4. Remove all loose concrete before starting the patch and thoroughly wet the surface to prevent patch mix moisture loss to the parent concrete.

5. Pack the patch tightly into the void and hand dress to match the texture of the parent.

6. Cure the patch by covering it to retain the moisture.

Project patching should be started after the finish has been produced and when there is sufficient work ahead to keep finishers busy. Good patching requires finisher continuity. Starting too soon can result in training many different finishers and producing variable results.

Clean-up: - Clean-up should be easy for a well planned and implemented job. Remove dirt and grime. Assure that all surfaces are sealed and there is no rust developing from exposed steel.

CONCLUSION

With proper contract documents and supervision, architectural concrete can be very rewarding. The Owner will have a structure which needs little maintenance. He will have a distinctive structure that he will not see repeated in the next block or the next city.

Table II [4] is a listing many of the causal factors for variable finish results. Attention should be paid to the many factors which effect design as well as execution. All are important to assure that the result will be as planned.

Concrete tests the skills of the architect to design structures of lasting beauty and the contractors who build them. If the architect does not produce contract documents which properly guide the project to a successful completion, he must accept the blame for his share of the problems. If the contractor does not follow good architectural concrete construction practices, the results will be a detriment to the concrete industry.

----

1. Shilstone, James M., "Architectural Concrete Contract Documents," CONCRETE INTERNATIONAL, November 1985

2. Shilstone, James M., "Concrete Construction - Making the Process Work," CONCRETE INTERNATIONAL December 1977

3. Shilstone, James M., "Achieving High-Quality Architectural Concrete by Understanding Details of the Construction Process", ARCHITECTURAL RECORD, May 1973

4. Shilstone, James M., "Surface Blemishes in Formed Concrete" presented at the International Conference on Facades of Buildings, Helsinki, Finland, 1977

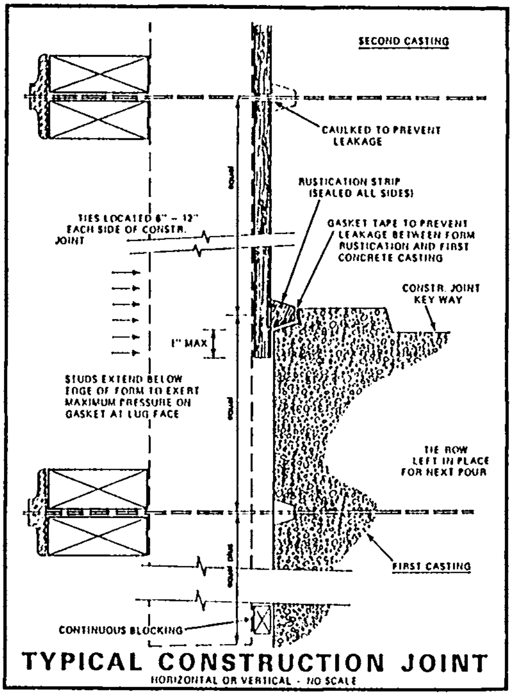

Figure 1

TABLE 5.1.4--RANGE OF CHARACTERISTICS, PERFORMANCE, AND APPLICATIONS OF INTERNAL VIBRATORS

Column (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			Suggested values of			Approximate values of		
Group	Diameter of head, in. (cm)	Recommended frequency, vibrations per min (Hz)	Eccentric moment, in.-lb (cm-kg)	Average amplitude, in. (cm)	Centrifugal force, lb (kgf)	Radius of action, in. (cm)	Rate of concrete placement, cu yd per hr per vibrator (m^3/hr)	Application
1	¾-1½ (2-4)	10000-15000 (170-250)	0.03-0.10 (0.035-0.12)	0.015-0.03 (0.04-0.08)	100-400 (45-180)	3-6 (8-15)	1-5 (0.8-4)	Plastic and flowing concrete in very thin members and confined places. May be used to supplement larger vibrators, especially in prestressed work where cables and ducts cause congestion in forms. Also used for fabricating laboratory test specimens.
2	1¼-2½ (3-6)	9000-13500 (150-225)	0.08-0.25 (0.09-0.29)	0.02-0.04 (0.05-0.10)	300-900 (140-400)	5-10 (13-25)	3-10 (2.3-8)	Plastic concrete in thin walls, columns, beams, precast piles, thin slabs, and along construction joints. May be used to supplement larger vibrators in confined areas.
3	2-3½ (5-9)	8000-12000 (130-200)	0.20-0.70 (0.23-0.81)	0.025-0.05 (0.06-0.13)	700-2000 (320-900)	7-14 (18-36)	6-20 (4.6-15)	Stiff plastic concrete [less than 3-in. (8 cm) slump] in general construction such as walls, columns, beams, prestressed piles, and heavy slabs. Auxiliary vibration adjacent to forms of mass concrete and pavements. May be gang mounted to provide full width internal vibration of pavement slabs.
4	3-6 (8-15)	7000-10500 (120-180)	0.70-2.5 (0.81-2.9)	0.03-0.06 (0.08-0.15)	1500-4000 (680-1800)	12-20 (30-51)	(15-40) (11-31)	Mass and structural concrete of 0 to 2-in. (5 cm) slump deposited in quantities up to 4 cu yd (3 m^3) in relatively open forms of heavy construction (powerhouses, heavy bridge piers and foundations). Also auxiliary vibration in dam construction near forms and around embedded items and reinforcing steel.
5	5-7 (13-18)	5500-8500 (90-140)	2.25-3.50 (2.6-4.0)	0.04-0.08 (0.10-0.20)	2500-6000 (1100-2700)	16-24 (40-61)	25-50 (19-38)	Mass concrete in gravity dams, large piers, massive walls, etc. Two or more vibrators will be required to operate simultaneously to melt down and consolidate quantities of concrete of 4 cu yd (3 m^3) or more deposited at one time in the form.

Notes:
Column 3 — While vibrator is operating in concrete.
Column 4 — Computed by formula in Fig. A.2 in Appendix A.
Column 5 — Computed or measured as described in Section 15.3.2. This is peak amplitude (half the peak-to-peak value), operating in air.
Column 6 — Computed by formula in Fig. A.2 in Appendix, using frequency of vibrator while operating in concrete.
Column 7 — Distance over which concrete is fully consolidated.
Column 8 — Assumes insertion spacing is 1½ times the radius of action, and that vibrator operates two-thirds of time concrete is being placed.
Columns 7 and 8 — These ranges reflect not only the capability of the vibrator but also differences in workability of the mix, degree of deaeration desired, and other conditions experienced in construction.

TABLE 1--ARCHITECTURAL CONCRETE QUALITY: RELATIVE SIGNIFICANCE OF CONSTRUCTION DETAILS ON THE RESULTS

	AS CAST FINISH				DISTRESSED FINISH													
	Abs*		Non-Abs.		Abrasive Blast				Impact Hammer				Combination					
	Smooth	Texture	Smooth	Texture	Brush	Light	Medium	Heavy	Scale	Bush	Jack	Tool	Reed and Hammer	Reed and Blast	Reed and Chisel	Very Reed and Blast	Texture Liner and Blast	Chemically Retarded
CONCRETE MIX																		
Cement Color	1	1	1	1	1	1	2	3	2	2	3	3	1	1	2	1	2	2
Fine Aggr.-Gradation	4	4	4	4	4	4	2	1	4	4	4	4	4	4	4	4	4	1
-Color	3	3	3	3	2	2	3	3	2	2	2	2	3	2	2	2	2	3
Coarse Aggr.-Gradation	4	4	4	4	4	4	2	1	4	4	4	4	4	4	4	4	4	1
-Color	4	4	4	4	3	2	1	1	2	2	2	2	2	3	2	3	3	1
Design Technique	2	3	2	3	3	3	2	1	3	2	2	2	3	2	2	2	3	1
Admixture	2	3	2	3	2	2	2	1	3	3	3	3	3	3	3	3	2	2
Consistency (slump)	2	3	2	3	3	3	2	1	3	3	3	3	3	3	3	3	3	1
Mixer Capabilities	4	4	4	4	4	4	3	1	4	4	4	4	4	4	4	4	4	1
FORMS																		
Selection of Materials	1	2	2	2	1	1	2	3	2	2	3	3	2	2	3	2	2	2
Reuse Limitation	1	2	3	3	1	2	3	3	2	3	4	4	3	3	3	3	2	2
Butt Joints-Location	1	3	1	3	1	2	3	3	3	3	4	4	2	2	2	2	2	4
-Rusticate	1	1	1	1	1	1	2	3	1	1	2	3	2	2	3	2	1	2
Tightness	1	1	1	1	1	1	2	2	2	2	3	2	2	2	2	2	1	1
Rigidity	2	3	1	3	2	2	3	3	2	3	4	3	2	2	2	2	3	3
Design Strength	2	3	2	3	2	2	2	2	2	3	4	3	2	2	3	3	4	2
Stripping Control	1	1	1	2	2	2	3	3	3	4	4	4	1	1	1	1	3	1
RELEASE AGENT																		
Product Selection	1	2	1	2	2	2	4	4	4	4	4	3	2	3	3	3	2	2
Application Technique	1	1	1	1	3	3	4	4	4	4	4	3	2	3	3	3	3	2
Surface Preparation	1	1	1	1	2	2	3	4	3	3	3	3	3	2	3	2	3	1
FORM TIES																		
System Selection	2	3	2	3	2	2	3	3	3	3	4	3	3	2	3	2	2	2
Installation Control	1	2	1	2	1	1	2	3	2	2	3	2	2	2	2	2	1	1
CONCRETE PLACEMENT																		
Technique	3	3	3	3	2	2	2	1	2	2	3	2	2	2	2	2	2	1
Equipment	3	3	3	3	3	3	2	1	3	3	4	3	3	2	2	3	3	1
Lift Height	2	3	2	3	2	2	2	1	2	3	3	3	3	2	2	2	3	1
Time of Lifts	2	3	2	3	2	2	2	1	2	3	3	3	3	3	3	3	3	1
CONSOLIDATION																		
Equipment Selection	2	3	2	3	2	2	1	1	2	2	2	2	3	2	2	3	2	1
Operator Training	1	2	1	2	2	2	2	1	3	3	3	3	3	2	3	3	2	1
Technique	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	3	2	1
Degree of Effort	2	3	2	2	2	2	2	1	2	3	3	2	2	2	2	3	2	1
REINFORCING STEEL																		
Detail Planning	2	2	2	2	2	2	1	1	3	3	3	3	3	2	2	2	2	1
Clear Space	2	3	2	3	2	2	1	1	3	3	2	3	3	2	2	3	2	1
Accurate Install	3	3	3	3	3	2	2	1	3	2	2	2	3	3	3	3	2	1
Support Methods	2	2	2	2	1	1	2	2	3	2	2	2	1	2	3	3	1	2
Splice Techniques	2	2	2	2	2	2	2	1	3	3	3	3	3	2	3	3	2	1
FINISHING																		
Timing	3	3	3	3	4	3	2	1	3	3	3	3	3	3	3	3	3	1
Equipment	–	–	–	–	3	3	2	1	2	2	2	2	3	2	3	2	2	2
Expendable Select	2	2	2	2	1	2	2	1	–	–	–	–	–	2	–	3	2	1
Tool Condition	–	–	–	–	2	3	3	2	2	2	2	1	4	3	2	3	3	–

*Absorptive

1 indicates a need for special attention by both design and construction personnel. 2 and 3 are intermediate indicators of importance. 4 signifies that if the work is done as with good structural concrete, the degree of effort will be satisfactory to produce the intended architectural quality finish.

TABLE 2--SURFACE BLEMISHES IN FORMED CONCRETE

I. CONSTRUCTION CONDITIONS	II. MIXTURE	III. PLACEMENT	IV. COMPACTION	V. FORMS	VI. OTHER INFLUENCES
A. Restricted Form Openings 1 Thin Section 2 Shape B BATTERED CONSTRUCTION C INTERFERING CONSTRUCTION 1 Projecting Resteel 2. Interference To Access 3 Str. Steel Fire Proof W/Min. D Internal Interference Blockouts 2 Conduits 3 Plumbing 4 Excessive Resteel 5 Steel Splices E. Weather 1 High Temperature 2 Low Temperature 3 Precipitation 4 Wind	A. Sticky 1. Excessive Sand 2. Low Sand-FM 3 High-SO-Sand 4 High Cement 5. High Air Content 6. Excessive Pozzolan 7. Particle Degradation B. Harsh 1. Excessive C A 2 Increase Sand FM 3. Poor Grading 4 Particle Shape C. Consistency 1. High 2. Low D Temperature 1 High 2. Low E. Early Stiffening 1 False Set 2 Flash Set 2 Excessive Mixing F. Admixture 1 Use 2 Type 3 Dosage	A. Bucket 1. Small Mouth 2 Configuration 3. Discharge Control B. Concrete Pump 1. Requires Fluid Mix 2. Breakdown 3 Slow Delivery C. Belt Conveyors 1. Segregation 2. Slump Loss 3. Mortar Loss D. Hopper/Tremie 1. Omitted 2 Too Small 3. Insufficient Number 4 Material E. Deposit 1 Spacing 2. Distant From Corner 3. High Volume 4. High Lift 5. Excessive Time Interval 6. Equipment Breakdown 7. Excessive Free Fall 8. Resteel Interfere	A. Equipment 1. Frequency 2. Amplitude 3 Power Source 4. Size 5 Number 6. Types 7. Voltage Drop 8. Maintenance B. Techniques 1. Vibration Period 2. Manipulation 3. Spacing 4 Depth 5. Head Partial Immersion 6. Too Powerful For Top 7. Placed Too Close To Form Joint 8. Continuity	A. Material Characteristics 1. Absorptivity 2. Roughness 3. Adhesion 4. Reaction With The Mix B. Leakage Control 1. Construction Joints 2. Corner Joints 2. Butt Joints 4 Tie Holes C. Release Agent 1. Type 2. Chemistry 3. Friction With Mix 4. Application 5. Cure D. Thermal 1. Cold 2. Heat	A. Curing B. Discoloration 1. Environment 2. Metal Stain C. Supervision 1. Understaff 2. Unqualified 3. Improper Planning D. Inspection 1. Understaff 2. Unqualified E. Workmen 1. Uninstructed 2. Unskilled 3. Insufficient Numbers F. Specifications 1. Inadequate 2. Inappropriate

Conformance and Performance for Economy and Quality

by C.H. Murphree

Synopsis: Forming economical concrete is discussed from the contractor's viewpoint. Two major concrete projects are used to compare manufactured with job-built systems for economy and quality. The contractor reveals his estimated and actual prices. The re-use of form panels, up to 72 times, produces real economy and achieves quality. The "team approach" in selecting the right system is used and recommended.

Keywords: concrete construction; contractors; economics; forming techniques; formwork (construction); performance; quality control; responsibility

Cecil H. Murphree, Vice President, Rudolph and Sletten, Inc. has devoted over forty years to construction. Prior to his present assignment he spent thirty-one years with a large and highly respected contractor in California specializing in concrete construction, in positions from field operations to Vice President, Construction. His experience includes commercial, industrial and heavy construction.

INTRODUCTION

My first real concrete experience was on the end of a shovel conforming to a cadence of 4 3 1 or 3 2 1 measuring aggregates, sand and cement into a half-yard mixer on the jobsite. When a public works project came along we built a cubic foot box with 2 handles on each side to meet the measured requirements of the agency.

My first choice for a title for this presentation was, "Do it right the first time", for this is our company motto. Then I questioned myself, "Just what did I want to say about contractors?" Here was where conformance and performance came in.

First - the contractor must conform. By definition, conform means "to be obedient or compliant" or "to prevailing standards or customs". Not many contractors are obedient or compliant. Then as a play on words, CON FORM combines both concrete and form.

Second - the performance of the contractor is all important. Perform means "to do in a formal manner or according to prescribed ritual". Notice again; the middle of the word performance is FORM.

The contractor's conformance and performance ultimately determine the effectiveness of the architect, the structural engineer, the American Concrete Institute and Portland Cement Association. Unless the contractor conforms to the structural engineer's requirements and unless the contractor performs his work as engineered and designed, the good research performed and made available by ACI and PCA is wasted.

We have in California, a group of specialty contractors who do only forms and concrete work. Some are good, many are not. We, as a general contractor, resist using them. The track record when we have used them, is not good. We lose schedule control and have a continuous problem with quality control. Our experience is that we must assign about the same supervision as though we did the work ourselves. Also, many general contractors are not known for their quality work.

Good concrete depends largely on the selection and proper use of the right form system. Every concrete job of 1,000 c.y. or more should be considered for repeat and re-use, surface finishes, configuration, line and plane and all restraint factors. It must consider all known systems and, of course, job-built ones. Detail the systems sufficiently to cost-out for decision making. This is the only way I know to decide on the best system for a particular project. The study and research is not a one-person job. I prefer to have as participants the foreman, the superintendent, the project engineer, the project manager and, of course, the estimator. Most superintendents do a fine job, but too often they are left to their own devices for the form selection. Frequently, many of them will use the system they've used successfully before. There is no substitute for the TEAM I've just mentioned.

This presentation proposes to give you concrete forming from the contractor's view. During my 40 plus years in building I've participated in placing over a million cubic yards of concrete. Here, I wish to share the forming of two of my most interesting and rewarding concrete projects. The two jobs are so unlike in their forming process -- yet they are alike in that each finished product is the ultimate in quality concrete. One project almost shouts "re-use" and "economy" from the proper use of large form panels. The other project emphasizes the need for detailing and precision in job-built form systems.

FORM RE-USE FOR ECONOMY

The San Jose/Santa Clara Water Pollution Control Plant handles the waste water for nine cities and communities. My tertiary (third stage) project increased the treated flow from 120 million gallons per day to 173 million gallons per day. This was a competitive bid job. The project consisted of five major buildings, five major concrete structures, several miles of piping up to 130-inches in diameter, and five live-wet tie-ins plus many other features. We formed and placed just under 100,000 c.y. of nearly perfect concrete. In our process of form selection, we considered seven different patented form systems, and, of course, job-built. We detailed, priced and analyzed each system. Here is what we selected and used:

1. The Tertiary Settling Tanks: Twelve (12) concrete tanks 144 feet diameter, fourteen (14) feet deep required 275,000 contact feet of forming. We selected and used Ewing-Records built metal forms as shown in figures 1 and 2. We purchased 60 degrees (74 feet)

and our re-use was 72 times. The cost model in Table A shows the forming labor, estimate, cost, and the square footage involved. A sweep mechanism was used to screed the 2" bottom surface topping to the required close tolerance.

2. The Ammonia Nitrification Batteries consisting of 11,650 LF of Y-wall and divider wall. The walls were twenty feet high with a batter at the bottom and contained 234,000 contact feet of formwork. We selected EFCO metal forms and modified them to fit our needs, (see figure 3). On the Y-walls we experienced 24 re-uses. On the divider walls we had 56 re-uses. See cost model Table A for estimated and actual costs.

3. The Box Culvert (Traveler) Metal Forms: The contract documents called for 4,000 LF of 144-inch concrete pipe from the Tertiary settling tanks to the Tertiary filter facility. This was not a legal highway load and would have required a plant on the jobsite. We proposed a substitution of 11 feet by 11 feet ID concrete culvert. The substitution was accepted at no change in price. For the 152,000 contact feet we used EFCO metal forms with 46 re-uses, (see figure 4). A unique "top-hanging support system" enabled us to drop the traveler and move forward every 2 days. Table A cost model details our experience with this form system.

4. Combination Radius and Straight Chlorine Contact Walls: These forms were job built using medium density plywood with fiberglas coating. These walls vary in height from 17 feet to 20 feet for a total of 221,000 sq.ft. We built a special frame on which to construct the actual form panels as shown in figures 5 and 6. Each of our form panels weighed 6,000 lbs. We realized 32 re-uses with this job-built system. A review of the cost model in figure A tells us that we might have selected the wrong system. We also experienced a surface bubble problem. If I were to do the same thing again, I would use a manufactured metal form with external vibrators to supplement the internal consolidation.

5. The Tertiary Blower Building Job-Built Forms: For the 63,000 contact feet we used job-built form panels and built in-place forming as shown in figure 7. This building did not lend itself to repeats. You will see from the cost model in Table A that it was our most expensive forming.

6. Form Hardware: With the exception of the blower building and box culvert, we used tapered ties because of the thick wall sections involved.

7. All of the forming costs in this discussion have been factored to 1986 dollars.

The Monterey Bay Aquarium - Job Built Forms

A negotiated Guaranteed Maximum Price Contract.

Since opening in October 1984, just under four million people have visited the Monterey Bay Aquarium.

The Aquarium has been the subject of feature articles in Architectural Record, Concrete International, Sunset Magazine, Connoisseur, Smithsonian, Newsweek, Science 84, Der Spiegel, Madame Figaro, Chevron USA, Engineering News Record, California Builder & Engineer, Ocean, and Dialogue (published in 10 languages by U.S. Information Agency), Wall Street Journal, New York Times, L.A. Times and other newspapers throughout the western world and carried by such television shows as National Geographic - PBS Television, Today Show, CBS Evening News and Good Morning America.

As builder of the Aquarium the greatest honor accorded this contractor was receipt of the Concrete Building Award of Excellence for 1984 from the Portland Cement Association and the American Concrete Institute at the Second International Conference in Chicago.

The Monterey Bay Aquarium came to this contractor in the design/pre-construction state. The major considerations of design were: a) It must duplicate in appearance the old Hovden Sardine Cannery, to be demolished, b) It must not contain any mistakes made by the other major aquariums in the U.S., c) It must be built to last "250 years". All of these considerations presented some problems to the design team and the contractor.

The owner wished to retain, as much as possible, portions of the sardine cannery to become part of the new aquarium. In this respect we were able to keep, by remodeling and stabilizing:

The old three story warehouse - as the administration building

The old boiler plant - as a museum

The old pump house - as the seawater intake pump chamber