Concrete in Dacca

The following pages contain excerpts and pictures from a truly unique document, kindly made available to Mimar by the author, Mr. Fred Langford. It is a report prepared in June, 1966 at the request of Louis Kahn, architect of the National Assembly Building in Dacca, concerning the potentiality for reinforced concrete formwork and construction in Bangladesh. Mr. Langford spent four months experimenting with materials and methods suitable to the location, to the capacities of local manpower, as well as the qualities of the architectural conception. Written and illustrated in the form of a manual, copies of the original report were left with the Department of Public Works for those who would subsequently execute the work, and it was sent to the architect's office to aid those who were commencing detailed of the National Assembly.

Apart from the rare and fascinating historical value of this document as it relates to the achievement of a monument of modern architecture, we feel that conditions in many parts of the developing world for applying this type of technology have not changed all that much since 1966. The insights provided here into adapting tools, expertise, and standards of performance to the local *context are, as relevant as they ever were.*

Local Conditions Relating to Concrete Work During the Experimental Period

1. Materials

Cement imported from China and Russia — limited supply from Sylhet, Bangladesh — stored on site in sacks — Russian type produced best concrete colour of the three brands — Pakistan as a producer, should be considered.

Stone hauled from Sylhet area of Bangladesh and crushed locally — produced good strength concrete — control of aggregate size during experimental wall casting was poor — pea gravel, which should have been limited to 25%, reached proportions of 75% in some cases which retarded the sliding action of the wet mix during the vibrating process, causing surface disfigurations — 25% pea gravel (3/8") and 75% (3/4" to 1") stone produced the best concrete surfaces.

Sand hauled from Sylhet area — granules of good size and shape — washed on site and sieve tested.

Water available on site — satisfactory for mixing but measuring by buckets and fractions of buckets often inconsistent.

Lumber for starter wall formwork usually a species similar to Philippine Mahogany or Luan — pronounced "gorjun" — easily worked with planes and chisels and receives nails without splitting — but not being seasoned it is subject to high volumetric change and warpage — most boards are delivered to the site 1" or 2" thick, 6" wide.

Nails single head (box type) — steel soft, they bend easily — most sizes available — double head type should be obtained.

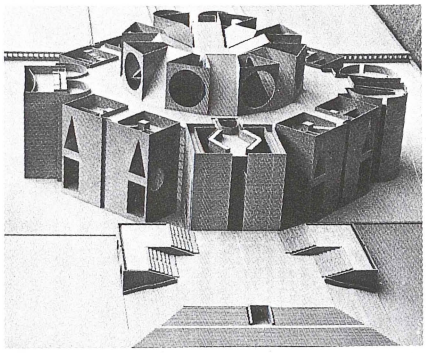
2. Tools and Equipment

Hand tools limited to small handsaws (20" length) ball pein hammers — wrenches (adjustable type) proved satisfactory — most carpenters have 2 or 3 planes and a variety of chisels — a few wood drills — 24" folding rules — the foreman used a 50' leather bound cloth tape for weeks before we discovered it was incorrect by 1" for every 10 feet.

Power tools like cutoff saws, portable hand saws, drills, sanders, routers, etc. were not available on the site, however these tools were present in the technical training centres in Dacca.

Saw mills in the Dacca area operated with very limited machinery, however the F.I.D.C. (Forest Industries Development Corp.) had a mill less than five miles from the site that was complete with modern equipment — unfortunately the work that was produced was poor due to the lack of skilled workers.

Mechanical vibrators (gasoline powered) were used on all pours after bamboo rodding technique was found unsatisfactory — the P.W.D. (Public Works Department) owned 14 vibrators all in a state of disrepair — only 3 partially operatable. Finally an electric powered vibrator was tried and proved dependable — also a combination electric belt driven unit was devised by the Workshop which also worked well — in the final stages of the experimental castings the P.W.D. Workshop became very cooperative and resourceful.



Model, project for the National Assembly, Dacca. Louis I. Kahn, architect.

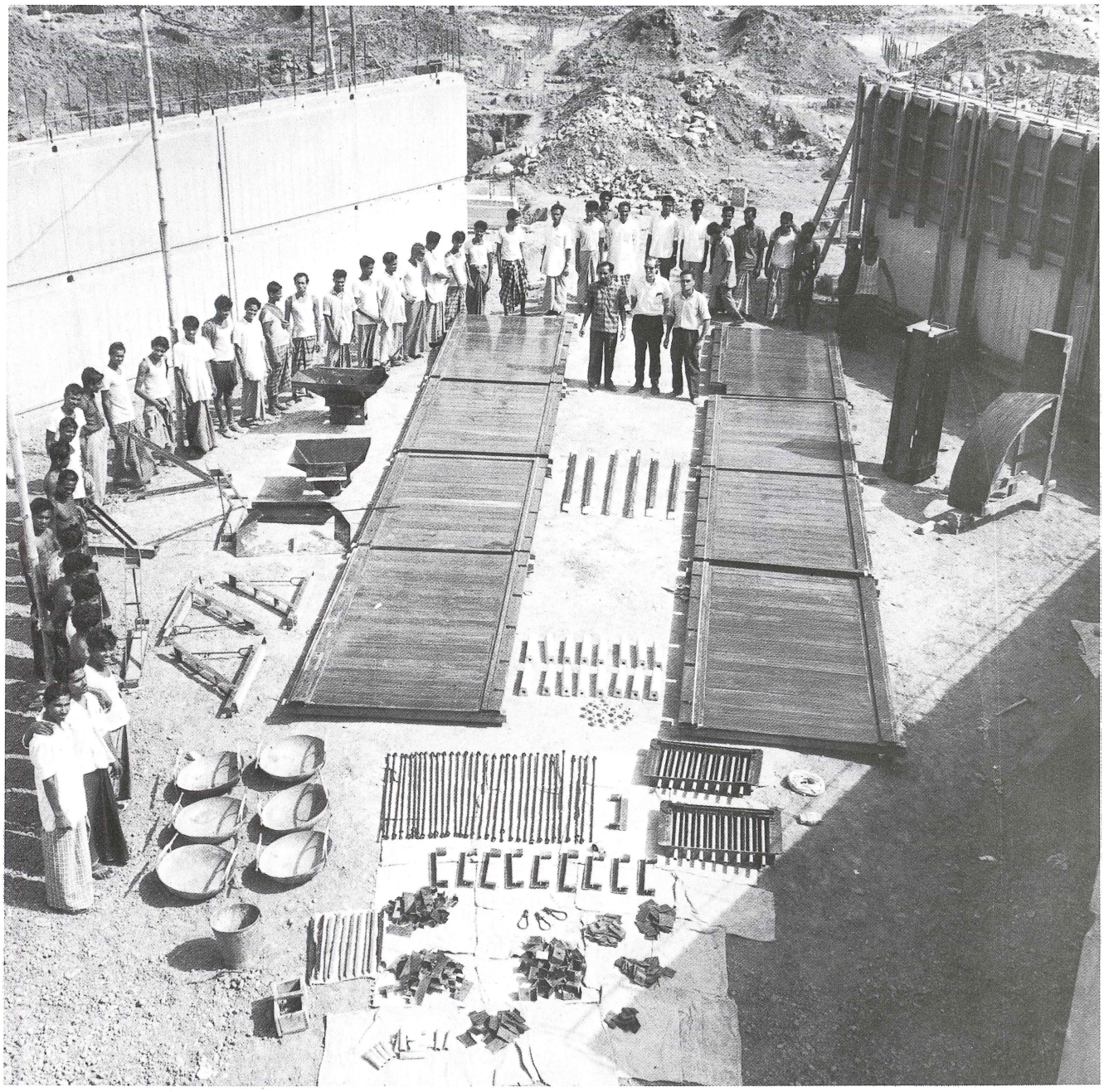
Cement mixers (two-bag type) proved very dependable — one-bag mixers were tried but output was inadequate to provide proper lift rate and variations in water measurements were greater with the one-bag mixers.

3. Labour

Classification and number of men making up each group that worked on the building experimental walls were as follows: Carpenters (4)), Masons (16), Labourers (50 to 70) — the Rod Mistries (craftsmen) (14), in addition to bending and tying steel, also erected the bamboo scaffolding.

Work hours started around 9 am — lunch 2

Article by Fred Langford.
All photographs courtesy of the author.

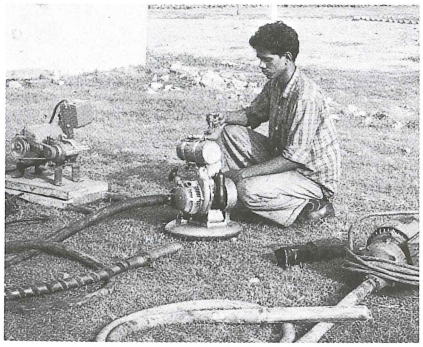


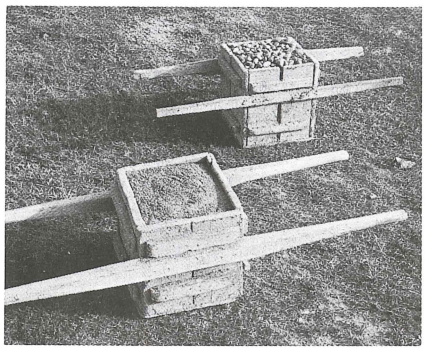
Group portrait of Bengali workers and Mr. Langford (centre) amid a display of the tools and formwork used during experimental casting of reinforced concrete structure. National Assembly, Dacca, 1966.

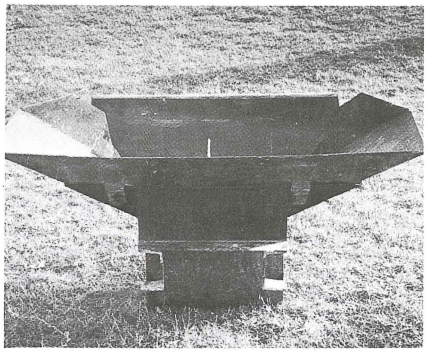
to 3 pm — as weather got hotter in April and May, lunch period became lunch and siesta period 2 to 4 pm — normal quitting time should have been about dusk (7 pm) but the entire crew always worked until 9 or 10 pm and about 25% of the time until midnight — 6 days a week in February and March — 7 days a week in April and May.
Delegation of responsibility was biggest problem in trying to maintain a planned work schedule — foreman was not capable of anticipating sequence of work procedure even though the same sequence was repeated as many as a dozen or more times — in the final stages of the experimental work, work teams were designated with specific responsibilities — the key men of each team started assuming more responsibility making scheduling more dependable and good workmanship easier to achieve.
Attitude: workers were always willing to cooperate to the best of their ability — willing to work long hours and rebuild formwork when necessary — form panels were handled and cleaned with loving care — some men became skillful in a very short time.

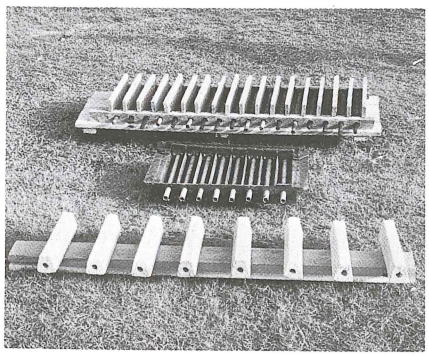
4. Weather
Temperatures between November and February are ideal with the range 60° to 85° Fahrenheit — in March temperatures will rise to the mid nineties — in April and May it often exceeds 100° F — from mid June till mid October (the rainy season) temperatures rise to the low 90's.
Humidity is very high during the rainy season, 75 to 100% — however, April and May are the most uncomfortable due to the combination of 95 to 100 degree temperatures and 70 to 85% humidity.
Rain totals about 100 inches annually in Dacca with showers starting in April and almost daily rains occuring in July, August, and September — finally subsiding in October.
Cyclones sometimes occur in April and May.

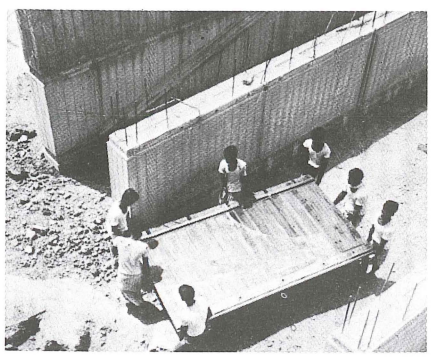
5. Methods
Excavating done by hand with hoe type











Left, top to bottom: Mechanical vibrators (gasoline-powered, electric, and combination electric belt-driven); Sand and stone carrying containers; Hopper. Steel plates fabricated to form a funnel that is shaped to gather the wet mix after it is dumped and to direct it downward between the reinforcing steel; Pre-cast spreaders (foreground) and the trays used to produce them. Spreaders are placed horizontally with tiebolts between form-panels; Manipulation of a form-panel, the basic increment of concrete forming system.

shovels — loaded in shallow baskets and then head-carried out of the trenches — because of the densly packed earth, cuts as deep as 10 feet can be made almost vertically — earth moving equipment owned by the P.W.D. but usually reserved for road building.

Formwork for pile caps and all starter walls fabricated on site — pile cap shuttering very crude but satisfactory — below-grade starter panels completely hand-made.

Form coating for starter walls 30 S.A.E. motor oil on raw wood — a greenish gray surface of concrete resulted — first sample walls above grade poured with panels coated with two coats of shellac — greenish-brown dull surface resulted — shellac was removed and two coats of imported water proof varnish was tried — produced good surface on first pour, but varnish started to peel off with the second and third use — panels were coated with imported polyurethane over varnish but this peeled on the first usage — panels had to be scraped and sanded down to raw wood — 8 panels were then coated with two coats each of polyurethane and 8 panels were coated with three coats each — the three coat system proved satisfactory.

Cement mixing handled in one-bag and two-bag mixers — sand and stone measured and carried in one cubic foot wooden containers — water measured in buckets — cement in sacks.

Transporting of wet mix starts by discharging the mixer to an area on the ground covered with metal sheets — it is then shoveled into round shallow pans — two men lift the full pan onto the head of a labourer — the labourer walks from 50 to 300 feet and dumps the contents of the pan into the formwork — the time element between the pick-up and the dumping, plus the small quantities involved has a tendency to settle the mix in the pan — result separation or a lack of adhesion after dumping.

Castings first made without vibrators — bamboo poles were used for rodding — wooden mallets used to tap outside of form during pour — many rockpockets resulted to system was abandoned for mechanical vibrators.

Various concrete shapes such as corners, tee sections, closures, etc. were tried with hand-made formwork on the starter walls that occured below grade.

Stripping of formwork presented very few problems — wooden wedges were made to assist the breakaway process — bolt threads were being damaged during removal until form-panels were handled without any benefit of hoists which presented dangerous situations at times — stripping above 38.00 level will have to incorporate mechanical means.

Curing originally was handled by covering new castings with burlap sacks and then keeping them wet for 7 days — this left brown deposits transferred from the burlap — white streaks where wall received uneven wetting and drying action.

Form-panel Design Criteria and Recommendations

1. Analysis of Various Materials

Plywood is good panel material but waterproof plywood is not available in Bangladesh.

Steel form-panels in tropical climates present a rust problem — modifications are difficult — reuse factor of less than 100 feasible. steel formwork exonomically not feasable.

Rough wood board panels produce a deep-textured surface that would encourage fungus growth — this would be objectionable.

Fiberglass not available.

Smooth wood planks, tongue and grooved to prevent leakage and retard cupping, should make an excellent form-panel.

2. Fungus Growth a Design Factor

Concrete and plaster surfaces, as well as masonry joints that are exposed to constant wetting and drying during the rainy seasons, develop a greenish brown moss or fungus growth.

Areas under protective overhangs are not affected — silicone treated surfaces are not affected for the first few years after the treatment — terrazzo surfaces are not affected. (Imperial Chemical Industries (ICI) says silicone treatment should be repeated every five years.)

Polyurethane resin form-coating will produce a surface almost as smooth as terrazzo if proper care is exercised — adding silicone to this surface every five years should keep the building free from any growth of fungus.

3. Well Seasoned Lumber Important

Moisture content should not exceed 12% — a species with a minimum volumetric change should be selected — teak is ideal but too expensive — *champa* and *chapalish* were selected for the experimental panels.

Chapalish worked better for the rear frame because it received nails well — as a form-surface chapalish proved very soft and also contained fluids with concrete staining ability.

Champa was too hard for the rear frame but very satisfactory for the surface planks.

4. Five-foot Lift Allows High Reuse Factor

Potential life of each panel should be based

on usage from the first pour to the top-out pour (22 lifts) without major repair — the panel should have the potential to be resurfaced and used 22 more times — 44 uses before cutbacks for secondary surfaces.
Proper care exercised in stripping and cleaning procedures is a prime factor in form-panel life.

5. Marble Recess Contains Bolt Line and Pour-joint
Continuous projection of top and bottom frame must produce the desired recess in the concrete between pours to allow for a straight and accurate setting of marble trim.
Recess-maker cannot be a nailed-on or glued on shape because of the many uses desired from each panel — it should be part of the solid edge-member, moulded from one piece of timber.

6. Each Panel Must Be Dimensionally Stable
Minimum moisture absorption is a key factor in maintaining dimensional stability in wood form-work — polyurethane coated surfaces allow very little moisture intrustiondurıng the pouring process.
Continuous high humidity that is characteristic of the rainy season will cause dimension increases in each member within a form-panel should accomodate small interior changes without allowing overall dimensions to grow or shrink.
Polyurethane resin (two coats) should also be applied to the back and rear frame of each form-panel in order to minimise effects of rain and high humidity.

7. Structural Integrity Important for High Reuse
Rigid surface perimeter frame should be glued at corners and bolted to the heavy back-up frame.
Internal surface or body of the form-panel should be vertical tongue and grooved planks backed by horizontal studs let into heavy vertical edge members which are shiplapped into the heavy top and bottom members.
Glued joints require the use of uria formaldahyde which is waterproof and is available in Bangladesh.

8. Leakage Must Be Prevented
Continuous 1/4" by 3/8" recess is provided in the bottom frame of each panel where it contacts the former casting — this recess should be stuffed with a cotton rope to prevent leakage at the bottom of the new pour.
String caulking can be very helpful in the prevention of leakage around filler strips, stair-keyways, circular block outs, etc.

9. Junctures allow for Length Corrections
Length corrections in order to respect reference control lines are a problem inherent in all concrete forming systems — to preserve the integrity of the individual panels, a make-up (dimensional correction) zone

Preparation of steel reinforcing rods.

must be established — the logical location for this zone is at the vertical gap that occurs between form-panels.
Fixed filler strips were used in the vertical gaps between panels on the building experimental walls.
Variable filler strips must be employed when a panel series includes a corner form — these strips will have to be custom shaped for each pour.
Flexible inserts (rubber or neoprene) should be studied as a joint sealer and as a variable-width gap-filler.

Placement of Concrete — Preparation and Procedure
The procedure and sequences listed below are for lifts up to elevation 38.42. From the 38.42 level up to the parapet a scaffolding system of a completely different nature will be required. A scaffolding system with a hoist system counterpart will greatly affect formwork erection procedures, pouring procedures, and stripping procedures.

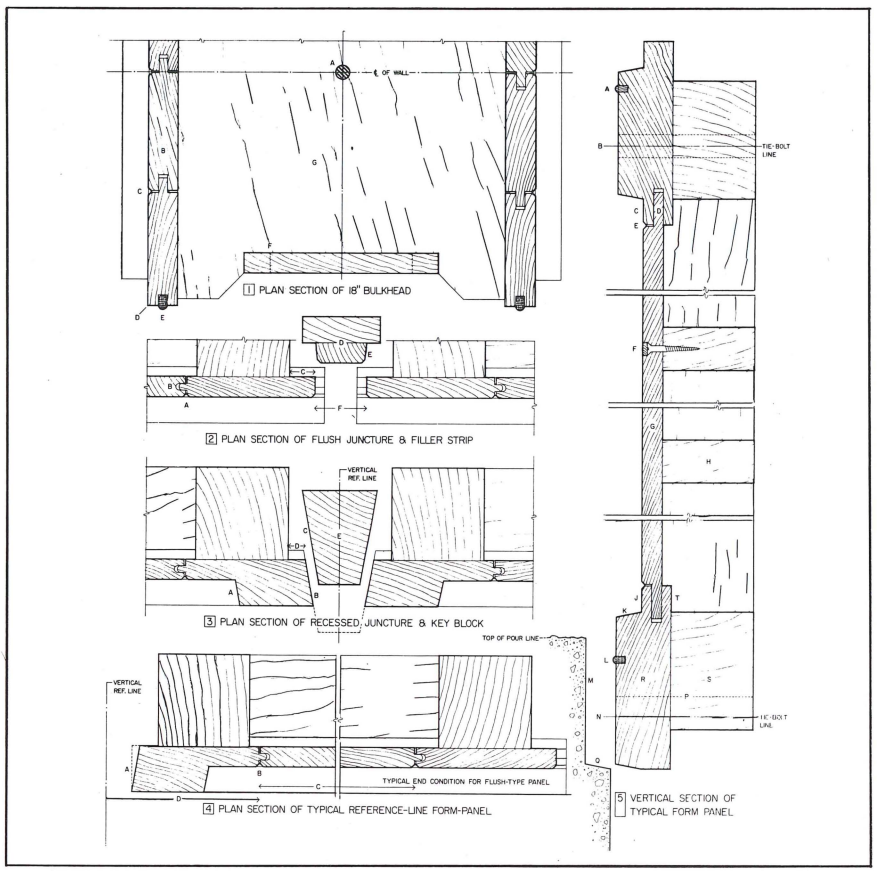
1. Material Check List
Cement (correct type — ample quantity).
Sand (correct type — washed).
Stone (correct sizes — proportions).
Water (source functioning).

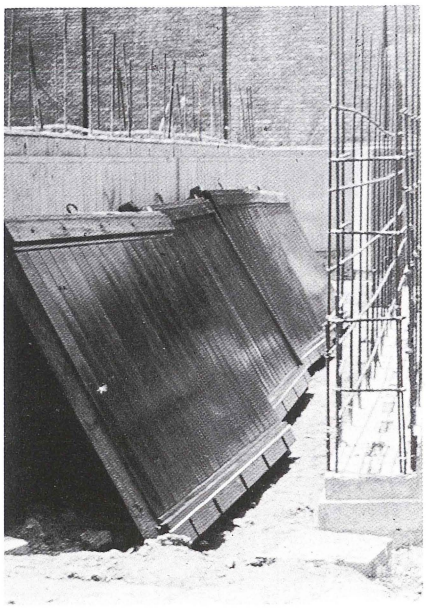
2. Scaffolding (up to wall level 38.00).
Scaffold brackets mounted.
Bamboo frame (proper elevation — cross braced).
Planks roped to brackets and to bamboo frame.
Ramp in place if necessary.

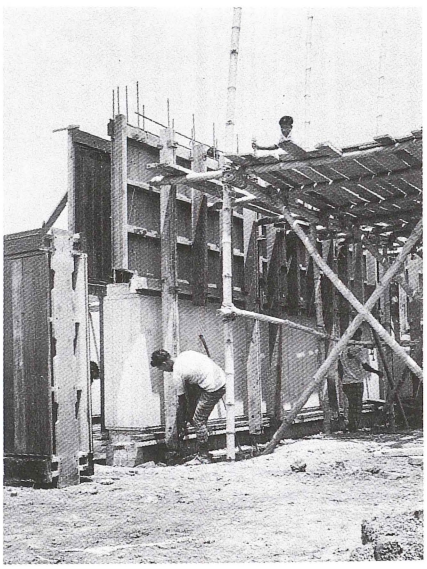
3. Equipment Check List
Mixer and all parts working (fuel check).
Vibrators capable of immediate starting (fuel check) (wiring check for electric type).
Lights hooked up and working in case pour is delayed.
Hoppers placed on formwork (proper relation to wall ends).
Vibrators placed on scaffolding.
Tool check (pans — trowels — shovels — brackets — wrenches — hammers).

4. Final Formwork Check List
Level, plumb, straight.
Corners and vertical references on control lines.
Check bottom of all key blocks and filler strips for leak-holes.
Fill the crack that is formed by bottom recessmaker of form-panel and previous casting with mortar.
Check wedges behind all juncture elements (key blocks — filler strips).
Check stair key-ways for inserts and string caulking for marble insert.
Check reinforcing steel for proper distance from all form surface (adequate wooden spreaders and pre-cast donuts).
Check for spreader loops (closed position).
Check panels for excess oil (this is the time for final wipedown if wall thickness permits).
All wood shavings, nails, debris, etc. should be cleaned out of the bottom of the wall.
Check all bolts for equal pressure.
Wet down hoppers, panels, top of previous pour.
Station a man under the formwork with bucket and water to wash down any leaks that may occur.
Start the mixer and holler "Thara Thari" (Quickly)!

5. Placing Concrete ("Pouring" — "Casting")
Mix should be tested for 3" to 5" slump —







Above: Typical details of form-panel construction. Right, above: Form-panels ready for assembly. Right: Typical wall endings created with a bulkhead, or box-like forming unit designed with vertical section details similar to a basic form-panel.

first 20% of pour should be near 5″ slump remaining 80% should be near 3″ slump.

Pan: if pan system is used, first 10 pans that are dumped in each hopper should be large type pans.

Hopper placement is very important — drop should always be at wall ends so fill can be from outside to inside from ends to middle.

Adjustable hopper chute will control initial build-up at wall ends — concrete must be dumped into the triangular zone formed by the intersection of the bulkhead and the existing pour — the mix should be slightly wet (5″ slump) — it should be vibrated immediately after placement, but not over vibrated.

Pan carriers should make one complete circuit for one hopper then make one complete circuit for the other hopper.

Chute: When the built-up reaches the end of the adjustable chute, the chute should be removed — at this time the hopper extension can also be removed. After the extension is removed the pan carriers can fill the two hoppers simultaniously by alternating one man to one hopper, the next man to the other hopper.

Extraction: When the build-up reaches the bottom of the hopper, the hopper should be extracted because now the wall is within 18″ of the top at each end.

Operators: when the hoppers are removed introduce the third mechanical vibrator and operator — this third man will have the responsibility of the middle section of the wall. The two original operators have the responsibility of maintaining the proper slope build-up (advancing slope method) — this slope may be 4 feet high at each end down to zero in the middle for a 30 to 35 foot wall length. The vibrator operator who has the responsibility for the middle one-third of the wall must work the bottom slopes of each side together — he must make a homogenious juncture so no vertical cold joint takes place — after the juncture the middle vibrator assists the other two operators in the maintenance of the two advancing slopes.

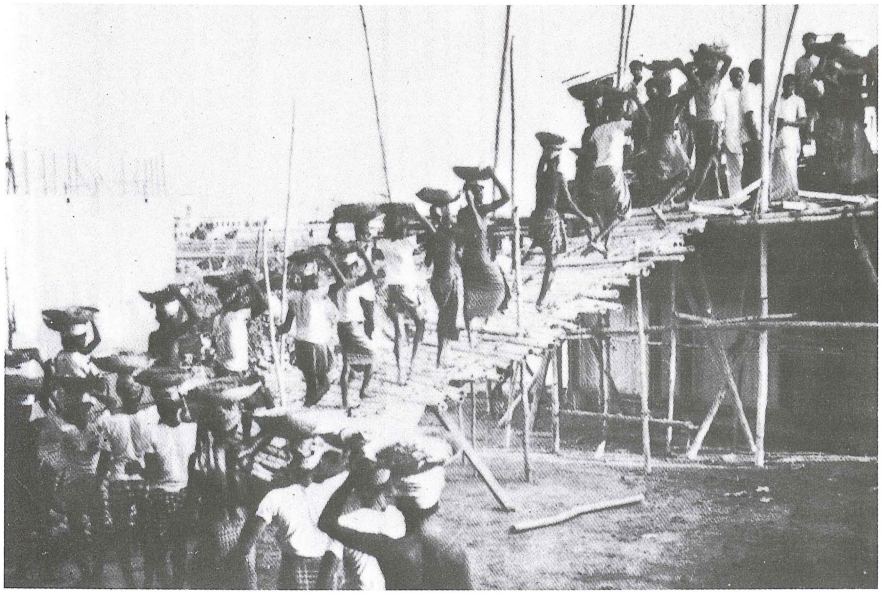
Dumping must always be from the high ends — the proper vibration will keep the top 6″ and 12″ of the slope constantly sliding, causing a wiping action on the form panels. No concrete should be dumped into the center section until the ends are filled for a distance of at least 10 feet and the center section has built up to within 12″ of the top.

Note: After many unsatisfactory experimental walls, this advancing slope method was the only procedure found to eliminate rockpockets. It is possible that with the add mixture pozzolith #3 the conventional horizontal layer-type system of placement will be satisfactory.

Topping out: as the end sections of the wall reach the "top-out" limit they should be floated level and a key-way strip inserted between each spreader. After the wall has been completely topped out each bolt that is contained in a precast spreader should be tightened one-half to one full turn — this action will overcome some of the wall thickness shrinkage that occurs at the top of all pours and causes the concrete surface to be dull and flakey.

Cleaning: after all bolts are tightened and all key-way strips set, the top edges of the formwork should be cleaned off before the concrete gets hard — all exposed reinforcing rods also should be wiped clean at this time.

Lift rate: the polyeurethane coated panels produce the best concrete surface when the wall is poured rapidly — a lift-rate of 5 fee per hour should be the minimum lift-rate — 10 feet per hour should be the maximum.



Left: Casting process. Workers dump concrete mix into a hopper.
Left, below: Concrete mix being transported in steel buckets by labourers.