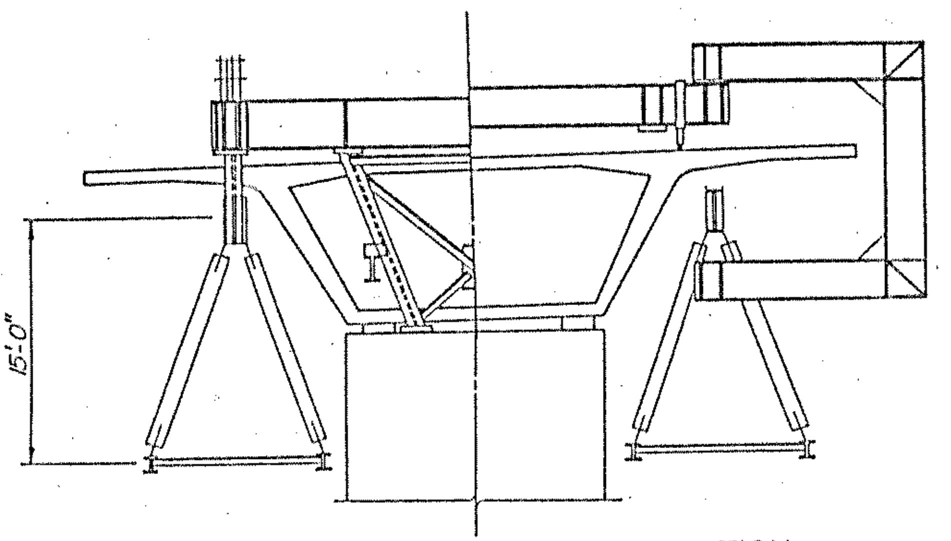
Figure 8 Glenwood Canyon Span-by-Span Underslung Trusses

WANDO RIVER BRIDGE (1988)

CONTRACTOR: T.L. JAMES



ELEVATION



HALF SECTION
CENTER FRAME SUPPORT

HALF SECTION
C-HOOK & REAR YOKE BEAM

GENERAL CHARACTERISTICS		
TRUSS WEIGHT	PER SIDE	
	TOTAL	MAIN TRUSSES: 224K LAUNCHING NOSE:
SEGMENTS WEIGHTS (KIPS/FT.)		10.7
MAXIMUM BRIDGE SLOPE		4%
SUPPORTS WEIGHT		CENTRAL: 25K REAR: 10K
AVERAGE TIME REQUIRED TO RESET FROM ONE SPAN TO THE NEXT		5 HOURS
DESCRIPTION OF SEGMENT SUPPORTS		ROLLERS WITH 50^T JACKS FOR VERTICAL ADJUSTMENTS - SLIDING PLAT AND SCREWS FOR HORIZONTAL ADJUST
AUXILIARY EQUIPMENT	WINCHES	FOR LAUNCHING
	P.T. PLATFORMS	
GENERAL REMARKS - THE TRUSS IS DESIGNED TO BE SUPPORTED ON THE TOP OF THE PIERS AND FROM THE ALREADY COMPLETED DECK. - THEREFORE, NO SUPPORTS ARE REQUIRED AT THE PIERS. - HOWEVER, THIS DISPOSITION REQUIRES HEAVY TRANSVERSE BEAMS FC LOAD TRANSFER.		

Figure 9 Wando River Span-by-Spa nderslung Gantry

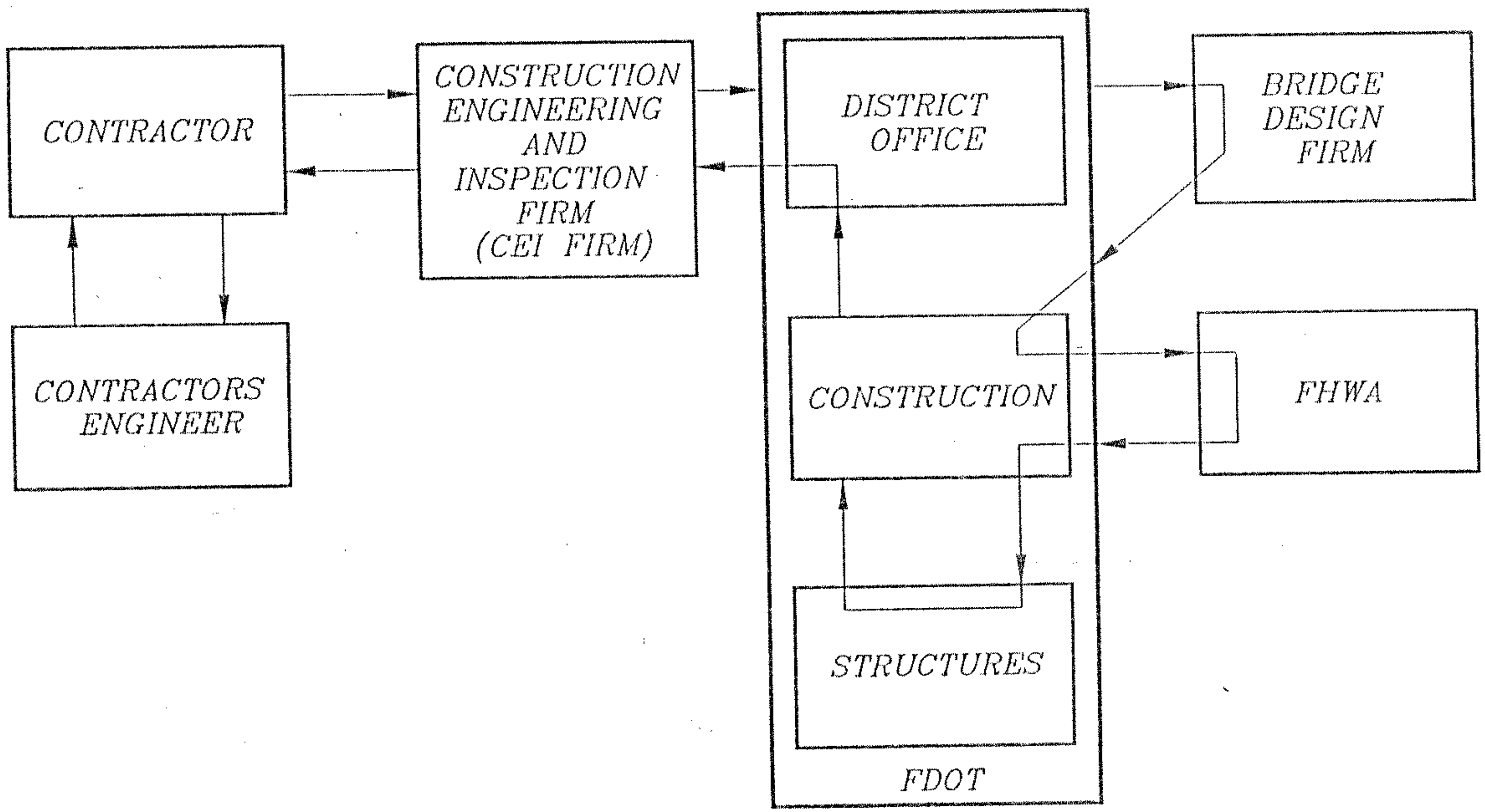


Figure 10 Flow of submittals for Design Revisions (I-595 projects)

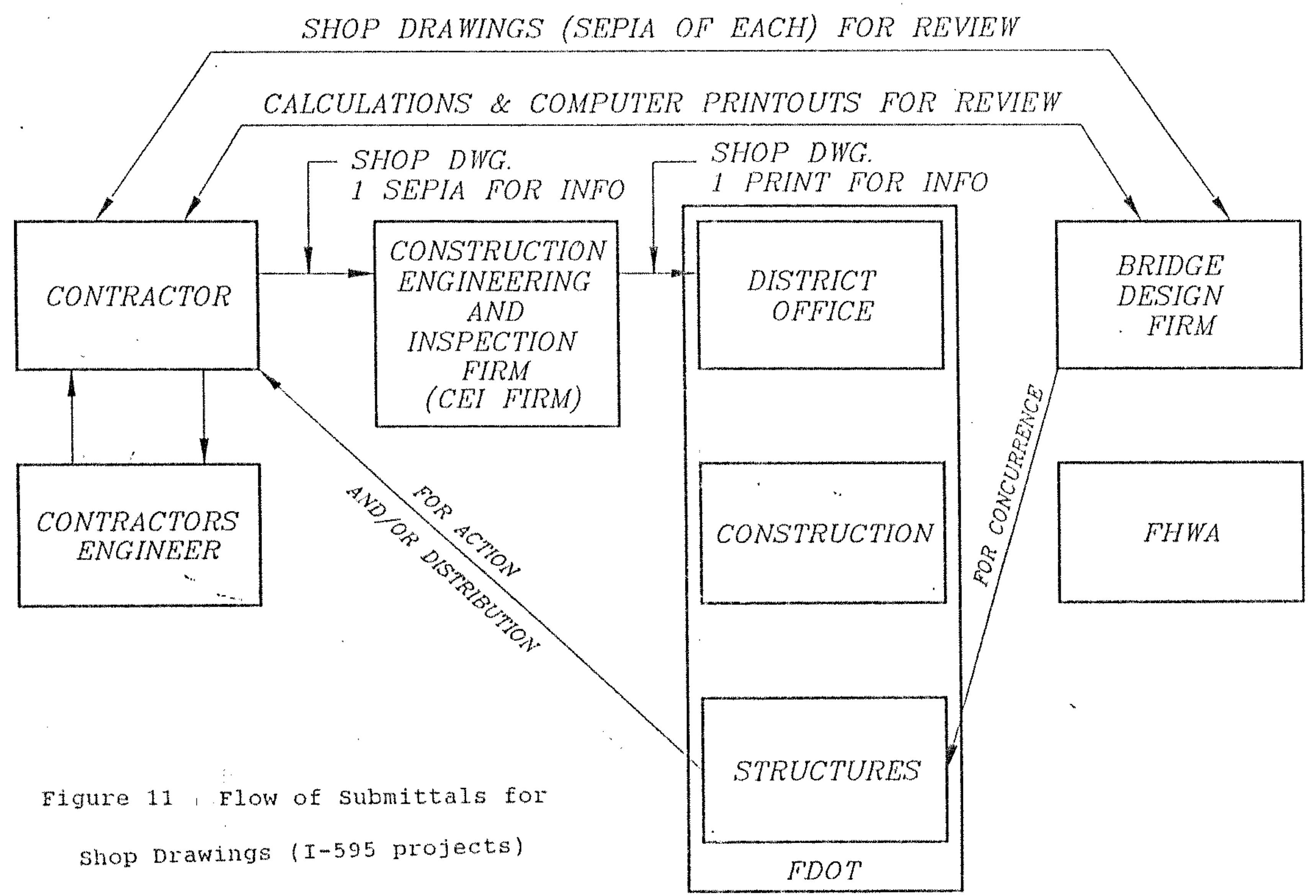


Figure 11 Flow of Submittals for Shop Drawings (I-595 projects)

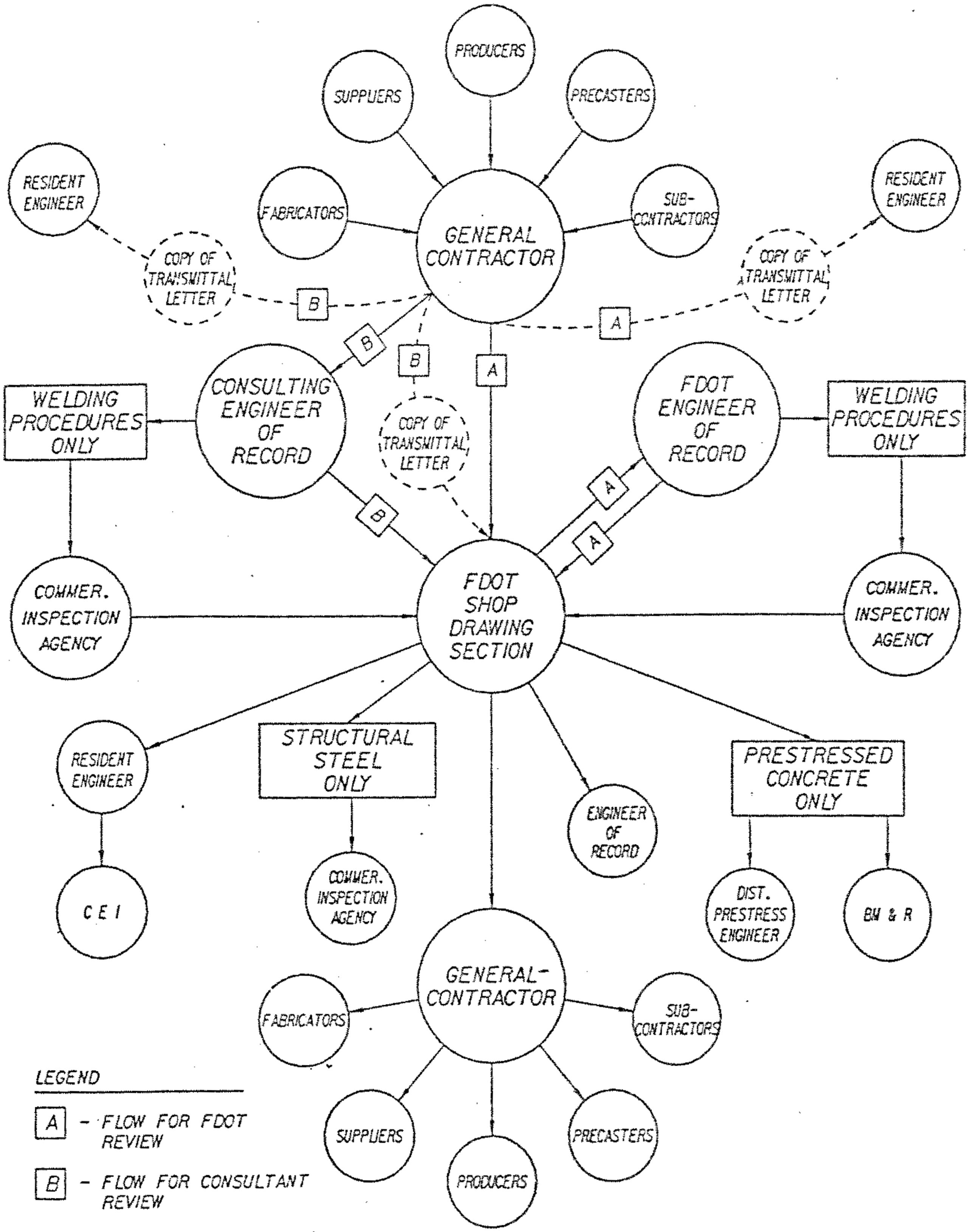


Figure 12 Shop Drawing Flow Diagram (Structural Items)

Project (Precast)	No. of Bridges	Balanced Cantilever	Span-by -span	
Built				
Long Key	1		*	)
Seven Mile	1		*	)
Niles Channel	1		*	)
Channel Five	1		*	) Total
Ramp I	1	*		) 31
Sunshine Skyway	1	main spans	approaches	) built
I75/I595	5	*		) to
Palmetto	5	*		) Aug.
Airport	4	*		) 1988
US 441/I595	2	*		)
I75/I595 - 2	9	*		)
Port of Miami	1	*	(Contract awarded 8/89)	
I95/I595	8	*		)11 alts)bid but
South Fork New River	2	*		)not)built
Howard Frankland	1	*	*	)
Edison	1		*	)In)Design
Golden Glades	(n)	*		)

** Steel or Precast girder alts. low bid in these cases.

Principal Features;

Balanced Cantilever	Span-by-span
-interchange sites	-over water
-curved	-straight
-cast in place substruct.	-precast and c.i.p. subst.
-mainly on driven piles	-mainly on drilled shafts

Table 1 - Precast Segmental Projects

	Span-by-span	Cantilever
Site:	over water	over land
Delivery:	barge	low-loader
Erection Equipment;		
Truss + floating crane	33% *	
Overhead gantry	67% *	
Crane on ground		91% *
Beam and winch		9% **
Stability towers	not required	used
Falsework	not required	used
Learning Period:	3-4 weeks	varied
Sustained rate:	3 spans/week	4-6 segments/ day/cantilever with 2 cranes

Note: * *The % is based upon the number of superstructure segments* erected per bridge *type.*

** This figure includes the segments in the continuous 11 span unit *of the Skyway cable stayed main spans and* balanced cantilever high level approach spans.

Table 2 - Erection Methods

Average bridge costs in Florida based upon plan area of bridge type constructed; (At 1986/7)

	% of all Bridge Construction.	$ per sq. ft.
Standard AASHTO girder overpass with 4 spans with pier caps and columns	25%	45
AASHTO girder simple span trestle bridge with pile bents	40%	29
Major structures of all types, large spans, long bridges, simply supported or continuous in steel or concrete including segmental	25%	42
Other miscellaneous bridges, bascules, etc.	10%	-
Overall Average		36.4

Table 3 - Average Bridge Costs in Florida

Appendix A

A. Administration Processes - Segmental Bridges.

A.1 Current Practice.

In general, practice in the U.S.A. has required the Contractor to produce many shop (construction) drawings detailing each and every precast segment and many other items. The production, submittal, review and correction of these is a great burden for the Contractor, Designer and Client. It has frequently led to unnecessary delays, differences of opinion, professional posturing and claims. Some guidance is provided in the AASHTO Guide Specification for the preparation of contract plans for segmental bridges but it does not address more fundamental administration matters where improvement is most needed.

Improvement must begin with fundamentals such as clearly establishing roles, responsibilities, corresponding liabilities, clear scopes for Designers and Construction Engineering and Inspection (CEI) services, the contractual and engineering obligations of Contractors and their supporting engineers, good communications and the mutual agreement of all documents from design criteria to contract plans and specifications. Most exist in some form; difficulties have arisen through ambiguities and omissions.

A.2 Recommendations for Segmental Construction:

A.2.1 Design Plans

Plans should be organized and presented for the convenience of the Contractor who has a short time to prepare his bid with little time to check the sufficiency of the plans and assess his engineering needs. Later, he has to fabricate and erect components from these plans.

It is strongly recommended that plans be prepared to follow "Method A" of the AASHTO Guide Specification for Segmental Bridges article 29.1.1. This would require but may not be limited to the following;

- Show large scale details of awkward areas, checked to avoid conflicts and ease of assembly of reinforcement and hardware fabricated to recognized industry standards.

- Avoid details which require special treatment outside of normal industry fabrication standards.

- Post-tensioning tendon alignments and duct sizes should be fully dimensioned and detailed.

- Allow for the dimensionally largest anchorages commercially available for the force-size of the post-tensioning tendons.

- The erection sequence assumed in the design should be shown, especially the order of making closures and adding or removing temporary supports as these affect the statical scheme

- Show the assumed stiffnesses of temporary supports and assumed erection equipment loads.

- State all assumed material properties and concrete maturity at each major step.

- Provide long term deflections or camber.

- Provide an envelope of design stresses.

- Show the maximum loads, moments and shear forces that can safely be carried by piers and foundations.

- State all required loads, movements and settings for bearings and joints.

- Finally, ensure that the drawings agree with the specifications etc..

Despite appearing obvious, it is surprising how easily and how often these can be overlooked. The emphasis must be upon constructability. If the above are properly addressed, the need for lots of shop drawings is greatly reduced.

A.2.2 Shop Drawings (Contractor's Construction Engineering)

Given the above emphasis on constructability in the design plans, shop drawings and construction engineering will be required for;

- Miscellaneous, minor detail changes to accommodate selected post-tensioning hardware and other embedments, (manufacturer's standard drawings), inserts, lifting holes etc.

- Any localized strengthening of the structure for selected temporary supports or equipment loads if not already provided in the plans.

- Checks for handling, storage or stacking of precast segments.

- Temporary works and equipment drawings (casting forms, gantries, towers, falsework etc.),

- A geometry control manual for casting and erection survey control.

- An erection manual or drawings detailing the sequence of operations for segment erection, post-tensioning tendon installation and stressing, erection equipment usage, activation and release of temporary supports etc..

- Any major redistribution of supports or significant changes to the erection equipment loads or erection sequences (making span closures) will require a global re-analysis by the Contractor and review by the Engineer as it would change the design.

A.3 Construction Conditions Which Affect the Bridge.

The sequence in which segments are erected, construction loads applied or removed from the structure, especially the sequence in which continuity is made through closures with adjacent spans and the sequence of installing and stressing post-tensioning are of particular interest to the Designer. If executed in a sequence different to his assumptions at the time of design, then the statical regime of the bridge may be changed and the continuity moments and forces will be different. It is therefore important that the Contractor submit a casting schedule, an erection sequence and schedule, erection loads, temporary support information, stressing data, erection analysis and step-by-step erection operations manual.

If the Contractor's schedules, sequences, erection loads and supports etc. are the same as assumed by the Designer, it may not be necessary to have him make an "erection analysis" but he will need to submit everything else.

Creep and shrinkage influence the final structural regime and it is important that they be considered in the design and construction (erection) analyses. They influence deflections throughout and after construction. This is more significant with cast-in-place construction than with precast since the latter has some maturity prior to loading. Generally, cast-in-place closures in precast construction have little extra influence above the precast behavior. However, it is normal to make compensations for deflections by casting segments to a "casting curve" which can be likened to "camber" for a steel girder - a "casting curve" is a combination of the geometric bridge profile and deflection compensations. A change from the Designer's assumptions for the material properties, casting and construction of the bridge will change the creep and shrinkage deflection corrections to some extent. It is normal practice for a Contractor to re-calculate these according to his chosen erection methods. This is most easily accomplished through an "erection analysis".

Since segmental bridge "erection analyses" are complex, they are normally performed using recognised computer programs. (FDOT recognizes BC, BRUCO, IDS-PRESTO and a few consultant programs) If a recognized program is used, it should not be necessary for the Designer to perform a separate check with his own program, unless he so wishes, just as long as he is satisfied that the program and results have been used correctly. However, this is not the only checking he should do - there are many other erection effects, local conditions and so on that such programs cannot consider.

A.4 Designer's Interests in Erection Equipment etc.

A.4.1 Launching Gantries and Trusses.

Special erection equipment like launching gantries and erection trusses are sophisticated structures containing machinery similar to cranes and derricks. (Figs. 7, 8, 9). Most involve structural steelwork, moving parts, winches, generators, electrical and hydraulic equipment with controls and instruments. Their design requires a multi-disciplined specialist with experience in these areas who also intimately understands the design and construction of the bridge itself. Often such special equipment is for a "one-off" application and so requires a very large project on which to write off the cost. Also, it is normal practice to perform a full scale load test on such equipment prior to proceeding with bridge erection.

Some erection equipment can impose loads approaching the design capacity of the bridge. This was particularly true of early overhead launching gantries for precast segmental cantilever construction where, in one part of the launching cycle, the load on the erected cantilever controlled the design of the negative moment region post-tensioning tendons. The design of cantilever gantries has gradually improved (Fig.2) and this need no longer be the case. Nevertheless, loads are imposed which the designer should check.

Overhead launching trusses for span-by-span erection, as for the Skyway Approaches (Fig 7) and underslung trusses, as for the I-70 Bridges in Glenwood Canyon Colorado (Fig 8) or the Wando Bridge in Charleston, South Carolina (Fig 9), tend to impart the largest loads more directly to the substructure. Sometimes they do so via special brackets, frames or a highly loaded superstructure pier segments which carry the main gantry supports. The pier segment or substructure may be more critical under such loads than in the final bridge.

With erection gantries and trusses, bridge structures must be checked for loads imposed during all stages of erection, including launching operations, wind effects, segment transportation and handling, segment erection and so on. It is normal for Contractor to perform an "erection analysis" of the permanent structure taking all intermediate erection loads and conditions into account. He should also pay particular attention to localised loads, torsion, braking, anchoring devices, and so on. All these conditions are of vital interest to the Designer and he must check the permanent structure accordingly.

The operation of a launching gantry or truss is very important and must proceed in a controlled manner according to the design and use of the gantry as established by it's designer ("Specialty Engineer"). It is normal practice to have a very detailed step-by-step "erection operations" manual for each and every task for the entire gantry operations and bridge erection. This manual should also agree with the "erection analysis" and no task should be overlooked.

All stages of erection should be checked by the bridge Designer. However, it is unlikely that the Designer will want, or would be able for liability reasons, to check the erection gantry itself. It is an item over which he has little control. Nevertheless, he should check the Contractor's erection analysis and erection operations manual for conformance with the bridge design.

A.4.2 Temporary Towers, Falsework and Span Closure Devices

Temporary towers are frequently used to provide stability for segmental cantilever erection where ground based or floating cranes are used to lift precast segments. Normally, they are located close to a pier shaft and rest on the pier footing. Temporary towers are usually purpose made from steel sections, tubing or concrete and are usually braced to the pier. Lockable hydraulic jacks at their tops are used to slightly adjust the vertical tilt of the cantilever as necessary and allow the loads in the towers to be released after a cantilever has been permanently connected to it's neighbor.

Falsework may be used for the same purpose, to carry a row of precast segments or to support sections of cast-in-place concrete superstructure. It is generally made from commercially available sectional framing and the loads per leg are typically very much lighter than temporary stability towers.

The localised reactions on both the superstructure and substructure from temporary towers can be quite high. The Designer should check their effects on the bridge. Falsework loads are of less concern as regards the structure itself. However, falsework frequently rests upon the natural ground and not on parts of the bridge foundations. Extra care should be taken to prepare a suitable foundation for each leg and ensure that settlement is negligible or at least well monitored and controlled by jacking, or other precautions.

Span closure devices are usually "strongbacks" (steel girders) tied down by high strength bars and secured across the adjoining tips of two cantilevers or similar to keep them together while a cast-in-place closure is made. This is a simple device but one which might impose high localised loads to top slabs of precast segments. The Designer should check the device for it's operation and effects upon the structure.

It is normal practice for towers, falsework and closure devices to be designed by an engineer working for the Contractor. (Specialty Engineer). However, Designers rarely want to take responsibility for checking the self-adequacy of such things for similar reasons to above. They are something they have little control over either in fabrication or use.

A.4.3 Other miscellaneous items

Special handling frames and other small devices are often fabricated for lifting, transporting and placing segments. Likewise, special casting forms used in the precasting yard are of interest for their ability (or not!) to make the segments according to requirements.

All these are of interest from a general safety or production viewpoint but have no influence on the final structural regime of the permanent structure and so are not of primary interest to the Designer.

A.3 Comments;

Improvements in procedures should be implemented through the mutual cooperation of various professional, client and industry organizations: such as, the Federal Highway Administration, American Association of State Highway and Transportation Officials, the American Segmental Bridge Institute, the Post Tensioning Institute and others.

Finally, in reality, there will always be a need for flexibility in construction techniques for segmental structures. Opportunities should be afforded to Contractors to make modifications to details and sometimes to the overall design to suit their prefered construction methods. This necessitates experience, preparedness and cooperative commitment by all parties.

Appendix B

B. Actions by the Florida Department of Transportation.

Since the introduction of the first precast segmental bridges, the Department has introduced several improvements; for example;

1. 1983 - introduced a design criteria for segmental bridges.

2. 1983 to present - clarify and improve specifications.

3. Introduced selected retention of designers for additional services during construction on sone projects.

4. 1987 - Published a "Guide to the Construction of Segmental Bridges" for inspection personnel.

5. 1987 - Introduced "Structures Design Guidelines" for all bridges.

6. 1987 - Clarified and defined the roles and responsibilities of all parties involved in the shop drawing process and defined the preparation, submittal, review, disposition and distribution process itself via a "Contractor's Form Letter".

7. 1989 - Introduced a standard, statewide technical scope of services for Construction Engineering and Inspection Consultants for all types of bridge construction.

8. 1989 - Introduced construction procedures for "Shop and Erection Drawing Approvals" and updated "Control of the Work" in the Standard Specifications.