What the inspector looks for

What you see is what you get—or is it?

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The work of a concrete construction inspector takes place in three stages: before, during and after concreting.

STAGE 1: INSPECTION BEFORE CONCRETING

Soon after the contract is awarded and well before any concrete work is started, inspection personnel should review the contractor's plans for all phases of concrete operations. Some specifications require the contractor to submit a list of the material suppliers as well as the plans for stockpiling materials and forming, batching, mixing, delivering, handling, placing, consolidating, curing, protecting and repairing concrete. These matters should be reviewed for conformance to the specifications.

The requirements and responsibility for preconstruction qualification of materials, certificates of compliance, mix designs, quality control testing by the contractor and quality assurance testing by the inspection personnel should be reviewed and agreed upon. Meetings should be held to inform inspectors of all the above matters, including decisions and agreements made between the contractor and engineer; correspondence regarding these matters should be made available to the inspectors for review. On large jobs with several inspectors and sometimes shift work, a checkout sheet for concrete placement (see figure) is generally used to note the completion and approval of various items requiring inspection. Only after all items have been signed off is approval given to place concrete.

Excavation and foundation preparation

Foundations for major structures should be designed by soils or foundation engineers on the basis of subsurface exploration and/or determination of the geology of the site. The inspector must see that earth foundations have been excavated to firm material, with any soft material removed and replaced by some satisfactory material. Sometimes backfilling with selected material or using subbase and base courses is required by the design and specifications. Rock excavation should be done with powder charges as light as practical to minimize shattering the rock. The rock surfaces should be normal for the loads transmitted to them from the concrete structure. Fault zones or other poor rock may require overexcavating and backfilling with suitable granular materials or backfill concrete.

The inspector should always know the foundation conditions anticipated and be alert to changes in these conditions. Any unexpected discovery should be brought to the attention of the designer for further review and consideration.

The inspector must also see that foundations are free of water and frost before concrete is placed on them. Earth foundations should be moistened to reduce absorption of water from the concrete. Rock surfaces can best be cleaned by air-water jets and pools of water can be removed by air jets.

Reinforcing steel

The primary purpose of steel reinforcement is to carry tensile forces for which concrete is relatively weak. The designer determines steel requirements based on the design considerations and shows these requirements in the specifications and design and contract drawings. It is the responsibility of the inspector to ensure that the steel is installed and used in accordance with the specifications and drawings. Steel inspection is usually concerned with the following:

Bar lists and diagrams

Bar lists are usually prepared by the contractor or steel supplier and show the bending diagrams, location and other details for all steel for the job. The inspector should be sure that the design office has approved them and then should become thoroughly familiar with them.

Type and grade of steel

Upon receipt of the steel at the jobsite, the inspector should determine that it is of the specified type and grade as shown by the identifying markings rolled into the bars. The bars should have mill tags identifying the heat number from which the mill test results and compliance with the specifications with respect to quality can be determined. If the bars are precut and bent prior to receipt at the job, they should have identifying tags in accordance with the bar lists.

Condition of steel

The inspector should see that the steel is free of mud and dirt, oil and grease, curing compound, soft or loose mortar and heavy, flaky rust.

A light coating of tightly adhering rust or mortar is not usually considered objectionable.

Placing and welding of reinforcement

The inspector should note particularly that the bars are of the required size and shape and have been placed within allowable tolerances ... that splices have the required lap and are not located at points of maximum tensile stress . . . that welded splices, if permitted, are done in accord with recommended procedures such as those of the American Welding Society (AWS D 12.1)* . . . that the reinforcement is being adequately tied and supported to remain in position when concrete is placed . . . and that the specified cover of concrete over the steel is being obtained. This latter requirement is particularly important to protect steel in concrete exposed to weather, earth or other potential deteriorating environments. Any foreseeable problems should be discussed when they are first noted; they can be more easily corrected then instead of after the final inspection. The reinforcing steel inspector will find much more detailed information given by the Concrete Reinforcing Steel Institute in Placing Reinforcing Bars—Recommended Practices.

Forms

The inspector must ascertain that the forms are capable of safely holding the plastic concrete to the required dimensions and tolerances.

*Recommended practices, standards and publications referred to in this article appear in "The Concrete Inspector's Bookshelf," page 575.

Forms must be designed to resist the pressures of plastic concrete with adequate structural strength, bracing, form ties and shoring. In some locations certain types of forms are required to be designed to building code requirements for safety by registered professional or structural engineers.

Inspectors for bridges and similar structures should check that shoring is placed on solid supporting material, not on loose soil, mud or frozen ground. On some jobs camber must be built into the forms to compensate for settlement of the shoring as the load of the fresh concrete is applied.

Sometimes lines (often called telltales) are strung so that settlement or deflections of forms can be watched for indications of weakness during concrete placement. A form watcher is usually assigned to this job to watch for potential problems.

Date: 5-30-74

CONCRETE PLACEMENT CHECKOUT SHEET

STA. FROM 18+50 - 19+00 STA. TO ELEV. FROM 429 50 ELEV. TO 441 50

FEATURE: Left wall in stilling basin POUR NO. L-16

CHECK OUT ITEM	FOREMAN	GFACo. Engr	DWR Engr	DT. & HR.
FORMING & BLOCKOUTS	DWPrice	FPA	RFA	5/15 1100
LINE & GRADE	JCK	FPA	HB	5/25 1200
REINFORCING STEEL	N.B.	FPA	RFA	5/22 1600
METAL SEALS	—			
EMBEDDED METAL ITEMS	—			
RUBBER WATER STOPS	DWPrice	FPA	RFA	5/25 1100
PIPING	—			
INSERTS	—			
ELECTRICAL	—			
TECHNICAL INSTALLATIONS	—			
ANCHOR BOLTS	HB	FPA	RFA	5/28 1300
ARCHITECTURAL ITEMS	—			
FINAL CROSS-SECTIONS	—			
ROCK FOUNDATIONS				
CLEAN UP	HDK	FPA	RFA	5/30 0730

O. K. TO PLACE CONCRETE

GFACo. Engr. FPA DATE 5/29 TIME 1600

DWR Engr. RFA DATE 5/30 TIME 0730

GFACo. Supt. SPH DATE 5/29 TIME 1630

POUR STARTED DATE 5/30 TIME 0830

POUR COMPLETED DATE 5/30 TIME 1530

COMPUTED CU. YDS. 98

CU. YDS. GROUT 1

CU. YDS. CONCRETE 98 1/2

TOTAL CU. YDS. PLACED 99 1/2

CU. YDS. WASTE AT POUR 1 1/2

CU. YDS. WASTE AT PLANT 0

TOTAL CU. YDS. PLANT 101

This checkout sheet records satisfactory completion of operations preliminary to placing concrete. It also includes a record of time and size of placement.

Form ties and anchorages are designed for certain concrete pressures which should not be exceeded. This may limit the rate of concrete placing to some specified value; it usually depends upon temperature and other factors as given in ACI Standard 347, "Recommended Practice for Concrete Formwork."

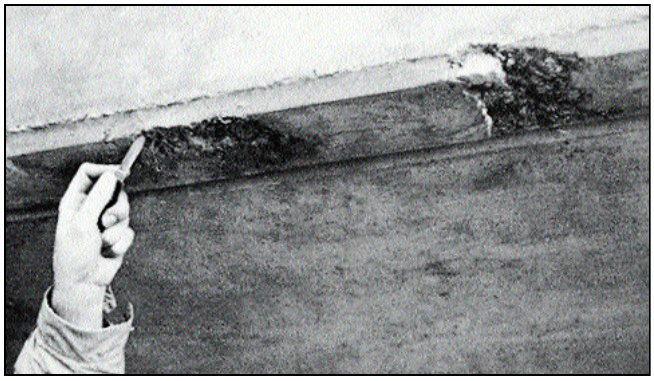
With architectural concrete or other exposed concrete where appearance is important, sample panels often are required for inspection prior to construction and sometimes are incorporated later into the structure where they cannot be seen. The inspector should check the form surface or form liner material (lumber, pressed wood, plywood, steel, aluminum, laminated fiber, corrugated paper, polystyrene foam or elastomeric material) if it is to produce the texture and appearance required. Sometimes the desired architectural texture is obtained by a surface treatment such as sandblasting or bushhammering after the forms are removed.

Grooves, rustication strips and chamfer strips should be used at construction joints, between panels and in corners to improve the appearance of the concrete.

The inspector should be aware that some woods can stain the concrete. Some other woods, when not treated or not sufficiently treated, cause a retardation of hardening at the concrete surface, creating a soft and dusting surface. This problem disappears as the forms are reused but it can be prevented entirely with proper treatment of the wood before its first use.

A competent inspector also sees that the forms have openings for washing out dirt just before the concrete is placed. Sometimes forms should have openings for getting the concrete into otherwise inaccessible places and for inserting vibrators to consolidate the concrete.

Forms should always be tight enough so that mortar does not leak out when the concrete is vibrated during placement, leaving voids which resemble unsightly and undesirable rock pockets (honeycomb), unless the architect specifies doing this in a controlled manner for its architectural effect. At horizontal construction joints the forms should fit very tightly against the existing concrete with only a small overlap, about 1 inch (25 millimetres), so as not to get offsets and mortar leaks from the concrete pressure bulging the bottom of the forms.



Wood chips and dirt were not cleaned out of the forms before this concrete was placed. Repair is needed.

Form faces may require treatment with form release or parting compounds for easy removal without concrete adherence, although some types of release agents, such as those containing waxes and silicones, may not be suitable if the concrete is to be painted. Some of the coating materials also provide a more durable surface for the form material to permit more reuses of the forms. For more information on form release agents and coatings, see the three-part series of articles appearing in the March, April and May 1975 issues of CONCRETE CONSTRUCTION.

The inspector can find very useful information on the general subject of forms in ACI Standard 347, "Recommended Practice for Concrete Formwork"; ACI Special Publication SP-4, *Formwork for Concrete;* and Joseph J. Waddell's *Concrete Construction Handbook*.

Embedded items and blockouts

The plans and drawings should show the location of embedded items (pipe, conduit, manhole frames, catch basins, waterstops, anchor devices for machinery, or attachments for supporting ductwork, piping and ceilings) and Lockouts (door, window, handrail, gate guide or seal openings) in the concrete and these should be noted by the inspector. If possible, any embedded items should be firmly anchored into place in their proper locations prior to placing concrete. When embedment is necessary during concrete placing, the location of these items should be noted on the forms.

Sometimes embedded items or blockouts interfere or conflict with the location of reinforcing steel. The inspector must be sure that a decision is made in these cases—whether to move or shift the item or steel, cut the steel or work out some other solution. If structural considerations are involved, the designer should be consulted for his approval or recommendations.

The inspector should also check anchor bolts for machinery bases. They should be set so the exposed portion of the bolt can be shifted slightly to compensate for inaccuracies in placing the bolts. Commercially available devices accomplish this or one can be made from a piece of steel plate and a pipe sleeve.

Construction joints

Where watertight construction joints and good bond between lifts of concrete are required, the inspector should be sure that the previously placed concrete is cleaned of laitance and any dirt or soft concrete. It is best done by wet sandblasting or a high-pressure water jet. This operation need proceed only enough to remove the soft material

to a clean, bright concrete surface without excessive cutting. Then the surface is preferably kept damp or wet (cured) until ready for the next placement. Prior to concrete placing the surface should be washed clean and any free water removed.

Some specifications require a mortar or neat cement grout to be scrubbed (broomed) onto the surface of a construction joint immediately before placing the first layer of concrete. Other specifications may require a richer mix with a slightly higher slump and sand content in the first layer. This can be accomplished by omitting part of the coarse aggregate (or the larger size of coarse aggregate) from the mix. In any case the inspector should check that the first layer of concrete is thoroughly vibrated.

STAGE 2: INSPECTION DURING CONSTRUCTION

Inspection of this phase of the concrete work is usually divided into two parts: concrete production and concrete placing. It is quite helpful to have good communications between the inspectors assigned to these two parts, especially if they are far apart. The inspector at each end can keep the other advised (perhaps by phone or radio) of progress and any problem affecting operations so that prompt action can be taken.

Batch plant inspector

This inspector should be familiar with the specification requirements for anything particularly pertinent to batch plant start-up such as scale checks, mixer performance tests, condition of plant and mixers, visual admixture dispensers, moisture and consistency meters, material certification or batch tickets. He or she should know the basic mix proportions to be used and the subsequent corrections that have been made in the aggregate and batch size. Familiarity with ACI Standard 211 .1, "Recommended Practice for Selecting Proportions for Normal and Heavyweight Concrete," will help the inspector determine that these and any other needed adjustments to the mix are made satisfactorily.

The batch plant inspector should have the necessary laboratory equipment to sample and make the required quality control tests on concrete and concrete materials. On a day when concrete will be batched, the inspector should arrive at the plant early to observe the condition of the aggregate in stockpiles and bins. He or she should be alert and observant during concrete production, particularly for any changing conditions which would affect the concrete quality control.

Placing inspector

This inspector should review the placement checkout sheet to determine that all items have been completed before the concrete is ordered. Concrete work proceeds best when the concrete is delivered, handled and placed systematically, rapidly and without delays. Inadequate or inefficient concrete handling equipment should be replaced.

The placing inspector should see that the concrete is handled without segregation. Concrete should be placed in the forms in layers not exceeding about 18 inches (450 millimetres) deep. Consolidation (usually vibration) of the concrete should systematically follow its placement so that all areas are uniformly compacted. Any separated concrete should get special attention to eliminate rock pockets.

If a vibrator is used, the concrete should be deposited where it is to remain and not made to flow long distances. Vibration should continue until the concrete is adequately compacted. Spare vibrators are a must—to replace any which fail to operate properly. The frequency of vibrators can be checked with a frequency-measuring instrument and the adequacy of the air or electric supply checked with a pressure gage or electrical instrument. A table showing the ranges of frequencies and other characteristics of internal vibrators is given in ACI 309, "Recommended Practice for Consolidation of Concrete." Data are also available from vibrator manufacturers.

Specification requirements on placing rates should be observed to control form pressures. It is considered good practice to put drier (lower slump) concrete in the top of a wall than in the lower portions. The specifications may require revibration of the concrete in columns, around openings or in walls required to be free of leakage.

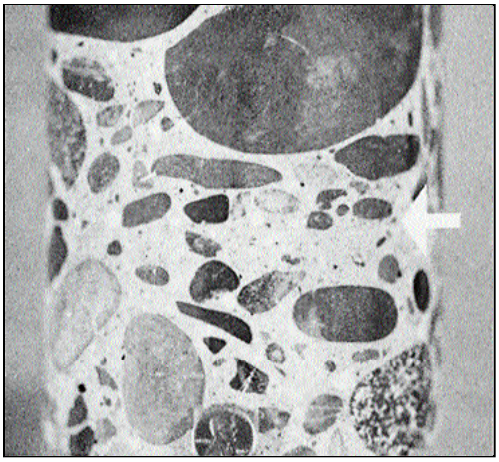
Following removal of the forms, placing and contractor personnel should examine the concrete for any defects so they can determine how to improve future placements. The inspector should either participate in making the examination or be informed about the conclusions drawn.

Inspectors of concrete production and placing will find much helpful information in ACI Standard 304, "Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete"; ACI Standard 309, "Recommended Practice for Consolidation of Concrete"; and ACI Special Publication SP-2, ACI Manual of Concrete Inspection.

Finishing flatwork

Finishing of concrete flatwork should consist of the proper performance of one or more of the following sequential operations: screeding, bull floating or darbying, waiting for bleeding to cease, edging and grooving, floating, troweling, and brooming or texturing.

During the screeding operation (striking off or removing the excess concrete to bring it to proper grade), the screed should be moved across the concrete with a sawing motion and pushed forward to remove the surplus. Screeding should be immediately followed by the bull floating or darbying operation to eliminate high and low spots and embed the coarse aggregate. The concrete surface should not be overworked.



This core was taken across a well-made construction joint in mass concrete. Apart from the change in aggregate size, the demarcation between old and new concrete is not apparent. The joint was well cleaned by sandblasting and no mortar or grout was used on the joint. Excellent bond was achieved.

After a waiting period for the concrete to harden and cease bleeding, the concrete surface may be edged, grooved and floated. The wood or metal float further embeds coarse aggregate, eliminates surface imperfections (including humps and voids) and compacts the surface. A second floating may be performed for a denser surface.

To provide an even smoother, denser surface, troweling with a steel trowel follows floating. A number of additional trowelings may follow, depending on how dense a surface is required. Power floats are used on all but the smallest jobs and these are followed by power trowels. The final troweling is done by hand.

Premature floating and troweling while the concrete is still bleeding may result in scaling, crazing or dusting—or a surface with reduced wear resistance. Only enough finishing should be done to provide the concrete surface required.

Brooming with a wire or bristle broom (either soft or stiff) may be done on floated or troweled concrete to provide desired textures and a nonskid surface.

The inspector will find excellent references on finishing in the ACI Standard 302, "Recommended Practice for Concrete Floor and Slab Construction"; Portland Cement Association's *Cement Mason's Guide;* and the *Concrete Construction* reprint collection entitled "Concrete Floor Construction" (originally published in the November 1973 special issue of *Concrete Construction*).

Testing concrete

The various test procedures used for quality control and quality assurance of concrete and associated materials are given in detail in ASTM and other standards. These procedures should be honestly and religiously followed; minor deviations may produce unexpected results different from those obtained by following a standard procedure.

Probably the most important part of a test procedure is the sampling. Unless the sample is representative and unbiased, tests are meaningless. It does no good to take a sample of concrete and test it for slump and strength and then immediately add water to secure additional slump. Such dishonest testing must not be tolerated because it gives a false indication of the quality of the concrete and may be dangerous.

Tests of concrete for quality control purposes during concreting are usually those for consistency (slump, ball penetration or other method), air content, unit weight and temperature. The test results are used to control or adjust the concrete. Concrete test cylinders or beams are made for strength tests at later ages.

The strength tests are made on either standard- or field-cured specimens or both. Field-cured specimens are usually tested at intervals to determine when the concrete has attained sufficient strength for forms or shores to be removed, or for concrete to be loaded or put into service. Standard cured specimens are tested to evaluate the quality control of the concrete. Strength tests are usually evaluated on a statistical basis.*

Newer testing procedures for more rapid strength evaluation are being more and more widely used. These strength tests utilize ASTM accelerated curing procedures and give results in one or two days. The results correlate well with those of the 28-day strength test and are much more useful; that is, they allow more timely correction of low strength conditions.

When strength tests are substandard, other strength evaluation testing may be done to confirm the strength tests or to determine if the concrete is good enough to remain in place. Tests that might be resorted to in such cases are strength tests of cores or specimens cut out of the structure and rebound hammer tests, penetration probe tests and sonic tests of the concrete. Such testing to evaluate the strength of hardened concrete to justify its remaining in a structure usually becomes a hassle.+ Much of this could be eliminated by good, honest inspection and workmanship during concreting.

STAGE 3: INSPECTION AFTER CONCRETING

Curing and protection

Curing (maintaining a satisfactory moisture and temperature condition in the concrete) is required for cement hydration so that the concrete will develop strength and other desirable properties. Curing is accomplished by either applying water or sealing the concrete surface to prevent loss of water. Water curing is accomplished by ponding or immersion, fog spraying or sprinkling, or covering with damp earth, sand, sawdust, straw or hay, or water-soaked rugs or mats (burlap or cotton). Curing by sealing the surface is accomplished by covering with plastic film, waterproof paper or a liquid membrane-forming compound (available as black, clear

or pigmented, usually white or grey). It is the responsibility of the inspector to determine that the curing measure specified is applied and satisfactorily maintained for the required curing period.

Curing should start as soon as possible after the concrete is placed and finished—and when the curing procedure can be accomplished without marring or damaging the concrete surface. Where appearance is important, curing must be uniformly applied. If a curing compound is to be used and the concrete will be painted or coated later, the inspector should check that the compound is known to be compatible with the paint or coating specified. Curing materials, procedures and minimum durations for various types of structures are given in ACI 308, "Recommended Practice for Curing Concrete."

Sometimes precautions need to be taken to protect concrete from the undesirable effects of weather, namely rain and cold or hot weather. Considerable information on the effects of hot and cold weather and the measures that can be taken to mitigate undesirable effects of weather can be found in ACI 305, "Recommended Practice for Hot Weather Concreting," and ACI 306, "Recommended Practice for Cold Weather Concreting." The inspector should anticipate the possible or probable need for these measures and see that the preparations are made beforehand. Long- and short-range weather forecasts and patterns expected in the area of work are helpful.

Form removal

Forms are usually removed as soon as practical after the concrete has hardened enough that no damage results. This permits early application of curing measures, early reuse of forms and the repair of any defects in the concrete at an early age, when the concrete can best be repaired.

Forms should be carefully removed, particularly when architectural concrete is involved. Steel pry bars frequently span edges and corners and mar the surface of the concrete. Sometimes wooden wedges can be used.

For reasons of safety the supporting forms and shores for structures which are loaded, such as bridge decks or floors in multistory buildings, must not be removed until the concrete has attained sufficient strength. This required strength is indicated by the designer. The strength of the concrete can be determined by using field-cured cylinders—those cured under conditions as near as possible to those for the concrete in the structure, especially the temperature. Other test methods that may be used include the recently developed cast-in-place pushout cylinders, cores, penetration probe, and rebound hammer.

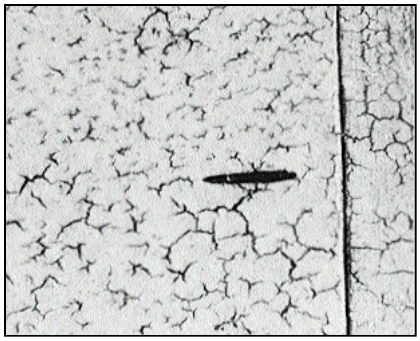
Reshoring, which is usually done in multistory buildings to help support the floors above, also requires inspection. Reshoring may remain in place in several successive floors.

Repairs

The inspector and the contractor's representatives should observe the concrete soon after the forms are removed to determine what repairs might be required. Sometimes this observation indicates deficiencies in the concrete handling and placing procedures which can be corrected in future placements, obviating the need for future repairs. Good repairs are difficult to make and expensive. Cheap repairs are unsightly and usually not satisfactory. The repairs should be inconspicuous. Sometimes white cement is added to grey cement to match color.

Soft mortar should not be plastered on a surface to make a repair; such repairs are not satisfactory. Shallow patches and spans can be built up using small dry-shotcrete equipment.

For larger repairs such as large areas of rock pockets (honeycomb), the defective concrete should be removed to sound concrete. Sometimes the area is outlined with a concrete saw to provide better appearance. Concrete is usually used for replacement. On vertical surfaces, the area is formed and provisions made for placing the repair concrete through a chimney or funnel arrangement. If a watertight repair is desired provision can be made to apply pressure to the concrete by tightening the forms or by using pressure on the concrete in the chimney. A small amount of aluminum powder in the concrete is useful in this type of repair to create a slight expansion where the concrete is confined.



The curing compound on this canal invert has alligatored because it was applied while the concrete was still bleeding. It consequently provides an inadequate curing membrane.

Bond of fresh to older concrete is best achieved by dampening the older concrete for several hours (allowing no free water on the surface) and scrubbing a neat cement paste into the surface. Another method is to apply a suitable bonding agent, such as epoxy, to dry concrete just before the repair concrete is applied.

For more information on repairs, see the U.S. Bureau of Reclamation's *Concrete Manual,* Eighth Edition, Chapter VII, as well as ACI Special Publication SP-21, *Epoxies with Concrete,* and the ACI Committee 201 Symposium, "Restoration of Deteriorated Concrete."

SPECIAL CONCRETES AND TECHNIQUES

Most of the foregoing discussion on inspection and concrete con-

struction refers to the conventional and most common type of concrete for cast-in-place buildings and other structures. There are many other special concretes or techniques for which the procedures discussed might or might not apply—such as precast, prestressed, post-tensioned, structural lightweight, heavyweight, insulating, tilt-up, slipform, tremie (underwater), preplaced aggregate, vacuum, shotcrete, architectural and mass concrete. Space does not permit discussing them.

Should the inspector become involved and have little experience in any of these special concretes and techniques, he or she can find much helpful information in the technical literature of the American Concrete Institute, the Portland Cement Association, the Prestressed Concrete Institute, the Post-Tensioning Institute, the Expanded Shale, Clay and Slate Institute, the Perlite Institute, and others. Literature from technical service engineers of various materials and equipment manufacturers and discussions with other inspectors and engineers are also helpful.

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