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Engineer-Contractor Relationship in International Projects

Relation entre l'ingénieur et l'entrepreneur dans des projets internationaux

Die Beziehungen zwischen Ingenieur und Unternehmer in internationalen Projekten

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SUMMARY

The process of engineering design, supervision and construction is still today determined by the traditional roles played by its participants. Owners, engineering consultants, construction managers and contractors must devise more open organizational forms to rationalize the process eliminating repetition, misunderstanding and unnecessary administrative efforts. Each participant should be encouraged to organize his part of the process to take full account of the most efficient task breakdown and the interface of responsibility with others.

RÉSUMÉ

Le processus actuel du projet de génie civil, de son contrôle et de sa construction reste influencé par les rôles traditionnels des partis concernés. Les maîtres d'ouvrage, ingénieurs-conseils, gestionnaires de la construction et entrepreneurs doivent imaginer des formes d'organisation nouvelles afin d'améliorer le processus et d'éliminer des répétitions, des incompréhensions et des efforts administratifs inutiles. Chaque parti doit être encouragé à organiser sa partie du processus afin de tenir entièrement compte de la répartition la plus efficiente du travail et du partage des responsabilités.

ZUSAMMENFASSUNG

Der übliche Projektablauf Planung, Ausführung, Überwachung wird bis zum heutigen Tag durch die traditionelle Rolle der Beteiligten geprägt. Bauherren, beratende Ingenieure und Ausführende müssen jedoch neue, unkonventionelle Organisationsformen finden, um durch Verbesserung der Zusammenarbeit mögliche Doppelspurigkeiten, Fehlinformationen und unnötigen Verwaltungsaufwand zu vermeiden. Jeder der Beteiligten sollte dazu ermutigt werden, seinen Teil im Rahmen der Zusammenarbeit so zu gestalten, dass sowohl die Aufgabenteilung als auch die Abgrenzung der Verantwortungsbereiche nahtlos und effizient sind.

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1. THE IDEAL RELATIONSHIP

Experienced Contractors have developed their organizational methods over many years. Such forms are common to most Contractors. Engineering and Construction Management Consultants prepare tender drawings and documents with an address in mind within the Contractors organization:

- clear breakdown into disciplines - structural concrete, structural steel, architectural, electrical, communications, plumbing, heating, ventilation
- clear breakdown into contract administration, logistics and engineering (see figure 1).

At all phases in the design and tendering process (prior to formalization of the Engineer/Contractor relationship through Contractor's contract with the Owner) the engineering Consultants maintain contact with potential bidding Contractors to assimilate into the design those forms of construction best suited to the execution of the project under prevailing local and general conditions:

- concrete technology, climate, aggregates, soil conditions, cement types, formwork and curing, pre-cast construction
- availability of structural steel, corrosion protection
- government determined monopolies use of locally produced materials, import restrictions.
- logistic influences upon time schedule
- time schedule of Owner activities, supply of equipment functionally necessary to project, nominated systems sub-contractors.

Tendering should best of all take place prior to absolute completion of the design, in order to permit competing Contractors to offer their own in-house developed technologies as possible alternatives, saving cost or time:

- an early decision for an agreed pre-cast technology enables the Contractor to design and erect the pre-casting plant in parallel to the Architect/Engineer completing his contract/working drawings (see enclosure 2, example of precast agreement between Construction Manager, Architect/Engineer and Contractor).

At the outset of the Architect/Engineer's design phase or even earlier the Owner's project management decides on a contractual organizational form for the project. The design approach of the Architect/Engineer is geared to that decision:

- Construction Management controlled projects are those which characteristically are open ended. Tender packages are broken down into basic disciplinary elements. - Structural, fitting-out, electrical, mechanical and equipment. Alternative technological solutions and bids are solicited and evaluated up to the latest possible time in the project schedule. Engineering design is neutral and proceeds parallel to the construction (see figure 3)
- Turnkey Contract projects should be totally pre-engineered in all disciplines thus permitting the contractor to complete construction without further technical clarification in the shortest possible time.
- Design and Build Contract projects should be pre-determined by a functional/performance scope of work only. The design and detail

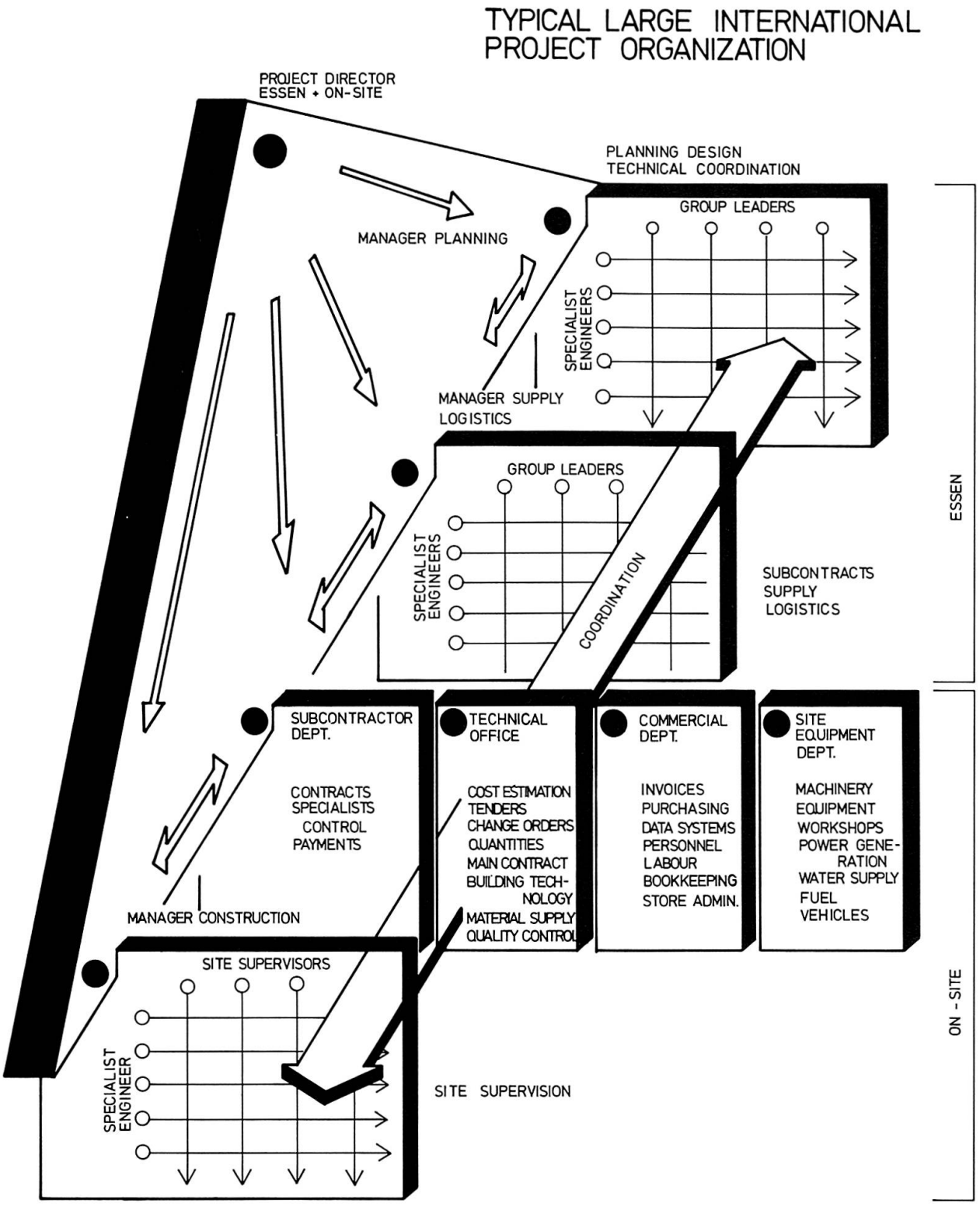
TYPICAL LARGE INTERNATIONAL PROJECT ORGANIZATION
PROJECT DIRECTOR ESSEN + ON-SITE
PLANNING DESIGN TECHNICAL COORDINATION
GROUP LEADERS
MANAGER PLANNING
SPECIALIST ENGINEERS
MANAGER SUPPLY LOGISTICS
GROUP LEADERS
SPECIALIST ENGINEERS
COORDINATION
SUBCONTRACTS SUPPLY LOGISTICS
ESSEN
SUBCONTRACTOR DEPT.
CONTRACTS SPECIALISTS CONTROL PAYMENTS
TECHNICAL OFFICE
COST ESTIMATION TENDERS CHANGE ORDERS QUANTITIES MAIN CONTRACT BUILDING TECHNOLOGY MATERIAL SUPPLY QUALITY CONTROL
COMMERCIAL DEPT.
INVOICES PURCHASING DATA SYSTEMS PERSONNEL LABOUR BOOKKEEPING STORE ADMIN.
SITE EQUIPMENT DEPT.
MACHINERY EQUIPMENT WORKSHOPS POWER GENERATION WATER SUPPLY FUEL VEHICLES
MANAGER CONSTRUCTION
SITE SUPERVISORS
SPECIALIST ENGINEER
SITE SUPERVISION
ON - SITE

FIG. 1

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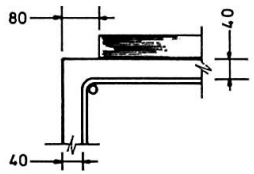
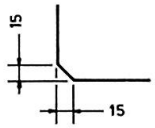
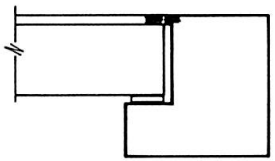
d. The bearing pads are set back 80 mm from the face of the supports.



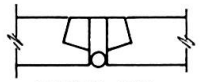
e. A tee chamfer of 15 mm is provided at the base of the stem. A 15 mm radius is used in the flange to web fillet.

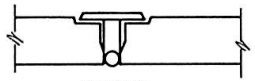


f. An adjustable screw is used in the flange to ledger girder to keep the girder from rotating under the eccentric loading.



g. Flange Tip Connections - Hochtief uses a grouted shear key continuous along the length of the member with welded connections at two locations along the length.


GROUTED KEY


WELDED

h. Dowel Connection - SOM showed Mr. Felsch a grouted dowel connection with the dowel cast in the girder element and pipe sleeve cast in the tee stem. Mr. Felsch felt that the placement of these dowels would present

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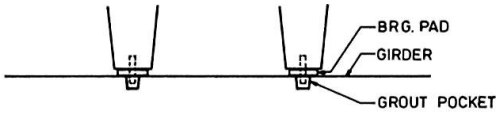
a tolerance problem. He suggested an adjustable screw insert in the tee stem which could be inserted into a grout pocket in the girder.



i. Precast Tee Design - Mr. Felsch made the following comments:

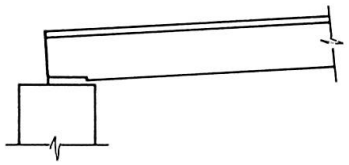
1) The precast plant design has assumed only straight tendon arrangement.

2) Hochtief has maximum and minimum effects of shrinkage and creep used in determining the critical camber cases.

3) The spacing of strands is closer than SOM had anticipated and is, therefore, conservative. Hochtief uses 2 times the strand diameter as clear between strands. Therefore, for a 1/2" Ø strand the clear space will be 1" and the center to center spacing will be 1 1/2" (SOM had designed with 2 " center to center)

4) Hochtief uses a strand equivalent to 250 K. They use a low relaxation strand.

j. Sloped Bearing Conditions - Hochtief uses a flat (typical) bearing pad and places it out of level with the base of the tee stem to match the pitch of the tee.
SOM mentioned that wedged bearing plates are also a possibility.



k. Harped Tendon Requirements - SOM pointed out that the Administration Building and portions of the Quarantine Facility required harped tendon arrangements for the tees to work within the depth. Three possibilities exist to solve this problem:

1) Increase the tee depth.

Figure 2.1

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e. SOM presented a study regarding temperature differentials for Jeddah based on available weather data.

f. Creep, shrinkage and prestress loss criteria for prestressed/precast elements were discussed.

3. SOM stated that any isolated spans in excess of 21.2 meters would be developed in a system other than precast/prestressed concrete as agreed in the meetings at SOM-New York on 6 and 7 November 1977.

4. For additional comments, see Attachment C.

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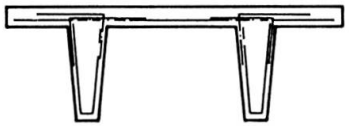
1. See Attachment C for summary comments regarding precast concrete meeting.

2. The following detail items regarding precast concrete were presented by Hochtief's Mr. Felsch:

a. We requested that a schedule of required concrete covers, both for prestressing strand and mild steel reinforcing, be provided him. (See Attachment D)

b. Mild Steel Reinforcing - A mesh is used in the web perimeter for shear reinforcing. A lapped second layer is bent from the top of the stem to the opposite flange typical. A full width layer of mesh is laid over the previous layers in the flange.



c. Bearing Pads - Elastomeric pads used, laminated with one steel plate. Allowable bearing pressure of 100 KG/cm2 is used. The standard pad is 100 mm (width) x 150 mm (long) x 21 mm (thick). Thicker pads are available for greater movement requirements.

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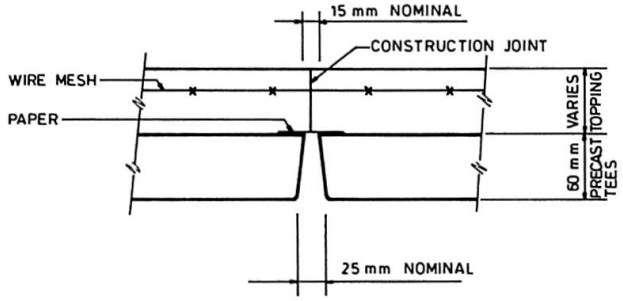
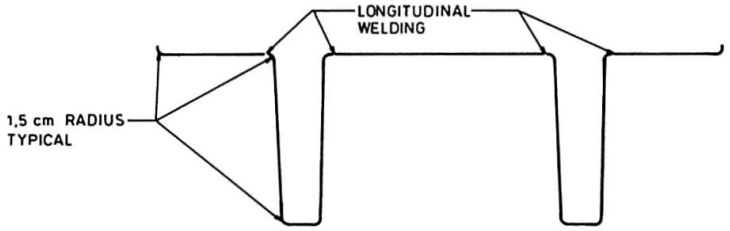
3. The gap joint between precast tee elements was agreed upon as shown below:



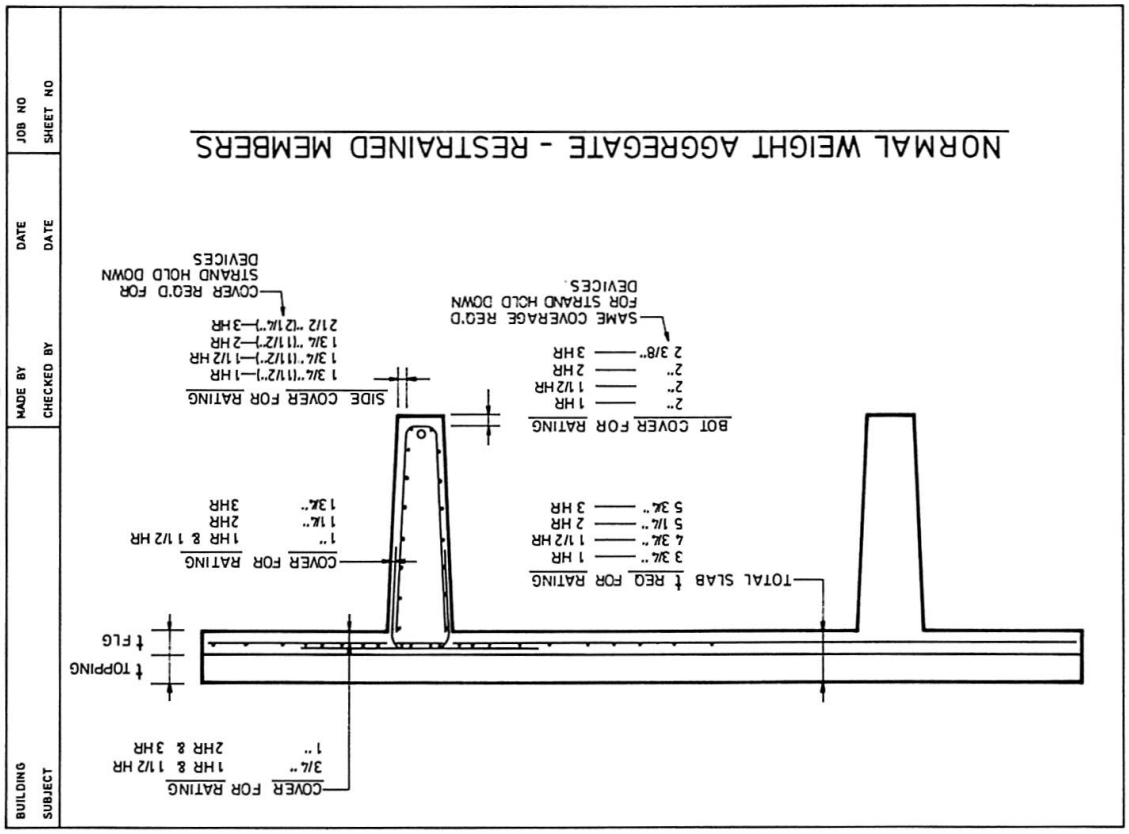
4. The precast tee forming system profile was discussed and tentatively agreed to as shown below:

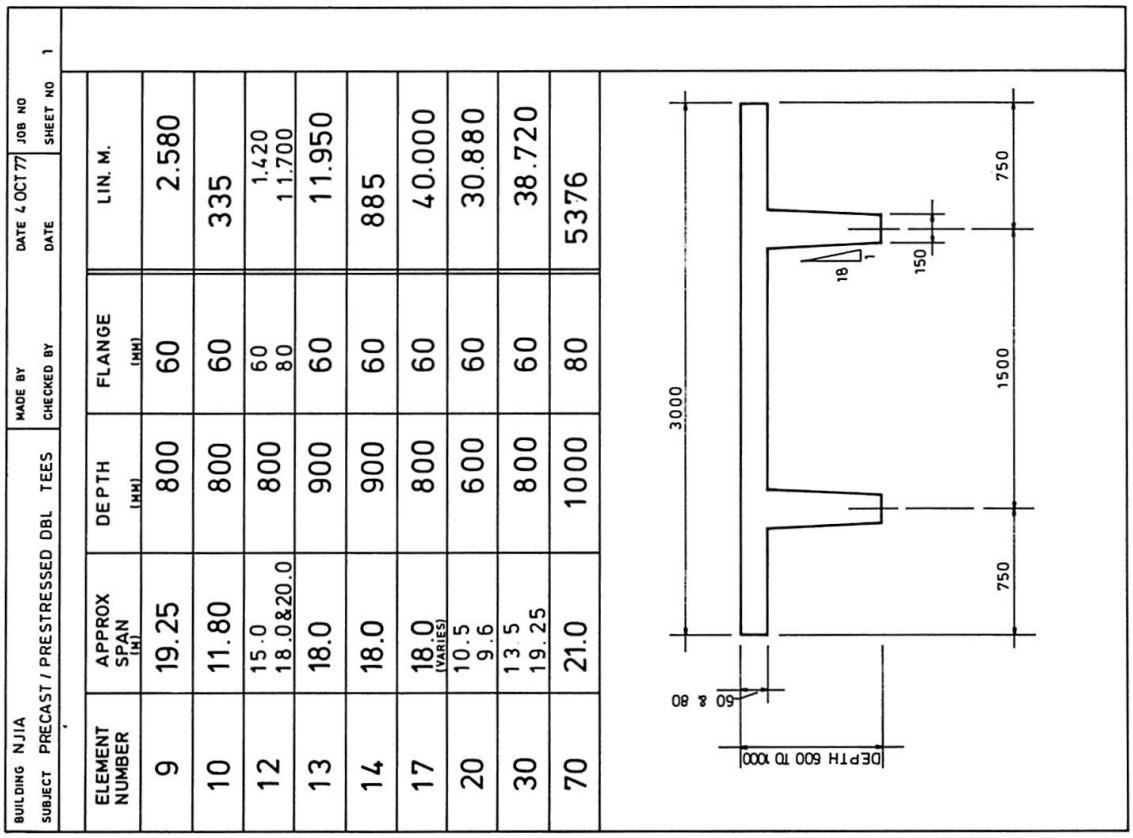


a) Transverse joints located at 2.5 meter spacing.
b) All welds ground smooth and flush.
c) Longitudinal welds to be located at tangent of radius.
d) Hochtief to verify and notify P/D and SOM if any deviation.

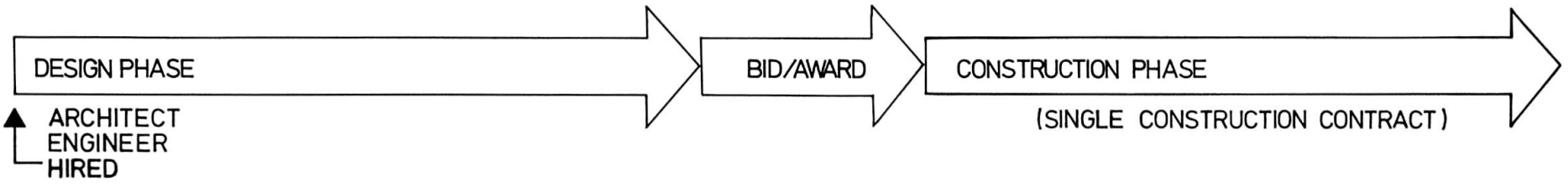
Figure 2.2

Figure 2.3

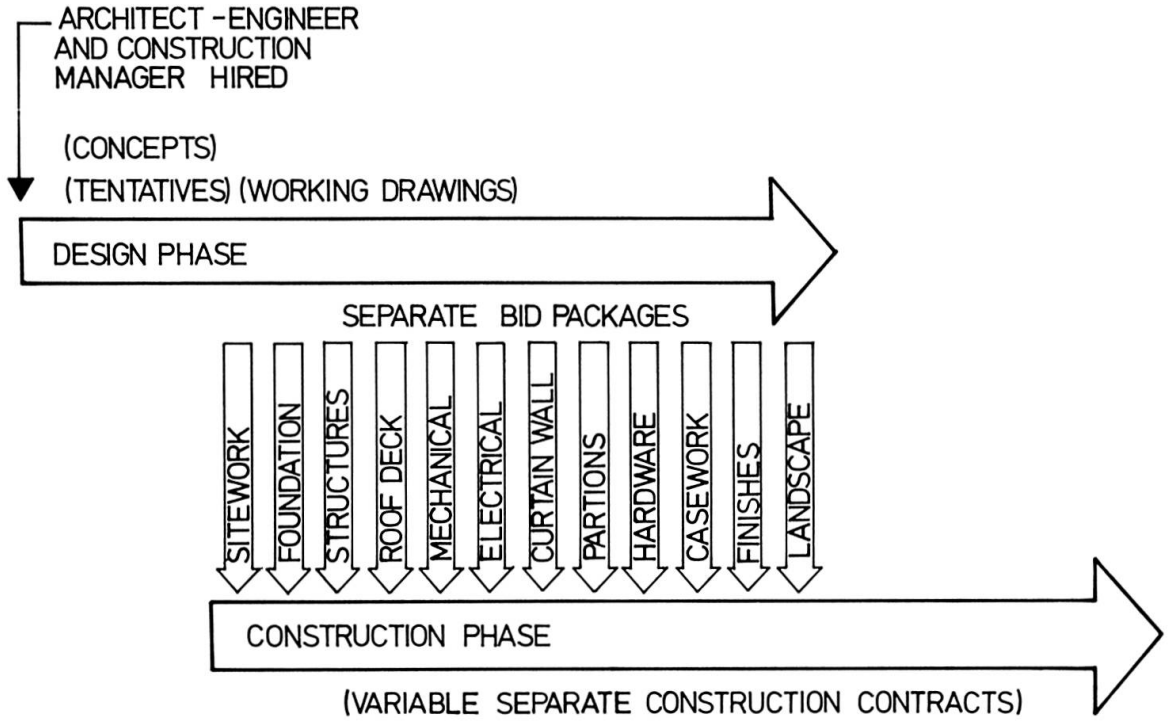




ELEMENT NUMBER	APPROX SPAN (M)	DEPTH (MM)	FLANGE (MM)	LIN. M.
9	19.25	800	60	2.580
10	11.80	800	60	335
12	15.0 18.0&20.0	800	60 80	1.420 11.700
13	18.0	900	60	11.950
14	18.0	900	60	885
17	18.0 (VARIES)	800	60	40.000
20	10.5 9.6	600	60	30.880
30	13.5 19.25	800	60	38.720
70	21.0	1000	80	5376



TRADITIONAL CONSTRUCTION METHOD



CONSTRUCTION MANAGEMENT PHASED METHOD

FIG. 3
TRADITIONAL AND PHASED CONSTRUCTION COMPARED

engineering should be dealt with by the Contractor's in-house organization.

The Architect/Engineer must take full responsibility for the design in both functional and constructional senses. Any engineering work undertaken by the Contractor shall be reviewed and approved by the Architect/Engineer, the consequences therefrom shall thereafter be his unrestricted responsibility. The Contractor shall be held responsible for the quality of the construction and the performance of materials and equipment as specified. In a design and build contract the Architect/Engineer need take no responsibility beyond the correct formulation of functional/performance requirements.

To assure the feedback of practical experience resulting from given design parameters and avoid false interpretation of standards and requirements in the construction phase, the original designing Architect/Engineer should be employed by the Owner, additionally to the Construction Manager/supervising engineer, with the responsibility to interpret and oversee the functionality and quality of the works through to handover and well into the maintenance period. A highly desirable side effect of this procedure lies in the added practical experience for the Architect/Engineer.

2. THE RELATIONSHIP IN PRACTICE

Architects/Engineers and Construction Managers have developed all-encompassing general and special conditions to the form of contract in order to achieve the desired quality and punctuality in the construction of the given project. Such conditions generally include:-

- long lists of applicable standards and codes of practice without clarification of the order of validity, although such standards may be contradictory one to another.
- Complex document approval procedures for shop drawings, material and equipment submittals (see figure 4) involving very high working man hours for the Contractor's engineers and high reproduction and administrative costs. Perhaps, worst of all, causing interruption of the construction work because such formalities have not been completed precisely in accordance with the terminology of the contract.
  Notwithstanding the complexity and cost and time inefficiency of such procedures, such approvals are signed off with the rider "Approved for construction, Approval does not relieve the Contractor of the responsibility for any error which may arise, as the Contractor and/or his subcontractors shall be responsible for the dimensions and design of adequate connections, details and satisfactory construction of all work".
  Recent litigation in the U.S. courts may have put an end to this last mentioned practice. It has been determined that when the Architect/Engineer approves Contractor's shop drawings he then takes the responsibility for their content.
- Excessive administrative quality assurance and quality control programmes involving certification, test procedure and voluminous documentation of standard industrial products common to the construction industry.

Tender and contract documents usually take the form of working drawings and specifications produced by the Architect/Engineer. In recent years two significant influences have had a negative effect upon the quality of these documents:-

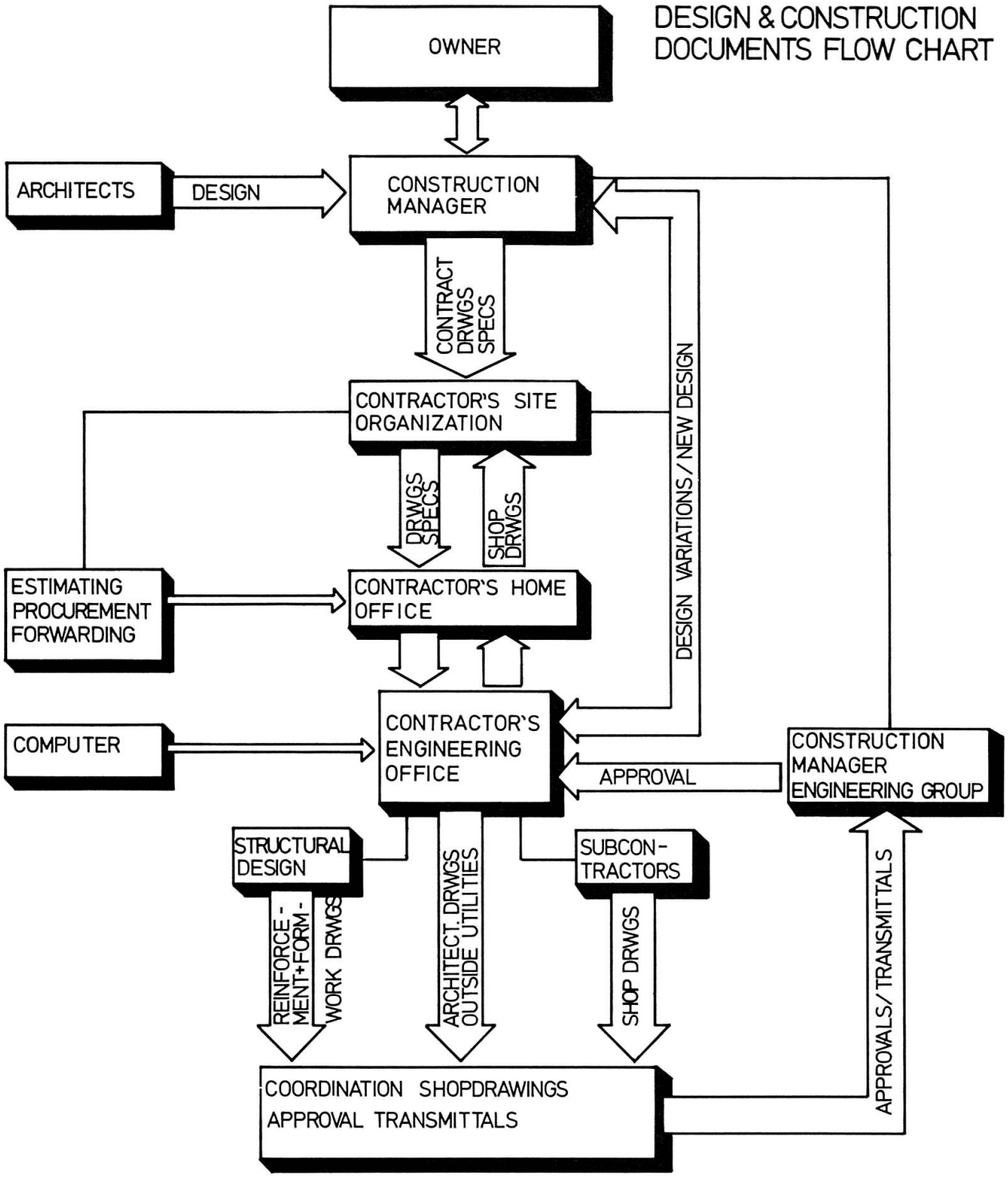

DESIGN & CONSTRUCTION DOCUMENTS FLOW CHART
OWNER
ARCHITECTS
DESIGN
CONSTRUCTION MANAGER
CONTRACT DRWGS SPECS
CONTRACTOR'S SITE ORGANIZATION
DRWGS SPECS
SHOP DRWGS
DESIGN VARIATIONS / NEW DESIGN
ESTIMATING PROCUREMENT FORWARDING
CONTRACTOR'S HOME OFFICE
COMPUTER
CONTRACTOR'S ENGINEERING OFFICE
APPROVAL
CONSTRUCTION MANAGER ENGINEERING GROUP
STRUCTURAL DESIGN
REINFORCE-MENT+FORM-WORK DRWGS
ARCHITECT DRWGS OUTSIDE UTILITIES
SUBCON-TRACTORS
SHOP DRWGS
APPROVALS / TRANSMITTALS
COORDINATION SHOPDRAWINGS APPROVAL TRANSMITTALS

FIG. 4

- Consultant's fees no longer seem adequate to cover the extensive volume of work necessary to produce a completely engineered set of contract documents.
- Many of the disciplines required to completely engineer the project are privy to manufacturing semi-monopolies and not practiced by consulting engineers.

Resultingly the tender and contract documents do not adequately define the works in a balanced coordinated form in all the disciplines:-

- Architectural drawings show a lot of information with regard to furnishings, are however not coordinated with electrical and mechanical services. The constructural details of the fitting-out trades are not resolved.
- Structural dimensions have been determined by rule of thumb empirical methods and must then be calculated by the Contractor's engineers.
- Central electricity generation plant has been sized by empirical rule of thumb and assumed diversity factors and therefore under - or over - dimensioned, whereas an equipment count would have provided more exact basis.
- Air conditioning design is limited to dimensioning the central air handling plant providing single line diagrams and writing the required conditions into each of the rooms and areas. The Contractor then designs the duct systems which prove to be too volumenous for the ceiling voids and ducts provided.
- Communications systems and specialist equipment design has either been left completely open to the discretion of the Contractor and his subcontractors or a manufacturing agency has been employed by the Consultant in the design phase with the promise of a subcontract for the work involved.

The last five mentioned examples of lack of information and restrictive practice can in extreme cases lead to a Contractor redesign starting with the coordination of architectural and structural work with that of the electrical and mechanical services.
The Contractor has considerable difficulty with prospective subcontractors who believe that they have exclusive rights, they are neither competitive nor cooperative, so that in such cases the Contractor tries to bring about a redesign with a subcontractor of his choice.

Most projects are designed by engineering Consultants working a long way from site of construction. Local conditions are usually only superficially recognized.

- Locally available materials are not usually specified.
- Equipment is specified which is readily available in the Consultant's country of origin which can however neither be supplied nor serviced locally.
- Construction standards and codes are referenced which only apply in the Consultant's country of origin. Although government authorities in most parts of the world have either developed their own standards or expressed preference for standards from one particular third country - usually where historical or traditional links exist. The Contractor then has to negotiate an intermediate status between the local authorities and the design

Consultant.

- The physical conditions determinand for the use of materials and methods of construction in widely differing regions are seldom fully recognized by the Consultants. Typical hereto are the problems with concrete in the Middle East - aggressive aggregates, high sulphate and chloride content of subsoils, lack of water, shrinkage and deformation due to climatic conditions. Standard works have been written on the subject - they however still do not get referenced by the designing engineers.

Many projects to-day have a significantly higher technological content than in the past when traditionally oriented forms of cooperation, contractual and working relationships were devised. Truly multi-disciplinary engineering teams capable of overseeing the entire design and construction process are not found in the Contracting or the Consultant engineering companies.

Owner's still place design contracts with separate Consultant engineering offices for each discipline and do not ensure contractually that one leading Consultant is responsible for the integration of the separate work packages into a functionally and physically coordinated unity. Traditionally architects have taken on the role of coordination however the willpower and the technological background are lacking in the profession.

During the construction process a high degree of detail design coordination has to be undertaken either by the design Consultants or the Contractor. Both parties showing unwillingness - the designer because his fee has already been paid and the Contractor because he did not calculate for such works. The Contractor's shop drawing production process - originally intended to add necessary details to the Consultant's working drawings has become a repeat design process with more detail.

Projects controlled by a separate Construction Management organization - a form which is becoming more prevalent - have the added disadvantage that the feedback process between execution of the works and the design process is cut off. The Architect/Engineer provides contract documents, these are then interpreted and/or renegotiated by the Construction Manager to achieve optimum cost. time and functional results. The modifications and clarifications thereby undertaken may be formalized as change orders but the information or reflected experience gained thereby remains privy to the Construction Manager and the Contractor.