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ABSTRACT

This workbook is one of a series of individually bound units of instruction for carpentry apprenticeship classes in a four-year apprenticeship program. It consists of two sections--the workbook section and a test section. The workbook section provides instructional materials on 10 topics: introduction to cement and concrete, specifications for concrete, aggregates, sampling and testing of concrete, concrete admixtures, methods of concrete placement, movement of concrete on the job, finishing of a concrete slab, curing of concrete, and reinforced concrete. For each topic, these materials are included: questions on which to focus during reading, informative material, and a study guide (review questions). Lists of required and recommended materials are provided. The test section contains a test for each topic in the workbook section. (YLB)

A column labeled "Date Assigned" has been provided at the right-hand side of each page number in the contents. Whenever your instructor assigns a topic, he or she should write this date in the appropriate blank. When you have completed the topic satisfactorily, your instructor should place his or her initials next to the assignment date. If this procedure has been followed, and you should transfer from one school to another, you will have an accurate record of the work you have completed. It should never be necessary for you to duplicate work on topics already studied or to skip topics not previously assigned.

To provide other school records needed, be sure to fill in your name, home address, and telephone number below. Then ask your instructor to fill in the official date of your enrollment in his or her class and to sign his or her name.

NAME ______________________________

ADDRESS ______________________________

______________________________ PHONE ______________

DATE ENROLLED ______________________________

INSTRUCTOR(S) ______________________________

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Course in Carpentry

CONCRETE

Workbook and Tests

Prepared under the direction of the

California State Joint Apprenticeship and Training Committee
for the Carpentry Industry
Carpentry Curriculum Revision Committee

and the

Bureau of Publications, California State Department of Education

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Course in Carpentry: Concrete is one of a series of 20 titles in the carpentry series containing workbook and testbook materials within one volume. The titles available, together with year of publication or revision and selling price, are as follows:

The Apprentice Carpenter and the Trade	(Rev. 1984)	$3.50
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Theodore R. Smith or Bob Klingensmith
Bureau of Publications
California State Department of Education
721 Capitol Mall
P.O. Box 944272
Sacramento, CA 94244-2720
(916) 445-7608

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Foreword

Welcome to the world of apprenticeship. Congratulations, too, on having selected carpentry as your area of specialization; you have chosen a time-honored and essential profession. Many formidable challenges lie ahead of you, both on the jobsite and in your related-instruction classes, but I believe that the pride and excitement you will experience and the more tangible rewards you will reap will greatly outweigh the difficulties inherent in meeting those challenges.

As an apprentice in the four-year carpentry apprenticeship program, you have a unique opportunity to receive excellent training in all aspects of the trade. I urge you to take full advantage of that opportunity and to apply yourself diligently in each phase of the training program, because in today's tight job market, workers who have mastered the full range of skills have the best chance of keeping themselves employed.

The role of the Department of Education in providing carpentry apprenticeship instructional materials goes back many years. The Department is proud of that role and pleased to be able to continue its cooperative association with labor and management in keeping *Concrete* and the other volumes in the Course in Carpentry series up to date. On behalf of the Department, I wish you great success as an apprentice and as a journey-level carpenter.

Bill Honig

Superintendent of Public Instruction

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Preface

The California State Department of Education, through the Bureau of Publications, provides for the development of instructional materials for apprentices under provisions of the California Apprentice Labor Standards Act. These materials are developed through the cooperative efforts of the Department of Education and employer-employee groups representing apprenticeable trades.

Concrete, which was first published in 1976, was planned and prepared under the direction of the California State Joint Apprenticeship and Training Committee for the Carpentry Curriculum Revision Committee. Many individuals representing employers, employees, and public education contributed to the 1976 publication. Those representing central and northern California included James Brooks, Charles Hanna, Gordon Littman, Charles Royalty, Hans Wachsmuth, Bill Walker, and Jimps Wilcox. Those representing the Los Angeles area included Tom Benson, Creighton Blenkhorn, John Cox, Allen Kocher, and Al Preheim. San Diego representatives were Paul Cecil, Jess Dawson, Robert Moorhouse, and Billy Williams.

This workbook is one of a series of individually bound units of instruction for carpentry apprenticeship classes. It consists of two parts—a workbook section and a tests section. A test is provided for each topic in the workbook section, and each test sheet is perforated and arranged so that it can be easily removed from the book, at the discretion of the instructor, without disturbing any other test. These books reflect the continuing cooperative effort of labor, management, local schools, and the Department of Education to provide the best instructional materials for California apprenticeship classes. They are dedicated to excellence in the training of carpenter apprentices.

WILLIAM C. PIEPER
Deputy Superintendent
for Administration

THEODORE R. SMITH
Editor in Chief
Bureau of Publications

Acknowledgments

Gratitude is expressed to the listed manufacturers and associations within the construction industry who contributed valuable technical information, drawings, and photographs used in this series of carpentry units.

American Plywood Association
American Technical Society
Duo-Fast Corporation
Formica Corporation
National Forrest Products Association
Red Cedar Shingle and Hand Split Shake Bureau
Republic Builders Products Corporation
Rockwell International Corporation, Power Tool Division
Schlage Lock Company
Stanley Tools
TECO Wood Fastenings
United States League of Savings Associations
Von Duprin Incorporated
Western Wood Products Association

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Concrete

TOPIC 1 – INTRODUCTION TO CEMENT AND CONCRETE

This topic is planned to provide answers to the following questions:

- **Why should the carpenter know as much as possible about concrete?**
- **What are the various types of cements?**
- **How is portland cement made?**
- **What are the properties of portland cement?**

The skilled building-trades journeyman today is one who understands the "why" as well as the "how" of construction processes. He also has a thorough knowledge of all the types of materials he uses so that he can select the most effective ones for specific applications. Concrete is one of the materials that the carpenter must understand thoroughly and must use correctly to be a capable journeyman.

Cement is the most important ingredient of concrete. The apprentice should learn all the important facts about cement before studying the other materials used in concrete.

Portland Cement

Cement is composed mainly of lime (about 60 percent) and silica (about 20 percent), plus alumina and iron. Cement rock containing some or all of these elements is mined in many different parts of the country. If the mined rock lacks any of the basic ingredients necessary for cement, these are added during processing to complete the composition. The cement rock is ground to a very fine powder that when mixed with water forms a paste to bond aggregate (sand and gravel) together as concrete.

Properties of Portland Cement

Although the carpenter need not have a detailed technical knowledge of the physical and chemical properties of portland cement, he should know what these properties are, the terms by which they are known, and what effect they have upon the performance of concrete. Some of the more important properties of portland cement–fineness, soundness, setting time, compressive strength, and heat of hydration–are discussed in the study assignment for this topic.

Types of Portland Cement

Portland cement is manufactured in a variety of types to meet a wide range of physical and chemical requirements. Most structures require one of the following types of portland cement:

Type I (normal portland cement). Type I cement is a general-purpose cement suitable for all applications in which the special properties of the other types–for example, increased resistance to sulfate attack–are not required.

Type II (modified portland cement). Type II cement is used where resistance to moderate sulfate attack is important. Type II cement will usually generate less heat, and at a slower rate, than Type I; this is an advantage when the concrete is to be placed in warm weather or is to be used in structures of considerable mass.

Type III (high-early-strength portland cement). Type III cement develops high strength relatively soon after placement. This characteristic makes it useful when forms are to be removed early or when the structure must be put into service quickly.

Type IV (low-heat portland cement). Type IV cement is especially suited for applications where the rate and amount of heat generated during hardening must be kept to a minimum, as in massive structures such as dams. Type IV cement develops strength at a slower rate than Type I.

Type V (sulfate-resistant portland cement). Type V cement is used only in concrete exposed to severe sulfate action. It gains strength more slowly than Type I cement.

Air-Entraining Portland Cements

Air-entraining cements correspond in composition to types I, II, and III, except that they have small quantities of air-entraining materials interground with the clinker (hard nodules produced by burning certain stone or clay-type materials in a kiln) during manufacture. Concrete made with air-entraining cement contains vast numbers of minute, well-distributed, and completely separated air bubbles, a feature that provides improved resistance to freeze-thaw action and to scaling caused by chemicals applied for removal of snow and ice.

Portland Blast-Furnace Slag Cements

Portland blast-furnace slag cements contain granulated blast furnace slag of selected quality, which is either interground with the portland-cement clinker or blended with the cement at some other point during manufacture. These cements can be used in general concrete construction when the specific properties of other types are not required.

Portland-Pozzolan Cement

Portland-pozzolan cements are manufactured by intergrinding portland-cement clinker with a suitable pozzolan or by blending portland cement or portland blast-furnace slag cement and a pozzolan. They are used principally for large hydraulic structures such as bridge piers and dams.

Masonry Cements

Masonry cements are mixtures of portland cement, air-entraining additives, and supplemental materials selected for their ability to impart workability, plasticity, and water retention to masonry mortars.

Special Portland Cements

Special types of portland cement include waterproofed cement and the so-called plastic cements. Waterproofed portland cement is usually made by mixing a small amount of special additive with the cement clinker during final grinding. Plastic cements, which are commonly used for making mortar, plaster, and stucco, are made by adding plasticizing agents to Type I or Type II cement during the manufacturing process.

Safety in Working with Concrete

In learning new skills, especially those involving new methods, processes, and materials, the carpenter must also learn the hazards involved in the work under study. The three basic requirements for accident prevention are recognizing the hazard, knowing what corrective action to take to eliminate or control the hazard, and taking the necessary risk-control action.

Burns from Fresh Concrete

Working with cement, water, and aggregates to produce concrete structures has its own hazards as well as those normally encountered in working with any dense construction material. For example, heat is produced as a result of hydration, a chemical reaction that occurs between cement and water in forming the strong paste that bonds together the aggregates in concrete. Many a worker has learned about this hazard the hard way—by receiving painful burns to the skin from contact with fresh concrete. The burns result partly from the heat of hydration and partly from the chemical action of the cement on the skin. Painful cement burns can be prevented by taking simple precautions to protect the skin from contact with the cement. This may be accomplished by use of personal protective equipment, including the wearing of gloves; shirts and jackets with long sleeves; goggles or other suitable eye protection; and proper footwear. The use of special hand creams—or even Vaseline—rubbed well into the skin, especially around the fingernails, will reduce the possibility of burns from hand contact with the "mud." Special care should be taken to protect broken places in the skin, such as cuts and abrasions, from contact with cement and fresh concrete. Immediate medical attention should be given to even minor injuries.

Eye Hazards

No excuse exists for the many eye injuries that occur in working with concrete; eye-protection devices are available in many styles. Use of adequate eye protection should be made a habit in all construction work where even the slightest eye hazard exists.

Dust Hazards

Perhaps the most ignored hazard in working with concrete is exposure to dry cement dust, for example, when newly placed concrete is being hand finished by sacking. Inhaling appreciable amounts of fine cement dust is harmful, especially to the lungs. Swallowing the dust is also harmful. Suitable respirators must be provided by the employer and worn by the workers when the hazard of air-borne cement dust exists. Employers are required to provide various kinds of physical safeguards and safety devices on the job, but only the worker who makes use of these devices will benefit from them.

Hazards in Moving Heavy Materials

Strains, sprains, and related back injuries can result from the lifting, pulling, and pushing required in handling the base materials and fluid mud that become concrete. The worker who understands the correct method of lifting—using the heavy muscles of the legs and arms and keeping the load as close to the body as possible, with the back erect—will greatly reduce his chances of suffering the misery and loss of income that accompany a "bad back."

1. Walter E. Durbahn and Elmer W. Sundberg, *Fundamentals of Carpentry*, Vol. 2 (Fifth edition, latest printing). Chicago: American Technical Society, 1977. Read the material on concrete in Chapter 3.
2. *CAL/OSHA, State of California Construction Safety Orders* (Latest edition). Los Angeles: Building News, Inc., 1979. Read Article 3.

TOPIC 1 – INTRODUCTION TO CEMENT AND CONCRETE

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. Cement is composed mainly of _1_ and _2_. — 1. ______ 2. ______
2. A mixture of sand and gravel is called _3_. — 3. ______
3. In the construction of piers and dams, _4_-_5_ cements are the types most often used. — 4. ______ 5. ______
4. A hazard associated with handling fresh concrete is the burns that can result from heat produced by the chemical process called _6_. — 6. ______
5. Inhaling fine cement dust is harmful, especially to one's _7_. — 7. ______
6. Workers who have been exposed to injurious substances should _8_ promptly and thoroughly after such exposure. — 8. ______
7. If mined rock used in making cement lacks any of the necessary elements, those elements are added during the _9_ of the rock to complete the composition. — 9. ______
8. Concrete made with _10_-_11_ cement provides the greatest resistance to damage from freezing and thawing. — 10. ______ 11. ______
9. In lifting heavy loads such as the base materials of concrete, a worker should keep his back _12_. — 12. ______
10. A safety device provided by employers to protect workers against the hazard of cement dust in the air is a _13_. — 13. ______

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TOPIC 2 – SPECIFICATIONS FOR CONCRETE

This topic is planned to provide answers to the following questions:

- Why are specifications necessary in the construction industry?
- What determines the quality requirements for a cement paste?
- How are concrete proportions and consistency controlled?
- How are the various concrete-mixing and placing operations performed?
- How are forms designed, constructed, and prepared for the placing of concrete?

No construction material could ever be developed into a quality product without some method for specifying in a standard way the characteristics desired for the product. Written specifications are employed for this purpose. The characteristics of the materials themselves are also governed by the specifications.

Concrete specifications provide a clear statement of the type of concrete desired and a means for ensuring that it will be produced with the correct materials and in the correct way. This topic contains, in abbreviated form, many specifications for both plain and reinforced concrete as suggested by the Portland Cement Association. On large construction projects, the specifications would be more detailed and more extensive than those indicated here. The specifications given in this topic are general in application and are intended as a guide. On every job, construction will be governed by the specifications and working drawings provided by the architect or engineer.

Concrete Quality

The production of high-quality concrete having adequate strength for the structural design is dependent upon a number of factors, including the quality of the paste, the proportions and consistency of the concrete mixture, and the quality of the aggregate. The aggregate must be clean and free from foreign matter, and it must be of proper density. The concrete must be subjected to a number of tests as the work progresses to ensure that the mixture meets applicable quality standards.

Quality of Cement Paste

The quality of cement paste required for a given concrete job must be based upon the most critical condition to which the concrete is likely to be exposed. The desired quality of the paste will be achieved by specifying either (1) the ratio of fine aggregate to a coarse aggregate and the amount of cement and water for the mix; or (2) the requirements for both minimum cement content and minimum strength.

Strength for Structural Design

The allowable stresses for a concrete structure of a given design are based on the specified compressive strength of a molded concrete test cylinder at 28 days or at the earliest age at which the concrete may be expected to receive its full load. Specifications usually require that several such cylinders be cast and tested as the work progresses.

Concrete Proportions and Consistency

Careful proportioning of the concrete materials is essential for the production of a good, workable mix. This applies also to the air content of air-entrained concrete.

Concrete proportions. The proportions of the concrete materials must produce a mixture that will work readily, with the placement method used, into the corners and angles of forms and around reinforcement. Neither the segregation of the materials in the mixture nor the collection of excess free water on the surface may be permitted.

Air content of air-entrained concrete. The air content needed in air-entrained concrete is dependent upon the amount of mortar in the mix; the amount of mortar, in turn, is usually dependent upon the maximum size of coarse aggregate.

Workability. The workability of fresh concrete is the property that determines the amount of effort required to consolidate the material fully. Because concrete-mix design is an art as well as a science, workability is difficult to measure; however, experienced technicians can successfully judge when the concrete is workable.

Measurement of concrete. The methods of measuring concrete materials must permit proportions to be accurately controlled and easily checked.

Tests on Concrete

As work progresses, the concrete must be sampled and tested in accordance with American Society for Testing Materials (ASTM) standard procedures. The sampling and testing of concrete will be discussed in a later topic.

Mixing, Placing, and Curing of Concrete

The basic steps in concreting include preparing the equipment and the place of deposit; mixing the concrete; conveying, placing, and curing the concrete; and making provision for protecting the concrete against both hot and cold weather during the curing period.

Preparation of Equipment and Place of Deposit

Before placement of the concrete, all equipment for mixing and transporting the concrete must be cleaned, and all debris and ice must be removed from the places to be occupied by the concrete. Forms must be thoroughly wetted (except in freezing weather) or oiled, and masonry filler units that will be in contact with the concrete must be well drenched with water (except in freezing weather). The reinforcing steel must be thoroughly cleaned of ice, dirt, rust, mill scale, and other coatings. The bottom of all forms must be carefully cleaned of all foreign materials such as scraps of wood.

Water must be removed from the place of deposit before concrete is placed, unless otherwise permitted by the architect or engineer. All laitance (fine material that has risen to the surface) and other unsound material must be removed from hardened concrete surfaces, such as footings and wall sections, before additional concrete is placed. Removal of such materials helps to ensure a good bond and joint.

Ready-Mixed Concrete

Ready-mixed concrete must be mixed and delivered in accordance with specifications for ready-mixed concrete.

Job-Mixed Concrete

For job-mixed concrete, the mixer must be rotated at a speed recommended by the manufacturer. Each batch of 1 cubic yard or less must be mixed for at least 1 minute after all materials are in the mixer. The mixing time must be increased 15 seconds for each additional cubic yard or fraction thereof.

Rule-of-Thumb Mix Design

On those occasions when the carpenter needs to mix a small amount of concrete, for example, where transit-mix service is not readily available, the mixing may be done in a mortar box or in a mechanical mixer. Whatever method is used, the mixing must be thorough.

Conveying of Concrete

Concrete must be conveyed from the mixer to the place of final deposit by methods that will prevent separation or loss of materials. Equipment used for chuting, pumping, and pneumatically conveying the concrete shall be of such size and design as to ensure a practically continuous flow of concrete at the delivery end without separation of materials.

Placing of Concrete

Concrete should be deposited as nearly as practicable in its final position to avoid segregation because of rehandling or flowing. The concrete must be placed at a rate fast enough to keep it plastic and to ensure that it will flow readily between the reinforcement bars. No concrete contaminated by foreign material shall be used, nor shall retempered concrete be used unless approved by the architect or engineer.

When placement is started, it must be carried out as a continuous operation until placement of the panel or section is completed. If construction joints are necessary, they must be made in accordance with the specifications.

All concrete must be thoroughly consolidated during placement. It must be thoroughly worked around reinforcement and embedded fixtures and into corners of the forms.

Curing

Concrete normally must be kept moist for at least five days after placement. High-early-strength concretes must be kept moist for at least the first two days when concrete and air temperatures are above 50° F. Longer periods of curing will be required when temperatures are below 50° F.

Cold-Weather Requirements

Adequate equipment must be provided for heating the materials and protecting the concrete during freezing and near-freezing weather. No frozen materials nor materials containing snow or ice should be used.

All forms, fillers, and ground with which the concrete is to be in contact must be free of snow and ice. All concrete placed in forms must have a temperature of 50° F. or higher upon placement, and adequate means must be provided for maintaining this temperature for three days thereafter. When high-early-strength concrete is used, a temperature of at least 50° F. must be maintained for two days after placement. Any additional time necessary to ensure correct curing of the concrete must be provided as directed by the architect or engineer. The housing, covering, or other protection used in curing shall remain intact at least 24 hours after artificial heating is discontinued. No dependence should be placed on salt or chemicals for the prevention of freezing.

Hot-Weather Requirements

In hot weather, suitable precautions must be taken to prevent drying of the concrete prior to finishing operations. Windbreaks, sunshades, fog sprays, or other devices must be provided as directed by the architect or engineer.

Concrete Forms, Reinforcement, and Joints

Requirements for the design and removal of forms; the cleaning, bending, placing and splicing of reinforcement; and the construction of joints are outlined in the following paragraphs.

Design of Forms

Forms must conform to the shape, lines, and dimensions of the members as specified in the plans and must be sufficiently tight to prevent leakage of mortar. They must be correctly braced or tied together so as to maintain position and shape, and they must adequately and safely support all imposed loads during placement and curing of the concrete. Carpentry work on floor forms must be completed before any protective oil coating is applied.

All framed panels for construction—including forms—must be securely anchored or braced to prevent them from falling or collapsing. Such panels that weigh more than 500 pounds must have positive lifting attachments that do not depend for strength on nailing into the panel. Lifting attachments must have a safety factor of 4.

Removal of Forms

Forms must be removed in such a manner as to ensure the complete safety of the structure and the workers. In no case should supporting forms or shoring be removed until the concrete members have acquired sufficient strength to support their weight and imposed loads safely.

Cleaning and Bending of Reinforcement

At the time concrete is placed, metal reinforcement must be free of loose, thick rust; mill scale; and other coatings that could destroy or reduce the bond. All bars must be bent cold, unless the architect or engineer allows bending to be done otherwise.

Placement of Reinforcement

Metal reinforcement must be accurately placed in accordance with the requirements on the plans and must be adequately secured in position by concrete; metal; or other approved chairs, spacers, or ties. Care must be taken to protect workers from the hazards of being cut by or impaled upon protruding reinforcing steel. This may be accomplished by covering the protruding steel with wood or other suitable material (*CAL/OSHA, State of California Construction Safety Orders,* Article 29, Section 1712). Safety requirements can be met by bending steel over for protection, but this method should be cleared by the project engineer, since bending certain critical bars may decrease their strength.

Reinforcing steel should not be used as guy attachments at deadman or other anchorage points.

Study Assignment

CAL/OSHA, State of California Construction Safety Orders (Latest edition). Read Article 28, Section 1698; and Article 29, sections 1709—1720.

TOPIC 2 – SPECIFICATIONS FOR CONCRETE

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. Written specifications provide a clear statement of the __1__ desired for construction materials and end products. 1. ________

2. On every project, construction is governed by the specifications and working drawings provided by the __2__ or __3__. 2. ________ 3. ________

3. The production of high-quality concrete is dependent upon such factors as the __4__ of the paste, the __5__ and __6__ of the concrete mixture, and the __7__ of the aggregate. 4. ________ 5. ________ 6. ________ 7. ________

4. The allowable stresses for a concrete structure are based upon tests conducted with __8__ concrete test __9__. 8. ________ 9. ________

5. Concrete mixtures should be so designed that they can be worked without great difficulty into the __10__ and __11__ of forms and around __12__. 10. ________ 11. ________ 12. ________

6. The air content needed in air-entrained concrete is dependent upon the amount of __13__ in the mix, which in turn is usually dependent upon maximum __14__ size. 13. ________ 14. ________

7. Before concrete placement is begun, all equipment for mixing and transporting the concrete must be __15__. 15. ________

8. The layer of fine material that sometimes rises to the surface of concrete during placement is known as __16__. 16. ________

9. Concrete must be conveyed from the mixer to the place of final deposit by methods that will prevent __17__ or loss of __18__. 17. ________ 18. ________

10. When concrete placement is started, it must be carried out as a __19__ operation. 19. ________

11. All concrete placed in forms during cold weather must have a temperature of __20__ ° F. or higher upon placement, and adequate means must be provided for maintaining this temperature for __21__ __22__ thereafter. 20. ________ 21. ________ 22. ________

12. Concrete forms must be correctly __23__ to maintain their position and shape, and they must be sufficiently tight to prevent leakage of __24__. 23. ________ 24. ________

13. For safety, all ends of reinforcing bars protruding from concrete in the work area should be covered with __25__ or other suitable material. 25. ________

14. When concrete is placed, metal reinforcement must be free of any type of coating that could destroy or reduce the __26__. 26.________

15. Except in freezing weather, forms for concrete must be thoroughly __27__ or __28__ before the concrete is placed. 27.________
28.________

TOPIC 3 – AGGREGATES

This topic is planned to provide answers to the following questions:

- **What are aggregates?**
- **What characteristics are desirable in aggregates?**
- **What are the various types of aggregates?**
- **Why is the proportioning of aggregate types important in the making of concrete?**
- **How are aggregates handled and stored?**

Aggregates are the fine and coarse filler materials that are mixed with cement and water to form concrete. Because they affect cost, strength, and durability, they are at least as important as cement and water in the making of quality concrete. Sand is the most common form of fine aggregate; gravel and crushed stone are typical coarse aggregates. Aggregates from responsible suppliers are graded carefully on the basis of size, shape, strength, and durability.

Aggregates used to make high-quality concrete should be clean and strong, and they should be free of chemical dust or coatings of clay and other fine materials that may affect the bonding and setting properties of the cement paste. The harmful materials most often encountered in aggregates are dirt, silt, clay, coal, mica, salts, and humus or other organic matter. They may occur as coatings or as loose fine material. In most cases, they can be removed by careful washing of the aggregate.

Characteristics of Good Aggregates

Good aggregates must have certain basic characteristics to make concrete workable, strong, durable, and economical. The characteristics include resistance to abrasion, resistance to freezing and thawing, compressive strength, chemical stability, good particle shape, and good surface texture.

Necessity for Good Aggregates

Aggregates that are hard and durable are best for most concretes. Aggregates that are soft and flaky and that will wear away rapidly through exposure to weather are generally unsatisfactory. Weak, friable, or laminated aggregate particles are also undesirable; among these are shale, stones laminated with shale, and most cherts (crystalline quartz).

Desirability of Clean Aggregates

Besides being hard and durable, the best aggregates are clean and free of contaminants such as fine dust, loam, silt, clay, or vegetable matter, which can prevent the cement paste from adequately binding the aggregate particles and thus reduce the strength of the concrete. Concrete made with contaminated aggregates hardens slowly or may never harden enough to serve its intended use.

Types of Aggregates

Aggregates are classed as fine, coarse, bank-run, commercially recombined, lightweight, and heavyweight.

Fine Aggregates

Fine aggregates consist of particles ¼ inch and smaller in size. Natural and manufactured sands may have particles as large as ¼ inch or particles small enough to pass through a sieve having 100 openings to the inch.

Coarse Aggregates

Coarse aggregates are usually gravel and crushed stone ranging in particle size from ¼ inch to the maximum size permissible for the job.

Bank-Run and Commercially Recombined Aggregates

Bank-run material is aggregate that is used as it is taken from the quarry or pit. The natural mixture of fine and coarse aggregates as taken from a gravel bank or a crusher usually does not make the most economical concrete unless it is first screened to separate the fine from the coarse aggregate and then recombined in the correct proportions. Most gravel banks contain too much sand in proportion to coarse material. When this is the case, more cement paste is required to produce concrete of a given quality.

Some commercial firms sell a mixed aggregate that has been separated into fine and coarse sizes;

and then recombined into the correct proportions for good concrete. Frequently, such aggregates must be washed to remove silt, clay, or other materials harmful to concrete. Since clean aggregates are essential for quality concrete, washing is well worth the effort.

When bank-run or recombined aggregates are sold by weight, one may assume for estimating purposes that a ton contains approximately 20 to 22 cubic feet of sand, crushed stone, or gravel. Concretes produced with these common aggregates range in weight from about 140 to 160 pounds per cubic foot.

Lightweight Aggregates

Expanded shale, clay, slate, and slag generally have a weight range of 30 to 70 pounds per cubic foot. They are used as aggregates in structural lightweight concretes that range in weight from about 90 to 110 pounds per cubic foot. Other lightweight aggregate materials are cinders, pumice, scoria, vermiculite, and diatomite, which weigh from 10 to 40 pounds per cubic foot. These materials are used in producing insulating concretes weighing from 20 to 70 pounds per cubic foot.

Heavyweight Aggregates

Barytes, limonite, magnetite, ilmenite, iron, and steel particles are used as aggregate materials in the production of heavyweight concretes.

Gradation of Aggregates

In the making of good concrete, each aggregate particle, regardless of size, must be completely surrounded by cement paste. The amount of concrete of a given quality that can be obtained using a given amount of cement depends upon the size, shape, and gradation of the filler materials. Fine and coarse aggregates must be proportioned so that the finer particles will fill the spaces between the larger ones. This results in the most economical use of cement paste and the best binding together of the aggregate particles.

Determination of the Maximum Size of Coarse Aggregate

The larger the coarse material in the aggregate mixture, the less paste is needed for the concrete and the more concrete is obtained per bag of cement. This means that in general the most economical concrete mix is obtained by using the largest coarse aggregate practical for the job. The maximum size generally depends on the size and shape of the concrete members and the amount and distribution of reinforcing steel. The common sizes of coarse aggregates are 3/8 inch, 1/2 inch, 3/4 inch, 1 inch, 1 1/2 inches, and 2 inches. In general, the size of the coarse aggregate in a mix should not exceed the following limits:

1. One-fifth of the dimension of nonreinforced members
2. Three-fourths of the amount of clear spacing between reinforcing bars or between reinforcing bars and forms
3. One-third of the depth of nonreinforced slabs on grade

Handling and Storage of Aggregates

Aggregates should be handled and stored by methods that prevent segregation of sizes and contamination with harmful materials. Stockpiles should be built up in layers of uniform thickness, and material should be removed from stockpiles in approximately horizontal layers to minimize the degree of segregation.

TOPIC 3 – AGGREGATES

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. Aggregates are categorized as __1__, __2__, bank-run, commercially recombined, lightweight, and heavyweight.	1.________ 2.________
2. Compressive strength, chemical stability, good particle shape, good surface texture, and resistance to __3__ and __4__ are the basic characteristics of good aggregates.	3.________ 4.________
3. The most common form of fine aggregate is __5__.	5.________
4. Harmful materials that may be found in aggregates include __6__, __7__, clay, coal, mica, salts, and humus.	6.________ 7.________
5. The best aggregates are hard and __8__.	8.________
6. Particles of fine aggregates are no larger than __9__ inch.	9.________
7. Gravel and crushed stone are examples of __10__ aggregates.	10.________
8. Bank-run gravel is used in the form in which it is taken from the __11__ or __12__.	11.________ 12.________
9. The maximum size of aggregate to be used in concrete depends on the size and shape of concrete members and the quantity and distribution of __13__ __14__.	13.________ 14.________
10. The most economical concrete mix is generally obtained by utilizing the __15__ __16__ aggregate that is practical for the particular job.	15.________ 16.________

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TOPIC 4 — SAMPLING AND TESTING OF CONCRETE

This topic is planned to provide answers to the following questions:

- What procedures are followed in obtaining test samples of fresh concrete?
- What is the value of the slump test?
- What are the methods for determining the air content of fresh concrete?
- How is the compressive-strength field test made?

The methods of sampling and testing both plastic and hardened concrete are too long and complex to be discussed completely in this unit. Although the carpenter does not normally do the sampling and testing, the apprentice should learn the techniques for these operations. A general knowledge of test methods and terminology will help him to understand his work more fully.

Obtaining of Test Samples

Test samples of fresh concrete may be taken from stationary and paving mixers, truck mixers, agitators, and dump trucks. The sample must include not less than 1 cubic foot of concrete mix when it is to be used for strength tests. Smaller samples may be permitted for routine air-content and slump tests.

Every precaution must be taken to ensure that test samples represent the actual nature and condition of the concrete. The following instructions are designed to assist with the sample taking:

1. With stationary mixers, except for paving models, pass a container through the discharge stream when about half the batch has been discharged.
2. With paving mixers, after the contents of the mixer have been discharged onto the subgrade, collect portions of the mix from several points to obtain a representative sample.
3. With revolving-drum mixers or agitators, take three or more portions at regular intervals during the discharge of the entire batch. Take samples by repeatedly passing a container through the entire discharge stream or by diverting the stream so that it discharges into a wheelbarrow or similar container.
4. With open-top truck mixers, agitators, dump trucks, or other types of open-top containers, take samples by any of the three procedures described above.

Sample Mixing

The sample material must be taken to the site chosen for molding the test specimens and must be remixed as quickly as possible with a shovel to ensure uniformity. No more than 15 minutes should elapse between the time of taking the sample material and the molding of the sample. The sample must be protected from sunlight and wind.

Temperatures

Concrete samples are particularly affected by temperature, and many specifications for sampling provide temperature limits for the fresh concrete. Temperatures can be recorded by an armored thermometer that is accurate to within ± 2° F.

Slump Test for Measuring Consistency

The slump test may be used as a rough measure of the consistency of concrete (its wetness or dryness). The slump test cannot be used to measure workability, nor should it be used to compare mixes of entirely different proportions or mixes that contain different kinds of aggregates. Any slump change that occurs on the job indicates that changes have been made in grading, in the proportion of the aggregates, or in the water content. The mix imbalance should be corrected immediately by adjusting the amount and proportions of sand and coarse aggregate to obtain the right consistency. The volume of water that is specified for mixing with each bag of cement (water-cement ratio) should not be changed.

A concrete sample for slump test should be taken immediately before the concrete is placed in the forms. The slump cone used for molding the sample is dampened and placed on a flat surface, such as a smooth plank or slab of concrete. It is then filled in three layers of approximately equal volume, with rodding after each layer (Fig. 4-1). The cone should be filled to a depth of about 2½ inches (after rodding) for the first layer and to a

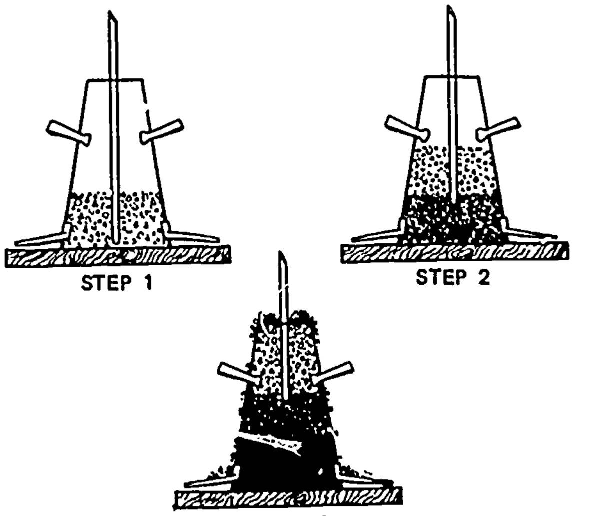

Fig. 4-1. Rodding a slump-test sample

point approximately half the height of the cone for the second layer. Each layer is rodded 25 times, with each rod stroke penetrating into the underlying layer.

After the top layer has been rodded, it should be struck off with a screeding and rolling motion of the tamping rod. The mold is removed by gently raising it vertically immediately after it has been filled. It is then placed gently beside the concrete specimen, and the slump is measured with a straightedge and a rule, as shown in Fig. 4-2. For example, if the top of the slumped pile of concrete is 5 inches below the top of the cone, the slump of the concrete is 5 inches.

Typical slump ranges for various types of construction are given in Table 4-1.

Unit Weight Test

The standard test to determine the unit weight of fresh concrete is similar to the test for the unit weight of aggregates. The concrete is placed in the test container in three approximately equal layers. Each layer is rodded, and the side of the container is then tapped with the rod 10 to 15 times or until no large air bubbles appear on the layer. The container is then struck off level full, excess concrete is cleaned off, and the net weight of the concrete is determined.

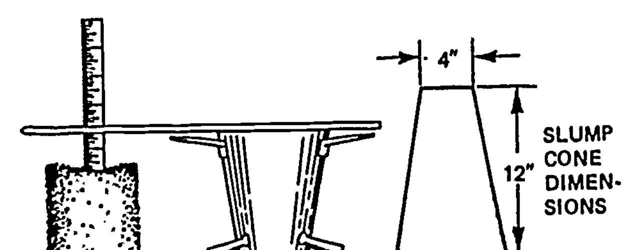

Fig. 4-2. Measuring concrete slump

TABLE 4-1

Typical Slump Ranges for Various Types of Construction

Types of construction	Slump (inches)* Maximum	Slump (inches)* Minimum
Reinforced foundation walls and footings	4	2
Unreinforced footings, caissons, and substructure walls	3	1
Reinforced slabs, beams, and walls	5	2
Building columns	5	3
Pavements	2	1
Sidewalks, driveways, and slabs on ground	4	2
Heavy mass construction	2	1

*When high-frequency vibrators are not used, the values may be increased by about 50 percent, but in no case should the slump exceed 6 inches.

Tests for Air Content

Various methods are used for determining the air content of fresh concrete. The following three methods have been standardized by the ASTM:

1. The pressure method is a practical way to field-test all kinds of concrete except those mixtures that are prepared with lightweight and porous aggregates.
2. The volumetric method is a practical way to field-test all concretes but is particularly useful for concrete made with lightweight and porous aggregates.
3. The gravimetric method requires an accurate knowledge of specific gravities and absolute volumes of concrete ingredients. This method is not practical as a means of conducting field tests, but it is satisfactory in the laboratory.

The unit weight test described earlier in this topic can also serve as a field test for checking possible changes in the air content or mix proportions of concrete. Changes in air content generally bring changes in the unit weight of concrete from one batch to another.

The approximate air content of fresh concrete can be checked with a pocket-sized air indicator of the type shown in Fig. 4-3. The small container is filled with a representative sample of mortar from the fresh concrete and is inserted into the large end of the glass tube. The tube is then filled with alcohol, and with the open end stopped, the tube is shaken to remove the air from the mortar. By use of a calibration chart, the approximate air content can be determined from the drop in the fluid level in the graduated small end of the tube. Since this test can be performed in a matter of minutes, it is particularly useful for estimating the air content of fresh concrete. However, it is not a substitute for the more accurate pressure and volumetric methods of determining air content.

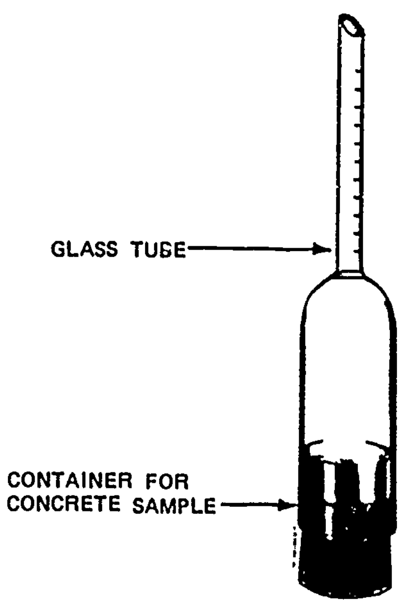

Fig. 4-3. Air indicator

Follow-up tests are conducted on many jobs to determine the effectiveness of the field control methods. These tests are usually made to determine compressive strength or flexural strength.

Occasionally, the need will arise to make compressive or flexural-strength tests with specimens taken from hardened concrete.

Strength-Test Cylinders

Field-control test specimens in the form of molded cylinders are sampled from concrete that is being used in construction work to determine whether the concrete has the specified compressive strength. Samples of the concrete are taken at three or more intervals throughout the discharge of the entire batch (but not at the beginning or the end of the discharge). Tests of the variously aged concrete specimens indicate the rate of strength gain and the effectiveness of job-site curing.

The molding, protection, and curing of the cylinders must be done carefully. Before the molds are filled, individual portions of the sample should be remixed with a shovel to ensure uniformity. The batch of concrete thus sampled is identified as to its location in the work, and the air temperature and any unusual conditions are noted.

The compressive-test specimen is prepared in a watertight cylindrical mold. Standard cylindrical molds 6 inches in diameter and 12 inches long are used if the coarse aggregate does not exceed 2 inches in nominal size. The mold is filled in three equal layers, each of which is rodded with ⅝-inch round steel rod about 24 inches long, with a bullet-shaped tip. Reinforcing rods or tools should not be used for this purpose. When the second and third layers are rodded, the rod should barely break into the concrete underneath. After the top layer has been rodded, the surface of the concrete is struck off and immediately covered to prevent loss of moisture.

Molds should be placed on a rigid surface that will be free from vibration and other disturbances. Test specimens should not be moved during the first 24 hours. They should be stored under conditions that will prevent the loss of moisture, with temperatures within a range of 60° to 80° F. The cylinders should be laboratory cured as soon as possible.

Standard procedures provide for curing of the specimens either in the laboratory or in the field. Specimens cured in the same manner as the structure they represent may give a more accurate indication of the strength of the structure at the time of testing. Both methods are used on some jobs, particularly when the weather is not favorable for accurate interpretation of the tests.

Concrete test specimens should be protected from rough handling, and they should always be maintained upright until they have hardened. If these precautions are disregarded, the test specimens will indicate strengths below normal. Rough handling and incorrect curing usually lead to erratic and low-strength test results.

TOPIC 4 – SAMPLING AND TESTING OF CONCRETE

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. A measure of the fluidity of freshly mixed concrete is provided by the __1__ test. 1.________

2. Sampling procedures are designed to obtain samples that are representative of the true __2__ and __3__ of the concrete sampled. 2.________ 3.________

3. A sample for a strength test must include not less than __4__ cubic foot of concrete mix. 4.________

4. Before a sample is molded, the concrete should be __5__ to ensure uniformity. 5.________

5. The slump test is *not* considered a test of the __6__ of concrete. 6.________

6. Any change of slump on a job indicates a change in __7__, in proportions of the __8__, or in __9__ content. 7.________ 8.________ 9.________

7. One way to check the approximate air content of fresh concrete is with a pocket-sized __10__ __11__ . 10.________ 11.________

8. At times, making __12__ or __13__ strength tests with specimens taken from the hardened concrete is desirable. 12.________ 13.________

9. Rough handling of concrete specimens and incorrect __14__ usually yield erratic and __15__ - __16__ test results. 14.________ 15.________ 16.________

10. The elapsed time between the taking and molding of a sample of concrete should not exceed __17__ minutes. 17.________

CONCRETE

TOPIC 5 – CONCRETE ADMIXTURES

This topic is planned to provide answers to the following questions:

- What are the various types of concrete admixtures, and what purposes does each type serve?
- What chemicals are used as admixtures?
- What standards should admixtures meet?
- What are workability agents, and how are they used?
- What is air-entrained concrete, and how is it used?

Special properties are often desirable in a concrete mix—extended time of set, acceleration of early strength, or greater workability, for example. These special characteristics can often be obtained by selecting the correct type of portland cement, but sometimes this is not practical. In such a case, the use of admixtures should be considered.

Limitations of Admixtures

Sometimes a desired characteristic in concrete can only be obtained through the use of an admixture, but no admixture of any type or amount should ever be used as a substitute for good practice in designing the concrete mix or selecting suitable materials. Taking the time to learn about mix design can prevent the failures that often occur through reliance on admixtures to solve mix problems. Another difficulty with admixtures is that not all of these materials fulfill the claims made for them by their manufacturers. However, admixtures produced by reliable firms are a valuable tool to the carpenter if he has the knowledge to use them correctly.

Effectiveness of Admixtures

The effectiveness of an admixture depends upon many variables, including cement type and amount; water content; aggregate gradation and proportion; mixing time; slump; and the temperature of the concrete and of the air. Trial mixes should be made with the admixture to observe its effects on the properties of both fresh and hardened concrete.

Types of Admixtures

Concrete admixtures are classed as air-entraining, retarding, and accelerating types.

Air-Entraining Admixtures

Air-entraining admixtures are used to improve the workability and reduce the segregation and bleeding of fresh concrete. They greatly improve the durability of concrete that is exposed to freezing and thawing, improve the resistance of concrete to sulfate attack, and increase its watertightness. Air-entrained concrete is discussed in greater detail later in this topic.

Retarding Admixtures

The high temperatures of fresh concrete (85° to 90° F. or higher) are often the cause of an increased rate of hardening, which makes the placing and finishing of concrete difficult. Reducing the temperature of the concrete by cooling the mixing water or the aggregates is one of the most practical methods of counteracting this effect. An alternative method is to use a retarding admixture. Retarding admixtures increase the setting time of concrete, but they do not reduce its temperature.

Retarders are sometimes used to offset the accelerating effect of hot weather on the setting of concrete or to delay the initial set of concrete or grout when difficult or unusual conditions of placement occur, as, for example, in massive structures. Most retarders reduce the amount of water required for the mix. They may also entrain some air in the concrete. Because retarders may affect various properties of concrete in unpredictable ways, acceptance tests of these admixtures should be made with the materials to be used on the job and under expected job conditions.

Accelerating Admixtures

The purpose of an accelerating admixture is to speed up the setting and strength development of concrete. A disadvantage of most of the commonly used accelerators is that they increase drying shrinkage.

Calcium chloride is a common ingredient of accelerating admixtures. Calcium chloride or admixtures containing soluble chlorides should not be used in the following kinds of concrete:

1. Prestressed concrete
2. Concrete containing embedded aluminum
3. Concrete in permanent contact with galvanized steel
4. Concrete subjected to alkali-aggregate reaction or exposed to sulfates

Pozzolan Admixtures

Pozzolans, including diatomaceous earth, opaline cherts, shales, and pumicites, are materials that have little or no cementing qualities but that react chemically with cement ingredients in the presence of moisture. Their range of possible effects on concrete is large. Pozzolanic materials are sometimes used to control the heat of hydration in large masses of concrete, such as in dams. Pozzolans are frequently used for this purpose in combination with other methods such as lowering the temperatures of the mix water and the aggregate or using slower-setting cements. Pozzolans used as cement replacements can substantially reduce the early strength of concrete. Prolonged wet curing and favorable temperatures are necessary when pozzolans are used in the mix.

Workability Agents

The workability of concrete often must be improved, especially if the concrete requires a troweled finish. Improved workability is also important for concrete placed in heavily reinforced members, placed by pumping, or placed by tremie methods. Frequently, increasing the cement content or the amount of fine aggregate will give the desired workability. In some cases, however, the use of a workability agent is required. One of the best workability agents is entrained air, which acts as a lubricant and is especially effective in improving the workability of lean and harsh mixtures.

Organic or finely divided materials are also sometimes used to improve workability. These organic compounds may be similar in composition to the water-reducing and retarding admixtures, and they also may entrain air.

Replacement of a portion of the portland cement by fly ash or natural pozzolan may reduce early strength and may tend to reduce the amount of entrained air in the concrete.

Air-Entrained Concrete

Air-entrained concrete—concrete made with a cement paste containing millions of tiny air bubbles—is produced by using an air-entraining admixture during mixing of the concrete, by using an air-entraining cement, or by using a combination of both of these methods. The entrained air bubbles are extremely small, ranging in diameter from about $\frac{1}{1,000}$ of an inch to about $\frac{1}{100}$ of an inch. These bubbles are not connected to each other, and they are well distributed throughout the paste.

Effect of Entrained Air on Properties of Fresh Concrete

Less water is required to make a cubic yard of air-entrained concrete than is required for the same amount of nonair-entrained concrete having the same consistency and maximum aggregate size. Entrained air improves the workability of concrete by increasing the quantity of the paste per unit of weight. Because of the improvement in workability, less water and sand are needed in the mix.

Fresh concrete containing entrained air looks and feels "fatty." Bleeding is retarded because water cannot readily pass through the air bubbles. The bubbles not only reduce bleeding but also hold up the aggregates and slow their rate of settlement toward the bottom of the placed concrete.

Air entrainment allows the initial finishing processes to be started earlier than with ordinary concrete mix. However, the absence of bleeding water should not be taken as an indication that the concrete is setting and that final finishing should begin.

Effect of Entrained Air on Properties of Hardened Concrete

As water freezes, it expands, producing pressures that can crack concrete. The bubbles in air-entrained concrete serve as reservoirs that relieve the pressure as excess water is forced into them. The air bubbles continue to serve their purposes throughout repeated cycles of freezing and thawing.

Chemicals used for snow and ice removal can cause serious scaling of concrete surfaces. Entrained air, which prevents salt scaling, is recommended for use in all concretes that come into contact with deicing chemicals.

Factors Affecting the Air Content of Concrete

The air content of a concrete mix is affected by such variables as aggregate size, cement content, content of fine aggregate, slump, vibration, temperature, and the type of mixing action used. This is true of any mix, whether the air is intentionally entrained or merely entrapped.

Maximum size of aggregate. The air content of a concrete mix increases sharply as the size of the largest aggregate in the mix is decreased below about 1½ inches. This is so because the quantity of paste required increases as aggregate size decreases.

Cement content. As the cement content of the paste increases, the air content normally decreases.

Fine aggregate content and gradation. Increasing the content of fine aggregate causes more air to be entrained for a given amount of air-entraining admixture or cement. Fine aggregate particles in the middle sizes (No. 30 to No. 100 mesh sieves) result in more air than extremely fine or coarse sizes. Fine aggregates from different sources may entrain different amounts of air even though identical amounts of aggregate pass for each sieve size; this is probably due to differences in particle shape and surface texture.

Slump and vibration. Both slump and the amount of vibration of the concrete affect the amount of air retained in the mix. The desired air content can be maintained as long as the slump does not become too great. Air content is lost rapidly when the amount of slump exceeds 6 inches. The normal amount of vibration does not affect the amount of entrained air, but excessive vibration should be avoided. For most concrete, 5 to 15 seconds of vibration is sufficient, and little entrained air will be lost.

Temperature. As the temperature of the concrete mix increases, the amount of entrained air decreases. If necessary, the quantity of air-entraining admixture should be increased when relatively high mix temperatures are expected, for example, during hot weather.

Mixing action. Mixing action may also affect the amount of entrained air in a concrete mix. This is especially important for ready-mixed concrete. The amount of entrained air varies with the type and condition of the mixer, the amount of concrete being mixed, and the rate of mixing.

Admixtures. Some types of admixtures in the concrete mix may chemically alter the air-entraining mixture itself and make it less effective.

Recommended Air Content of Concrete

The amount of air in air-entrained concrete should be varied to suit the job. This will usually depend upon the type of structure for which the concrete is intended, the climatic conditions to which the concrete will be exposed, and whether the concrete must withstand the effects of deicing chemicals and poor soil and water conditions.

Concrete mixtures with low water-cement ratios do not require as much entrained air for durability as do concretes of lower quality. Test samples to determine the air content of fresh concrete should be taken immediately upon discharge from the mixer. Because of the effects of mixing and vibration, test samples in some cases should be taken from concrete that has been placed and consolidated.

TOPIC 5 – CONCRETE ADMIXTURES

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. An admixture is an ingredient other than cement, __1__, and __2__ that is added to concrete before or during mixing. — 1. ________ 2. ________
2. The three most frequently used types of admixtures are air-entraining, __3__, and __4__. — 3. ________ 4. ________
3. A chemical commonly used in accelerator admixtures is __5__ __6__. — 5. ________ 6. ________
4. The effect of hot weather on the hardening rate can be offset through the use of a(n) __7__ admixture in the concrete mix. — 7. ________
5. A disadvantage of accelerator admixtures is that they increase the __8__ __9__ of concrete. — 8. ________ 9. ________
6. Pozzolanic admixtures are sometimes used to control the __10__ of __11__ in large masses of concrete. — 10. ________ 11. ________
7. Pozzolans when used as cement replacement may substantially reduce the __12__ __13__ of concrete. — 12. ________ 13. ________
8. One of the best workability agents is __14__ __15__. — 14. ________ 15. ________
9. The principal reason for using entrained air in concrete is to improve resistance to __16__ and __17__. — 16. ________ 17. ________
10. The air bubbles in air-entrained concrete improve workability and reduce __18__ of the aggregates. — 18. ________

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CONCRETE

TOPIC 6 – METHODS OF CONCRETE PLACEMENT

This topic is planned to provide answers to the following questions:

- Why is concrete "placed" rather than poured?
- Why is time important in placing concrete?
- What are the methods of transporting concrete?
- How is segregation prevented in placing concrete?
- What precautions should be taken with forms?
- Why should water not be added to the mix at the job site?
- When is use of a vibrator an advantage in placing concrete?

Factors in the Correct Placement of Concrete

In all operations involving concrete, quality workmanship depends to a great extent upon correct placement. Incorrectly placed concrete invites cracking and other defects and also creates an uneven and unsightly job.

Advance preparation for concreting includes compacting, trimming, and moistening the subgrade; erecting the forms; and setting the reinforcing steel. Other important considerations for production of good concrete work are control of elapsed time from mixing to placement, careful transportation of the concrete mix on the job, and use of correct methods of placement.

Time from Mixing to Placement

Concrete must be delivered and discharged from the truck within 1½ hours after the water has been added to the mixture. In hot weather, or under other conditions that would contribute to quick stiffening, less time should elapse before the concrete mix is placed. If possible, concrete should be placed in forms within 30 to 60 minutes after mixing. The site must be in readiness, and ready-mix trucks must be able to move without delay. If a delay should occur, excessive mixing and hydration may cause the concrete to become stiff and difficult to place and finish, which can adversely affect schedules and quality. Also, the trucking company may levy an additional charge for "standing time."

Ready-mixed concrete is usually delivered to the site correctly prepared and in the right consistency for the specific job. Adding excessive water to the mix to make it flow easily into the forms without the need for working it will seriously affect every useful property of the finished concrete, including durability, strength, and watertightness. The workman should not expect to get good concrete into place without effort.

Transporting of Concrete on the Job

The methods employed for moving concrete to the forms from the mixer or truck will depend largely upon job conditions. Wheelbarrows are generally used for this purpose on small jobs. Concrete may also be transported over chutes and runways; in hand or powered buggies; in buckets by means of cranes or cableways; or in small rail cars or by truck. Other methods include pumping the concrete through pipelines or forcing it pneumatically through hoses.

Whatever means of transportation is used, segregation must be prevented as the concrete is being moved. A stiff mix and smooth runways are usually required to prevent segregation. However, the choice of concrete consistency should be governed by concrete-placing conditions and not by equipment considerations. Thus, if conditions permit the use of a stiff mix, the handling and transporting equipment used should be the best suited for that mix.

The job should be planned so that the ready-mix truck can be moved as close to the work site as possible to save time in moving the concrete by hand. Debris and unnecessary equipment should be removed to provide a large work area for the truck.

Ramps and Runways

Access ramps and runways used for wheelbarrows and concrete buggies must be well planned and soundly constructed. This is important not only to ensure the safety of workmen but also to permit the concrete to be placed as close as possible to its final position, and thus reduce handling time.

Placement in Forms

Forms should be clean, tight, adequately braced, and constructed of materials that will produce the desired texture in the finished concrete. Sawdust, nails, and other debris should be removed before concrete is placed. Wooden forms should be moistened before the concreting is done to prevent the expansion of the forms and possible damage to the concrete. Forms should be oiled or lacquered to simplify their removal. Loose rust, mill scale, hardened mortar, and other foreign matter should be cleaned from the reinforcing steel before the concrete is placed.

The concrete should be placed between the forms or screeds and as close as possible to its final position. For effective consolidation, the concrete should be vibrated mechanically or spaded as it goes into the form, then thoroughly spaded next to the forms to eliminate voids or honeycombing at the sides. In areas that are difficult to reach, the forms can be vibrated or hammered lightly to achieve the same results. This procedure creates a dense concrete surface by forcing the coarse aggregate back from the form or face.

The concrete should not be overworked while it is in a plastic state; this will cause water and fine material to rise to the surface, which may later cause scaling or dusting. If concrete is placed in layers no more than 12 to 18 inches thick along a form, uniformity will be satisfactory. Each layer should be thoroughly consolidated by vibration before the next one is placed.

Placement in Slabs

In slab construction, the placing of concrete should be started at the form located at the most remote end of the slab area so that each batch may be dumped against previously placed concrete. The concrete should not be dumped in separate piles to be leveled and worked together; nor should it be placed in a large pile and allowed to run or be worked over a long distance to its final position. In either case, honeycombing and separation may occur since the mortar tends to flow ahead of the coarser material. Water should not be permitted to collect at the ends and corners of forms and along form faces.

Reduction of Bleeding

When concrete is placed in tall forms fairly rapidly, water may bleed to the top surface, especially with nonair-entrained concrete. Bleeding can be reduced by using stiffer concrete and placing it more slowly.

Placement of Concrete Where Needed

The old rule that "good concrete is placed, not poured" is still valid. Also, concrete should be placed where it is needed; it should not be allowed to flow or be pushed or dragged into place. When buggies, wheelbarrows, or other conveyances are used in placing concrete, the contents should be dumped into the face of the previously placed concrete, not away from it.

Use of Drop Chutes, Elephant Trunks, and Tremies

A chute, an elephant trunk, or a tremie is recommended for dropping fresh concrete more than 6 feet. If concrete is allowed to strike one side of the form and bounce off, the resulting separation will cause stone pockets and sand streaking.

Drop chutes can be used to prevent mortar from striking the reinforcement steel and forms and drying on them. In thin sections, drop chutes of rubber or metal should be used. In narrow wall forms, the metal drop chutes are rectangularly shaped to fit between reinforcing steel. The chutes are available in several lengths or in sections that can be hooked together to make the length adjustable as concreting progresses.

Safety in Working from Elevations

The men who handle the drop chute, do the vibrating, or operate a hopper gate from a crane must be provided with a safe place from which to do the work. Too often, little or no attention is given to this requirement in safety planning. Safety regulations require that when work is to be performed from exposed locations, suitable protection from falls shall be provided. At times, this requirement may be satisfied through use of safety belts and lifelines. In other situations, safety nets are required under workers.

Taking the time to plan for safety in every operation will ensure both a lower accident rate and a smoother-running job. A basic principle of accident prevention is that safety and efficiency go hand in hand.

Consolidation of Concrete in Forms

Concrete is usually consolidated in forms by vibration. The correct use of vibrators makes possible the placement of stiff mixes that could not be placed and consolidated readily by hand spading. In most instances, the slump required when concrete is to be vibrated is at least one-third less than that required for hand consolidation, and in many cases it can be less than half as much.

Types of Vibrators

Vibrators used for consolidating fresh concrete may be of the internal or the external type.

An internal vibrator consists basically of a slim metal tube that encloses a vibratory mechanism, which is usually powered by an integral electric or pneumatic motor. Some vibrators are powered by a flexible shaft that is driven by a gasoline engine or a pedestal-mounted electric motor. In use, the tube is pushed into the fresh concrete, vibrated 5 to 15 seconds, then withdrawn. The operation is repeated in locations throughout the concrete mass to achieve uniform compaction.

Form vibrators are clamped or bolted to the exterior of forms. They are especially useful for consolidating concrete in thin-walled members and where metal forms are used.

Limitations of Vibrators

Vibrators are excellent tools for placing and consolidating relatively dry mixes. They should be handled with extra care in wet mixes to avoid bringing too much water and fine sand to the surface. The period that a vibrator should be left in the concrete is governed by the slump of the concrete. High-slump material requires little or no vibration.

Overvibration can result in aggregate segregation and spreading of the forms, and a carelessly operated vibrator can tear forms apart. Vibrator damage to the inner surfaces of forms will result in surface defects in the cured concrete. Vibrator heads should never be held against reinforcement steel.

Safety with Electrical Equipment

Special care must be taken when vibrators or other electrically operated equipment must be used in placing concrete. Wet materials, damp earth, and the 220-volt power required for most vibrators and other heavy-duty electrical equipment greatly increase the shock hazards for concrete workers. All electrical equipment used on the job must be carefully maintained and correctly grounded. The ground connection must be continuous from the metal case of the tool through the power cord to the service ground or other approved ground. Power cords (and extension cords, if used) must be of heavy-gage 3-conductor Type S cable and must have 3-pole fittings. Repairs to electrical equipment, including power and extension cords, must be made only by persons qualified and authorized to do so.

Study Assignment

CAL/OSHA, State of California Construction Safety Orders (Latest edition). Read Article 17; Article 21; Article 24; Article 28, sections 1698 and 1700; and Article 33. Study Plate B-17 in Appendix B.

TOPIC 6 – METHODS OF CONCRETE PLACEMENT

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. Advance preparation for concreting includes the _1_, _2_, and _3_ of the subgrade; erection of the _4_; and setting of the reinforcing _5_. — 1. ____ 2. ____ 3. ____ 4. ____ 5. ____

2. Good concrete is _6_, not poured. — 6. ____

3. Important considerations for production of good concrete work are control of the elapsed time from _7_ to _8_, _9_ of the concrete mix on the job, and use of correct methods of _10_. — 7. ____ 8. ____ 9. ____ 10. ____

4. In the transporting of concrete to the forms, care must be taken to avoid _11_ of materials. — 11. ____

5. Concrete should be placed in the forms as near as practicable to its _12_ position. — 12. ____

6. In slab construction, concrete placing should start at the most _13_ end of the slab area so that each batch will be dumped against previously _14_ concrete. — 13. ____ 14. ____

7. Good uniformity can be obtained by placing the concrete in _15_. — 15. ____

8. No additional _16_ should be added to ready-mix concrete after the concrete is delivered to the job. — 16. ____

9. The preferred maximum angle for slope of ramps is _17_ degrees. — 17. ____

10. Moistening forms before concrete is placed in them helps to prevent _18_ of the forms and the possibility of damage to the concrete. — 18. ____

CONCRETE

TOPIC 7 – MOVEMENT OF CONCRETE ON THE JOB

This topic is planned to provide answers to the following questions:

- What equipment and methods are used for moving concrete from transit-mix truck or batch plant to point of deposit?
- Why is there need for more than one way of moving concrete on the job?
- Why must concrete-moving equipment be permanently maintained in first-class condition?
- What safety rules apply in the operation of cranes, hoists, and construction elevators?

The choice of equipment for moving freshly mixed concrete from the transit-mix truck or batch plant to the point of deposit depends on such considerations as the height and shape of the forms, the volume of concrete to be moved, and the space available for the moving equipment. Stationary and portable hoists and cranes of various types are commonly used for this purpose. The relatively new technique of using pumps to transfer the concrete mix to the forms is becoming increasingly popular as the method improves.

Importance of Equipment Maintenance

Whatever method is used, the concrete-moving equipment must be permanently maintained in first-class condition. When the mix arrives on the site, movement to the place of deposit must continue without interruption until the entire batch has been placed. On large projects such as dams, where concrete placement continues around the clock seven days a week, qualified maintenance men must be on the job at all times to keep the equipment in good working order.

Hoists and Cranes

In general, a hoist is a device for lifting and lowering a load vertically in a fixed location. A crane is a more complex device designed to lift a load, move it horizontally a reasonable distance, then land it at the desired location. Hoists and cranes for moving concrete may be portable (truck or trailer mounted) or stationary types.

Portable Tower Hoists

Portable tower hoists are self-contained structures designed to be moved to the job and set up in the desired location. Some are mounted on trucks; others are mounted on trailers. They may elevate a platform on which a concrete buggy or a wheelbarrow is carried, or they may have a large bucket in which the concrete is raised to the desired elevation and then dumped into a hopper. From the hopper, the mix is loaded into concrete buggies and moved to the spot where it is to be placed. When not being used to move concrete, such a hoist may be used to elevate other structural materials. The lifting range of portable hoists is usually not more than 75 feet.

Stationary Tower Hoists

Heavy-duty stationary tower hoists are often used on high buildings or on structures where a large volume of concrete must be handled. Hoists of this type consist of a well-braced timber or tubular-steel tower within which a large bucket or hopper (or in some cases a platform) rides up and down on rails. Hoisting power is supplied by a drum, which is usually located some distance from the base of the tower. Cables run parallel to the ground from the drum to sheaves in the tower base, then up to sheaves at a "cat's head" at the top of the tower, and finally back down to the hopper or platform.

Often, two such towers are erected side by side—one for concrete and other construction materials, the other for hoisting workmen and limited amounts of material (a "man hoist" or construction elevator for hoisting workmen). Workers are never permitted to ride a construction elevator or other hoisting machine unless it meets specific, rigid requirements to ensure the safety of passengers. Safety regulations govern the erection and operation of all types of hoisting machines.

Truck Cranes and Crawler Cranes

Where space permits their use, truck cranes and crawler cranes offer the advantage of being easy to move from place to place on the job. Their main booms, which are generally of the rotary or swinging type, can usually be lengthened if necessary to meet job requirements. Many of the larger cranes of this type include a jib boom mounted at an angle to the main boom. The jib is an aid in placing the concrete or other material in the exact location where it is to be used.

Tower Cranes

Even if it has a very long boom, a truck crane or crawler crane is of limited use in erecting a very high building. The longer the boom, the greater the problems of balancing and positioning it, especially where space for maneuvering the crane is restricted. The tower crane overcomes this difficulty by having the working boom mounted on a vertical tower or mast, which is usually set up in a semipermanent location within or alongside the building. In some installations, the tower crane is set on the ground on rails that run close along one side of the building.

The boom of a tower crane can be a hinged jib, but in most cases it is a long, cantilevered and counterbalanced horizontal member that may reach all the way across the building. It can usually be swung horizontally in a wide arc around the tower. In a climbing-type tower crane, the horizontal boom (and the operator's cab) can be raised or lowered on the vertical mast.

Tower cranes designed to be set up within the building are raised from floor to floor as the building rises. This simplifies the task of placing concrete and other materials exactly where they are needed as the work progresses.

The climbing crane probably has the greatest potential for accidents of all the cranes used in construction work. This is so mainly because the operator does not "feel" the effects of the load, for example, weight changes. Rigid safety requirements govern the installation; maintenance and repair records; safety devices; and control and testing of these cranes, most of which are of foreign design and manufacture.

Tower Cable Cranes

The tower cable crane is used mainly in the construction of dams. It consists of two large towers, one on each side of the project, with heavy cables forming a line between them. The towers are sometimes placed on rails. The towers and cableways are electrically or hydraulically powered, and they are usually so large that they can handle concrete buckets of 20-cubic-yard capacity.

Movement of Concrete with Pumps

Moving concrete to the forms by pumping it through pipelines offers advantages over traditional methods, particularly where obstructions or space limitations make placement with conventional equipment difficult. Pumping equipment that will deliver freshly mixed concrete 400 feet or more horizontally and up to 160 feet vertically is now available. Pumping concrete over such long distances at the present time requires use of a mix having more cement and more water than would be needed for conventional methods of placement. However, pumping equipment is being improved very rapidly, and much is being learned about preparing aggregates and designing mixes to make best use of this new technique.

Study Assignment

CAL/OSHA, State of California Construction Safety Orders (Latest edition). Read Article 14; Article 15; and Article 29, Section 1718. Study plates C-11, C-11-a, and C-11-b.

CONCRETE

TOPIC 7 — MOVEMENT OF CONCRETE ON THE JOB

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. The lifting and lowering of a load vertically in a fixed position is generally done by means of a(n) _1_. — 1. ________

2. Generally, a portable hoist can be used to elevate materials to heights of up to _2_ feet. — 2. ________

3. If concrete is to be pumped over great distances, the mix requires more _3_ and _4_ than are required for conventional methods of placement. — 3. ________ 4. ________

4. Once concrete mix has arrived on the job site, movement to the place of deposit must be done without _5_ until the entire batch is placed. — 5. ________

5. If a load must be moved horizontally and vertically, a(n) _6_ must be used to do so. — 6. ________

6. The type of crane with the greatest potential for accidents is the _7_ crane. — 7. ________

7. To signal the operator of boom equipment to lower the boom, the worker should extend his arm downward, point his _8_ down, and move his hand in small horizontal _9_. — 8. ________ 9. ________

8. The bucket of a tower cable crane generally has a capacity of _10_ cubic yards. — 10. ________

9. Tower cable cranes are used mostly in the construction of _11_. — 11. ________

10. The type of equipment to be used for moving concrete from the truck or batch plant to the point of deposit depends on the _12_ and _13_ of the forms, the _14_ of concrete to be moved, and the amount of space available for the equipment. — 12. ________ 13. ________ 14. ________

TOPIC 8 – FINISHING OF A CONCRETE SLAB

This topic is planned to provide answers to the following questions:

- **What tools and methods are used for concrete finishing?**
- **What is meant by striking off?**
- **What are the methods of final finishing?**
- **How does troweling benefit the finished concrete?**

This topic deals with finishing the placed concrete, a most important aspect of concrete work. Only the finishing of concrete slabs will be discussed; the volume of this work is large, and most of the processes used apply also to other kinds of concrete finishing.

Slab-Finishing Techniques

The correct choice of concrete finish depends on how the completed structure is to be used and what architectural effect is desired. For some surfaces, finishing may involve little more than striking off to correct contour and elevation; while for others a broom, float, trowel, or exposed-aggregate finish may be specified.

Consolidation of Concrete

The first step in finishing a slab is consolidating the concrete. This is necessary to provide a uniform, plastic mass without stone pockets or large air voids. Concrete in deep forms is usually consolidated by means of internal or external vibrators of the type described in Topic 6. The tool most commonly used for consolidating concrete in slabs is a strike-off board or straightedge. Other tools used for consolidating a slab include tampers; rollers or the roller screed; vibrating screeds; and the jitterbug or jitterbug crawler.

Striking Off

Striking off (sometimes called screeding) is a leveling operation that removes humps, fills hollows, and provides a true concrete surface. Consolidation and strike-off are often combined in a single operation by using a strike-off rod or straightedge, which is usually a specially prepared tool. A piece of 2 x 4 or 2 x 6 lumber 1 to 2 feet longer than the section being finished may be used in an emergency. The surface is struck off or rodded by moving the straightedge back and forth like a saw across the top of the forms or screed, advancing it slowly with each movement. Some concrete should be pushed ahead of the straightedge to fill in low spots and to maintain a plane surface. Vibrator screeds, roller screeds, and mechanical screeds are also used for screeding or striking off.

Darbying

Immediately after screeding and before any free water has bled to the surface, concrete should be darbied and bullfloated to eliminate ridges and voids left by the strike-off operation. This initial smoothing also helps embed large aggregate beneath the surface and brings enough mortar to the surface to allow preparation for other finishing operations. Overworking the surface should be carefully avoided during this operation.

Because it has a long handle, the bullfloat is more convenient than the darby for leveling wide slabs. However, a serious hazard is often overlooked in using bullfloats and other long-handled tools. Workers have been badly burned—and in some instances killed—as a result of accidentally reaching into electrical lines with such a tool wrongly equipped with a metal handle. Safety regulations require that handles on bullfloats be made of nonmetallic, nonconducting material.

Edging and Jointing

A wide-flange tool having a radius of ⅛ inch or less should be used for initial edging. Joints with greater radii are difficult to maintain. The marks left by the edger or jointer should be removed by floating unless they are desired for decorative purposes. In that case, the edger or jointer should be rerun before and after troweling to maintain uniformity or to remove kinks.

Control joints should be made soon after the concrete has been placed so that the larger pieces of coarse aggregate can be worked away from the joint. A finisher will occasionally use a brick mason's trowel to cut the joint approximately one-fourth to one-fifth the slab depth. A groover with a ¾-inch bit is then used to finish the joint.

Control joints are generally placed 15 to 25 feet apart on slabs-on-grade.

Since the development of special concrete-cutting saw blades, sawing contraction joints has become common. A sawed joint is clean and attractive and works well when cut to the correct depth. On larger jobs, the joints are made with a special mobile concrete saw. On smaller jobs involving sidewalks and driveways, a portable electric handsaw may be used. In either case, the operator must keep the saw blade straight during the cut so that it will not shatter.

Floating

After the concrete has been darbied, it should be allowed to harden to the extent that the weight of a man would leave only a slight indentation. Floating should not be started until the water sheen has disappeared. The surface should then be floated with wooden, cork, or metal floats, or with a finishing machine.

Final Finishing

A final finish is applied to concrete surfaces to provide the desired appearance and texture. This work is usually done immediately after floating. Choosing the correct time for troweling or finishing is important. Finishing should be delayed until the surface is quite stiff, yet workable.

Broom finish. Brooming is usually done at right angles to the direction of traffic.

Burlap or belt finish. A final finish on driveways, pavements, and similar work can be produced by drawing a 6- to 12-inch-wide strip of burlap, canvas, or rubber across the surface immediately after the wood float has been used. The strip is moved back and forth as it is advanced. Burlap or belt finishing is performed in two operations—a first pass with strokes of about 12 inches followed by a faster forward movement with 4-inch strokes.

Hand-float finish. Applying a hand-float finish is not to be confused with the initial floating operation. A second floating is necessary after the concrete has partially hardened so that a permanent finish can be produced. The second floating provides gritty, nonslip surfaces that wear well, are attractive, and provide secure footing.

Troweling

When a smooth, dense surface is desired, floating is followed by steel troweling. This operation should be delayed as long as possible without allowing the concrete to become too hard to finish with the trowel. The tendency in most cases is to trowel the surface while the concrete is too soft and plastic. This should be avoided, for excessive troweling at this stage may cause "crazing" (cracking) and dusting and may reduce the wear resistance of the surface.

The practice of spreading dry cement on a wet concrete surface to absorb excess water is not recommended. Such wet spots can usually be avoided by adjustment of the mix proportions and consistency and by correct grading. When wet spots occur, finishing operations should be delayed until the water either disappears or is removed with a squeegee.

A second troweling is applied after the concrete has become hard enough to keep mortar from adhering to the edge of the trowel. When the concrete is ready for this operation, a ringing sound will result as the trowel passes over the surface. Additional trowelings may be necessary, depending on the expected traffic and exposure conditions. During the final troweling, the trowel should be tilted slightly and a heavy pressure should be exerted to compact the surface thoroughly. An interval should be allowed between successive trowelings while the concrete set is increasing.

Power Trowels

Power trowels are time savers in concrete finishing, but they should not be used until the concrete is firm. The concrete must be hard enough to support the power trowel and prevent the blades from throwing mortar.

Fire hazard with gas-powered trowels. Troweling machines are often gasoline powered. The engine of a gas trowel must always be stopped before fuel is added. Many workers have suffered serious and often fatal burns as a result of ignoring this safety rule.

Shock hazard with electrically operated trowels. Electrically operated troweling machines must be equipped with a correctly installed multiconductor power cable having a grounding-type cap. The power cable must be connected only to a grounded receptacle of the correct voltage and phase (larger trowels may require 220-volt single-phase or three-phase power). All types of manually guided troweling machines are required to be equipped with a "deadman" control, which shuts off the power whenever the operator removes his hands from the handles.

The hazard of electrical shock is many times greater for a worker using a portable electric tool around fresh concrete or in other wet or damp locations than it would be if he were working on a dry floor or on dry ground. The best insurance against electrical shock is use of well-maintained, correctly grounded electrical equipment.

Study Assignment

CAL/OSHA, State of California Construction Safety Orders (Latest edition). Review Article 28, Section 1698; and Article 33.

Topics for Discussion

1. What are the steps in placing and finishing a concrete slab? (Be prepared to discuss at least four.)
2. What tools are needed for finishing a concrete slab?
3. What are the purposes of the various floating operations in concrete finishing?
4. In what order are the various concrete-finishing operations performed, and how can the worker tell when the concrete is ready for each operation?
5. What safety precautions must be observed in the use of concrete-finishing equipment?

CONCRETE

TOPIC 8 – FINISHING OF A CONCRETE SLAB

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. Screeding is the process of striking off the excess concrete to bring the top surface to its correct _1_ and _2_. — 1.______ 2.______
2. Immediately after it has been screeded, the concrete should be _3_. — 3.______
3. Handles on bullfloats must be made of _4_, _5_ material. — 4.______ 5.______
4. Striking off and _6_ of a slab are often combined in a single operation. — 6.______
5. Darbying eliminates voids left by _7_. — 7.______
6. Brooming is usually done at right angles to the direction of _8_. — 8.______
7. The final finishing of the slab is usually done immediately after _9_. — 9.______
8. Excessive troweling of concrete that is too soft and plastic may cause _10_ and _11_ and result in reduced _12_. — 10.______ 11.______ 12.______
9. If a smooth surface is required for a slab, floating should be followed by _13_ _14_. — 13.______ 14.______
10. Spreading _15_ _16_ on a wet surface for the absorption of excess water is a bad practice. — 15.______ 16.______

TOPIC 9 – CURING OF CONCRETE

This topic is planned to provide answers to the following questions:

- What causes concrete to harden?
- How does rapid water loss during curing affect concrete?
- What are the methods of keeping concrete moist for curing?
- What factors are involved in curing concrete?
- What is the most favorable temperature range for curing concrete?

Concrete must be kept moist during the initial hardening period after it is placed and finished. This process, which usually takes from a few days to two weeks, is called curing. Keeping the concrete moist enough to ensure that it will be strong, durable, and watertight requires that the right curing conditions and curing time be provided on each job. The strength of concrete increases very rapidly during the first few days of curing after placement, continuing at a high rate for approximately one week and at a declining rate for a long time thereafter. However, this gain in strength can be stopped if the newly poured concrete is allowed to become dry.

Hydration

Concrete hardens because of hydration, the chemical reaction that occurs when portland cement is mixed with water. Approximately three gallons of water are required for each bag of cement to ensure complete hydration. However, additional water is needed in the concrete mixture to make it workable for placement and finishing.

Excessive evaporation of water from newly placed concrete can cause an early stoppage of the cement-hydration process. Protecting the concrete and starting the curing as soon as possible after the final finishing will prevent this loss of water. A rapid loss of water also causes concrete to shrink, creating tensile stresses at the drying surface. If these stresses develop before the concrete has attained an adequate strength, plastic shrinkage cracks may occur.

Effect of Curing

All of the desired properties of concrete are improved by acceptable curing practices. Concrete that is moist-cured for seven days is about 50 percent stronger than concrete that has been exposed to dry air during the entire cure period.

Methods of Keeping Concrete Wet During Cure

Concrete may be kept moist either by applying additional moisture or by preventing the loss of moisture by covering or sealing the concrete surface.

Water Flooding and Spraying

Water curing by flooding or mist spraying is widely done. This is a most effective method in terms of preventing evaporation of mix water, but it is sometimes impracticable because of job conditions. The flooding or "ponding" method is easy to use on flat surfaces such as pavements, sidewalks, and floors: a small dam of earth or other water-retaining material is placed around the perimeter of the slab, and the enclosed area is then kept flooded.

Continuous sprinkling of the surface is another excellent method of curing, provided that the area is sprinkled at correct intervals. The concrete must not be allowed to become dry between applications of water. A constant supply of water prevents crazing, or cracking, which is caused by alternate wetting and drying.

Use of Coverings for Moisture Retention

Continuously wet coverings, such as sand, burlap, canvas, or straw, may be used to retain moisture in newly placed concrete. When one of these is used, the entire concrete surface–including exposed edges or sides–must be covered (for example, the sides of pavements and sidewalks from which the forms have been removed). The material used for water retention must be dampened constantly during the curing period. If the covering is allowed to dry out, it will absorb moisture from the concrete. In vertically formed concrete, a simple way to prevent the drying-out process is to leave the forms in place, sprinkling them as required to keep them damp.

Mechanical barriers of waterproof paper or plastic film are often used to seal the water in and to prevent evaporation. One important advantage of the mechanical barriers is that no periodic wetting down of the concrete is required when they are used. They also help prevent damage from subsequent construction activity and shield the concrete from the sun.

These materials should be applied as soon as the concrete has hardened sufficiently to prevent surface damage. The widest practicable width of material should be used. Edges of adjacent sheets should be overlapped several inches, then tightly sealed with sand, wooden planks, pressure-sensitive tape, mastic, or glue.

In some instances, plastic films may discolor hardened concrete. This may be particularly evident when the concrete surface has been steel-troweled to a hard finish. It is also true for exterior or exposed concrete. When discoloration is objectionable, use of another curing method is advisable.

Chemical-Spray Curing

Chemical membranes may be sprayed on concrete to help the curing. When used correctly, liquid membrane-forming curing compounds are effective in retarding or preventing evaporation of moisture from concrete. The application should be made immediately after the concrete has been finished, just when the water sheen disappears from the surface. If a delay occurs, the concrete should be kept moist until the membrane is applied. However, membrane-type curing compounds should not be applied when free water is on the surface; if this is done, the water will be absorbed by the concrete, and the membrane will be broken. Also, the compound should not be applied after the concrete has dried out, because the compound will then be absorbed into the concrete and a continuous membrane will not be formed. Adequate and uniform coverage of curing compounds is essential. In most cases, two applications are required.

Chemical membranes are suitable for curing fresh concrete and also for further curing after the forms have been removed, or following the initial moist curing. Curing compounds are of four general types—clear or translucent, white pigmented, light-gray pigmented, and black. During hot sunny days, the white-pigmented compounds are most effective because they reflect the sun's rays and reduce the temperature of the concrete.

Curing compounds can be used to prevent the establishment of a bond between hardened and fresh concrete. Consequently, the compounds should not be used if a bond is necessary. For example, a curing compound should not be applied to the base slab of a two-course floor, because it may prevent the topping from bonding. Similarly, some curing compounds affect the adhesion of resilient flooring materials to concrete floors. The curing-compound manufacturer should be consulted to determine whether his product shows this deficiency.

General Curing Requirements

In general, concrete should be cured for at least three days and preferably for a week after it is placed. The curing time depends in large part on the temperature of the concrete; but it is also influenced by such other variables as cement content; mix proportions; required strength, size, and shape of the concrete mass; weather; and future exposure conditions. Curing may require a month or longer for lean concrete mixtures used in massive structures such as dams, but it may take only a few days for richer mixes. Since all the desirable properties of concrete are improved by curing, the curing period should always be as long as practicable. The longer concrete is moist-cured, the better will be its durability, strength, watertightness, wear resistance, and volume stability.

Concrete should be protected so that moisture is not lost too rapidly during the early hardening period, and it should be maintained at a temperature that is favorable for hydration. The best temperature range for curing concrete is from 55° to 73° F. At higher temperatures, hydration takes place more rapidly, but the concrete does not attain its full strength. Hydration proceeds more slowly when temperatures are below 70° F., and it practically ceases when the temperature is near freezing. Developing a given strength in concrete takes more than three times as long at 33° F. as it does at 70° F. No gain in hardening can be expected while concrete is frozen, but hydration will resume after it is thawed if suitable curing is applied. Freezing within the first 24 hours of the curing period is almost certain to result in permanent damage to the concrete.

Topics for Discussion

Be prepared to discuss the following if asked to do so:

1. Why must concrete be cured?
2. What are the necessary conditions for correct curing?

3. How is concrete cured? (Be prepared to discuss four ways.)
4. What is the most favorable temperature range for curing concrete?
5. What properties of concrete are improved by curing?
6. Why should forms be left on concrete walls for several days?
7. What are the two general methods of curing concrete?
8. Why does proper curing of concrete increase its resistance to wear?
9. How do high temperatures affect curing?
10. What is meant by "ponding"?

CONCRETE

TOPIC 9 – CURING OF CONCRETE

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. Only about _1_ gallons of water are required for each bag of cement for complete hydration, but additional water is needed in the mix to make it _2_.	1.________ 2.________
2. Concrete must be kept _3_ during the curing period.	3.________
3. The strength of concrete increases rapidly during the first few _4_ after placement.	4.________
4. Concrete hardens because of a _5_ reaction between portland cement and water.	5.________
5. Rapid loss of water adversely affects the curing process and causes newly placed concrete to _6_ and develop surface _7_.	6.________ 7.________
6. When waterproof paper or plastic sheeting is used over newly placed concrete for moisture retention, the material should be _8_ several inches and tightly _9_.	8.________ 9.________
7. An objection to the use of plastic films in curing is that in some instances they _10_ the concrete.	10.________
8. The best temperature range for curing concrete is from _11_° F. to _12_° F.	11.________ 12.________
9. A sprayed-on membrane sealing coat should not be used in curing a base _13_ that is to receive a top coat.	13.________
10. All the desirable properties of concrete are improved by good _14_.	14.________

TOPIC 10 – REINFORCED CONCRETE

This topic is planned to provide answers to the following questions:

- **What is reinforced concrete?**
- **What are the various kinds of reinforcement used in concrete?**
- **What forces acting upon the concrete are resisted by reinforcement?**
- **What general rules are followed in reinforcing concrete?**

All structural-type concrete contains some kind of reinforcement. No matter how well the concrete is placed and finished, the job will fail if the reinforcement is incorrectly installed.

Reinforcement of Concrete

Concrete has great compressive strength; that is, strength to resist loads placed directly upon it. However, the tensile strength of concrete–its resistance to stretching–is only about one-tenth its compressive strength. Some kind of reinforcement, usually steel bars or welded-wire fabric, is therefore required in structural concrete to increase its resistance to forces that would tend to pull it apart. Depending on the amount of reinforcement used, the tensile strength of the concrete can be made equal to or greater than the compressive strength.

Kinds of Reinforcement

Through the years, many different kinds of materials have been tried as reinforcement in concrete. Steel has proved to be the best, and today it is universally accepted and used for this purpose. An important advantage of steel as a reinforcing material is that its contraction and expansion with temperature change is nearly the same as that of concrete.

Reinforcing steel is made in the form of bars or welded-wire fabric. The bars may be either smooth or deformed, the smooth bars usually being of small diameter. Deformed bars have lug-like ridges that increase the bond between the concrete and steel. Reinforcement bars come in standard sizes, which are designated by number, and are usually supplied in 20-foot lengths. The size bar to use depends on the amount of tensile force to which the concrete will be subjected. The standard bar sizes (up to 1 inch in diameter) and the weight per 100 feet of bar are shown in Table 10-1. Bars larger than 1 inch in diameter are available for extremely heavy construction.

Welded-wire fabric, which is made in many types and wire sizes, is used for jobs that require relatively light reinforcement. The most common type used in light construction has the wires spaced on 6-inch centers both ways. Wire sizes generally available are 6-, 8-, and 10-gage. Welded-wire fabric is usually referred to by a short expression made up of the numbers of its wire spacing and its wire gage; for example, "six-six-ten-ten" or " six by six Number 10" means a fabric in which both the longitudinal and transverse wires are spaced on 6-inch centers and are of No. 10-gage wire.

TABLE 10-1

Size and Weight of Reinforcing Bars

Bar number	Bar diameter (inches)	Approximate weight of 100 lineal feet (pounds)
2	¼	17
3	⅜	38
4	½	67
5	⅝	104
6	¾	150
7	⅞	204
8	1	267

How Reinforcement Works

A structure can be subjected to tensile forces in several ways: by straight tensile pull, by bending, and by contraction from changes in temperature and moisture.

Straight tensile pull. In many structures–round water tanks and farm silos, for example–concrete is subjected to a straight tensile pull. Because pressures within a tank tend to push the tank wall apart, reinforcing steel is placed in the wall to help hold it together. Steel is needed around the entire tank wall, since pressures are exerted equally in all directions. In such structures, the steel is usually placed near the center of the wall cross-section, preferably slightly outside the center line.

Bending loads. In the case of a concrete beam under a bending load, only a part of the beam is subjected to tensile forces. When the load is applied, the ends of the beam move closer together at the top and farther apart at the bottom. The concrete is therefore compressed at the top of the beam and stretched at the bottom (Fig. 10-1). Because concrete cannot take much stretching or tension, reinforcing steel must be placed in the beam.

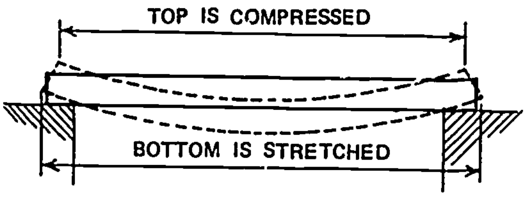

Fig. 10-1. Effects of a bending load on a simple beam

The location of the reinforcement steel is just as important as the amount of steel used to resist bending loads. For example, in concrete lintels across door or window openings and in beams, the reinforcement is placed near the lower side of the member, since that is the side that tends to pull apart under tensile stresses when the beam is loaded.

Reinforcement to Prevent Cracking

Concrete, like other construction materials, expands and contracts because of changes in temperature and moisture. Such expansion and contraction can cause cracking of the concrete. Reinforcement wire is sometimes used to control this cracking. Although welded-wire fabric will not prevent cracks, it generally prevents large ones and distributes them over a wider area.

In concrete slab work, the method of jointing the slabs into 10- or 15-foot squares is usually more economical than using reinforcement if the sole purpose is to control stresses due to temperature and shrinkage.

Placement of Steel

The size, location, and spacing of reinforcement are usually determined in advance by engineers; but the important operation of placement must be performed by workers on the job. Contractors' supply houses and concrete-accessory manufacturers stock a wide range of materials to help make steel-placement tasks easier, including such items as form ties, bar chairs, bar spacers, and slab bolsters.

In general, all reinforcement should be placed so that it is protected by an adequate coverage of concrete (Table 10-2).

TABLE 10-2

Concrete Required to Protect Reinforcement*

Concrete members	Minimum concrete protection required
1. Footings	3 inches
2. Concrete exposed to weather	2 inches for bars larger than No. 5; 1½ inches for No. 5 and smaller
3. Slabs and walls	¾ inch
4. Beams and girders	1½ inches
5. Joists	¾ inch
6. Columns	1½ inches or 1½ times the maximum size aggregate
7. Surfaces exposed to corrosive atmosphere or severe exposure	Protection to be suitably increased

*American Concrete Institute, ACI 318, "Building Code Requirements for Reinforced Concrete."

Splicing of Reinforcement Steel

Because reinforcement steel carries tensile loads in concrete, the steel must be overlapped where a splice is required. The amount of overlap for deformed bars should always be at least 24 bar diameters, with a minimum overlap of 12 inches. Bars with smooth surfaces must be overlapped even more than these amounts. Welded-wire fabric is spliced by lapping at least the width of one full stay plus 2 inches; that is, for 6 x 6 fabric, at least an 8-inch overlap would be required.

Slab Reinforcement

Reinforcement is often used in the floor slabs of homes under the following conditions:

1. If load-bearing partitions are more than 4 feet from the center axis of the slab

2. If the slab is placed on fill more than 2 feet deep, or if more than 10 percent of the area within the foundation wall has been excavated and backfilled
3. If heat ducts or pipes are embedded in the slab
4. If unheated slabs are more than 30 feet long

The use of reinforcement, either bars or welded-wire fabric, will not ensure the prevention of cracks, but it may reduce the size of the opening if a crack does occur. The reinforcing steel should be placed about 1 inch from the top surface of the slab and held in this position during the pour. If welded-wire fabric is used, it should be set on bolsters or similar supports, not placed on the subbase and pulled up with a rake or hook after the mix is poured. Controlling its position by the latter method is virtually impossible.

Placement of Concrete Around Steel

Concrete should be placed around and under all reinforcement and all embedded fixtures, and it should be made to settle in place without voids. This can be accomplished by vibrating the concrete or the form; tapping the form with a rubber or wood mallet; or using any other similar practical method of consolidation.

General Rules for Steel Reinforcement

The following general rules should be observed in placing reinforcement for concrete:

1. Use only clean steel that is free from oil and grease, rust, paint, scale, and hardened concrete.
2. Place steel in accordance with the recommendations given in Table 10-2, "Concrete Required to Protect Reinforcement."
3. Limit the aggregate size in the concrete mix to no more than three-fourths of the minimum spacing between reinforcing bars or between reinforcement and forms.
4. Overlap all bars a minimum of 24 times their diameter and never less than 12 inches.
5. Place reinforcement in such a way that it will resist any tension forces to which the concrete will be subjected.
6. Provide adequate protection over the ends of protruding reinforcing bars when workers will be working above or when a tripping hazard exists in the area.

New Developments in Reinforcement

In the past several years, great advances have been made in the technology of reinforced concrete. For example, reinforcing bars are constantly being improved; the deformed bars used today bond to the concrete much more firmly than those of only a few years ago. This improvement was made possible by changing the shape of the lugs. Another recent development is the high-strength-steel reinforcement bar. When such bars are used, the amount of reinforcing steel normally required can be reduced.

Study Assignment

CAL/OSHA, State of California Construction Safety Orders (Latest edition). Review Article 29, Section 1712.

CONCRETE

TOPIC 10 — REINFORCED CONCRETE

Study Guide

Determine the correct word for each numbered blank in the sentence, and write it in the corresponding blank at the right.

1. When welded-wire fabric or steel bars are placed in concrete, the resulting product is called <u>1</u> <u>2</u>.	1. ______ 2. ______
2. Steel is placed in concrete to increase its <u>3</u> <u>4</u>.	3. ______ 4. ______
3. If enough reinforcing steel is added to concrete, the <u>5</u> strength of the concrete can be made equal to or greater than the <u>6</u> strength.	5. ______ 6. ______
4. One reason steel is used as the reinforcing material in concrete is that it has nearly the same <u>7</u> and <u>8</u> characteristics as concrete.	7. ______ 8. ______
5. Reinforcing bars may be either the <u>9</u> type to increase bond or the <u>10</u> type.	9. ______ 10. ______
6. No. 4 reinforcing bar is <u>11</u> inch in diameter and weighs about <u>12</u> pounds per 100 lineal feet.	11. ______ 12. ______
7. Reinforcing bars are usually supplied in <u>13</u> -foot lengths.	13. ______
8. If welded-wire is specified as "six-six-eight-eight," this means that the longitudinal and transverse wires are <u>14</u> gage and are spaced on <u>15</u> - <u>16</u> centers both ways.	14. ______ 15. ______ 16. ______
9. Welded-wire reinforcement steel is used on construction projects that require relatively <u>17</u> reinforcement.	17. ______
10. On a concrete lintel or beam that carries a load, the reinforcing steel should be placed near the <u>18</u> side of the <u>19</u>.	18. ______ 19. ______
11. Welded-wire fabric reinforcement will not prevent formation of <u>20</u>, but it will generally prevent <u>21</u> ones.	20. ______ 21. ______
12. The size, location, and spacing of reinforcement are usually determined by <u>22</u>.	22. ______
13. Reinforcement for floor slabs should be located approximately <u>23</u> <u>24</u> from the top surface of the slab.	23. ______ 24. ______
14. In general, all reinforcement should be placed so that it is protected by an adequate <u>25</u> of <u>26</u>.	25. ______ 26. ______
15. A recent development in concrete reinforcement is the use of <u>27</u> - <u>28</u> steel in the reinforcement bars.	27. ______ 28. ______

Instructional Materials

Materials Required for Each Apprentice*

1. *Carpentry—Concrete* (Workbook and tests) (1976 edition). Sacramento: California State Department of Education, 1986. (Orders to: Department o. Education, Publications Sales, P.O. Box 271, Sacramento, CA 95802-0271.)

2. *Constitution and Laws of the United Brotherhood of Carpenters and Joiners of America* (as amended).

3. Durbahn, Walter E., and Elmer W. Sundberg. *Fundamentals of Carpentry,* Vol. 2, *Practical Construction* (Fifth edition). Chicago: American Technical Society, 1977. (Orders to: American Technical Publishers, 12235 S. Laramie Ave., Alsip, IL 60658.)

Materials Recommended for Further Reference*

1. *California Labor Code.* Compiled by the California Legislative Counsel. (Orders to: Department of General Services, Publications Section, P.O. Box 1015, North Highlands, CA 95660.)

2. *CAL/OSHA, State of California Construction Safety Orders.* Los Angeles: Building News, Inc. (Orders to: Building News, Inc., 3055 Overland Ave., Los Angeles, CA 90034.)

3. *Carpentry* instructional units. Washington, D.C.: United Brotherhood of Carpenters and Joiners of America, Apprenticeship and Training Department.

4. *The Carpenter.* The monthly publication of the United Brotherhood of Carpenters and Joiners of America. (Orders to: United Brotherhood of Carpenters and Joiners of America, 101 Constitution Ave., N.W., Washington, DC 20001.)

5. Durbahn, Walter E., and Robert E. Putnam. *Fundamentals of Carpentry,* Vol. 1, *Tools, Materials, Practices* (Fifth edition). Chicago: American Technical Society, 1977. (Orders to: American Technical Publishers, 12235 S. Laramie Ave., Alsip, IL 60658.)

6. Feirer, John, and Gilbert Hutchings. *Carpentry and Building Construction.* Peoria, Ill.: Charles A. Bennett Company, Inc., 1976. (Orders to: Charles Scribner's Sons, Order Department, Front and Brown Sts., Riverside, NJ 08075.)

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*Use latest editions of all references.

Course in Carpentry

CONCRETE

Tests

The following section contains objective tests for each topic of the workbook. The value of the tests depends to a great extent on the care taken by instructors and school supervisors in keeping them confidential.

Supervisors and instructors should feel free to modify the application of the workbook material and the tests to satisfy local needs. Also, instructors will probably supplement the information in the workbook with other material that they have developed, and they will need to augment the tests with questions based on any supplementary material they may use.

Instructors and supervisors should be aware that the test pages are perforated to facilitate removal of the tests, either individually or as a complete set, at the discretion of the instructor or supervisor.

Concrete Tests

TOPIC 1 – INTRODUCTION TO CEMENT AND CONCRETE

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. The principal ingredient of portland cement is: 1.______

   1. Shale
   2. Lime
   3. Silica
   4. Aggregate

2. The general-purpose portland cement normally used in the construction of pavements and sidewalks, reinforced concrete buildings, bridges, and railway structures is designated by the American Society for Testing and Materials as Type: 2.______

   1. I
   2. II
   3. III
   4. IV

3. The special portland cement intended for use in structures exposed to soils or waters of high sulfate content is designated as ASTM Type: 3.______

   1. I
   2. III
   3. IIIA
   4. V

4. The portland cement used where high strengths are desired at very early periods of cure is designated as ASTM Type: 4.______

   1. I
   2. III
   3. V
   4. VII

5. The portland cement recommended for use in large piers, heavy abutments, and heavy retaining walls when the concrete will be placed in warm weather is ASTM Type: 5.______

   1. II
   2. III
   3. IV
   4. VI

6. The portland cement recommended where the amount and rate of heat generation must be kept to a minimum, as in large gravity dams, is ASTM Type: 6.______

   1. I
   2. II
   3. IIIA
   4. IV

7. The chemical reaction that causes cement to set and harden is called: 7._____

1. Setting
2. Oxidation
3. Hydration
4. Curing

8. The cement to use for making concrete that will resist severe frost action is: 8._____

1. Type II cement
2. Low-heat cement
3. Type V cement
4. Air-entraining cement

9. Portland-pozzolan cement is used mainly in the construction of: 9._____

1. Sidewalks and pavements
2. Large hydraulic structures
3. Reinforced concrete buildings
4. Footings and foundations

10. Handling fresh concrete without taking precautions to protect the skin from direct contact with the mixture can result in: 10._____

1. Nausea
2. Muscle spasms
3. Painful burns
4. Acute poisoning

CONCRETE TESTS

TOPIC 2 – SPECIFICATIONS FOR CONCRETE

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. The standard for specifying concrete strength is the compressive strength of a molded test cylinder at: 1._____

   1. 4 hours after placement
   2. 24 hours after placement
   3. 28 days after placement
   4. 33 days after placement

2. A 3-cubic-yard batch of concrete is to be mixed in a large on-site mixer. After all the materials for the batch have been placed in the mixer, at least how many minutes should be allowed for mixing? 2._____

   1. 1
   2. 1½
   3. 3
   4. 5

3. The method specified for conveying concrete from the mixer to the place of final deposit on the job must: 3._____

   1. Allow delivery of all the concrete in 30 minutes.
   2. Prevent entrainment of air in the concrete mix.
   3. Prevent separation of the concrete materials.
   4. Allow delivery of at least 1 cubic foot per minute.

4. Normal concrete should be kept moist for at least how long after placement? 4._____

   1. 8 hours
   2. 24 hours
   3. 2 days
   4. 5 days

5. When concreting must be done in cold weather, the job specifications should require that the concrete materials: 5._____

   1. Contain antifreeze.
   2. Be at air temperature.
   3. Contain an accelerating admixture.
   4. Be free from snow, frost, and ice.

6. Specifications for cold-weather concreting should require that the temperature of the concrete after placement be at least how many degrees Fahrenheit? 6._____

   1. 30
   2. 50
   3. 60
   4. 70

7. Specifications should require that reinforcing material shall not have: 7._____

   1. Welded splices
   2. Bends
   3. Protrusions
   4. Coatings that might prevent bonding

8. Form panels weighing more than 500 pounds are required to have: 8.____

1. A safety factor of 4
2. Properly nailed lifting devices
3. Positive lifting attachments
4. Support cables tied to reinforcing steel

9. If protective oil coatings are required on floor forms, the oil should be: 9.____

1. Heated before being applied
2. Applied before the form panels are placed
3. Cut with kerosene for cold-weather application
4. Applied after the carpentry work on the forms is completed

10. The ends of protruding reinforcing steel must be: 10.____

1. Covered or bent over for safety
2. Coated with asphaltic paint
3. Tack welded to adjoining bars
4. Filed to remove burrs

CONCRETE TESTS

TOPIC 3 – AGGREGATES

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. The most common form of fine aggregate is: 1. _____

   1. Powdered limestone
   2. Sand
   3. Crushed shale
   4. Slag

2. The best aggregates are composed of materials that are: 2. _____

   1. Hard and durable
   2. Soft and flaky
   3. Eroded
   4. Laminated

3. The minimum particle size for coarse aggregates is: 3. _____

   1. ⅛ inch
   2. ¼ inch
   3. ½ inch
   4. ¾ inch

4. The term "bank-run aggregate" refers to: 4. _____

   1. Aggregate as taken directly from the quarry or pit
   2. Aggregate that consists entirely of fine-graded rock
   3. River sand that is not washed
   4. Screened and recombined aggregate

5. Loam, silt, clay, and vegetable matter when found in an aggregate mixture are classed as: 5. _____

   1. Binders
   2. Coloring agents
   3. Catalysts
   4. Contaminants

6. Concrete made with dirty aggregate: 6. _____

   1. Slumps excessively
   2. Sets too rapidly
   3. Hardens slowly
   4. Develops cracks

7. In good concrete, each particle of aggregate must be completely surrounded by: 7. _____

   1. Sand
   2. Entrained air
   3. Cement paste
   4. Additives

8. Which one of the following is *not* a factor in determining the maximum size of aggregate in a concrete mix? 8. _____

   1. Size of the concrete members
   2. Type of cement used
   3. Shape of the concrete members
   4. Distribution of reinforcing steel

9. Aggregate should be removed from the stockpile: 9.______

1. From the front
2. From the bottom
3. In layers
4. In random fashion

10. The most economical concrete is obtained through use of what type of aggregate? 10.______

1. Fine only
2. A mixture of coarse and fine
3. Coarse only
4. Siliceous

CONCRETE TESTS

TOPIC 4 – SAMPLING AND TESTING OF CONCRETE

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. Concrete sampling and testing operations should be governed by the standard test methods adopted by the: 1._____

    1. Contractor
    2. ASTM
    3. Cement manufacturer
    4. STPC

2. The test for consistency of a concrete mix is called the: 2._____

    1. Slump test
    2. Unit-weight test
    3. Cylinder test
    4. Air-content test

3. The pressure method of testing fresh concrete for air content is practical for all mixes except those that contain: 3._____

    1. Air-entrainment additives
    2. Accelerators
    3. Porous aggregates
    4. Magnetite or ilmenite

4. The height of a standard slump-cone mold is how many inches? 4._____

    1. 6
    2. 8
    3. 10
    4. 12

5. The maximum time that may elapse from the taking of a concrete sample to the molding of the sample is: 5._____

    1. 15 minutes
    2. 30 minutes
    3. 45 minutes
    4. 1 hour

6. Which one of the following slump measurements would indicate a very dry mix? 6._____

    1. 1 inch
    2. 3 inches
    3. 5 inches
    4. 7 inches

7. Where high accuracy is not required, a quick field test for the air content of fresh concrete can be made by using: 7._____

    1. The pressure method
    2. The volumetric method
    3. The gravimetric method
    4. An air indicator

8. Samples of fresh concrete for molding compressive-test specimens should be taken: 8. ______

1. Twice during the discharge of the batch
2. After placement of each 150 cubic yards or less
3. At least three times during discharge of the batch
4. After placement of each 300 cubic yards or less

9. Filled compressive-test cylinders should be protected against: 9. ______

1. Vibration
2. Loss of moisture
3. Extremes of temperature
4. All of the above

10. The maximum slump permitted for concrete that is to be used for pavements is how many inches? 10. ______

1. 1
2. 2
3. 3
4. 4

CONCRETE TESTS

TOPIC 5 – CONCRETE ADMIXTURES

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. The purpose of concrete admixtures is to: 1._____

   1. Compensate for errors in mix design.
   2. Reinforce weak or dirty aggregate materials.
   3. Eliminate the need for vibration in consolidating concrete.
   4. Provide special characteristics in concrete mixes.

2. Which one of the following is not a type of admixture? 2._____

   1. Accelerators
   2. Retarders
   3. Workability agents
   4. Alkalizing agents

3. A common ingredient of admixtures for increasing the rate of strength gain in concrete is: 3._____

   1. Fly ash
   2. Pozzolan
   3. Calcium chloride
   4. Ilmenite

4. The need for admixtures in a concrete mix can often be eliminated by: 4._____

   1. Adding sodium chloride
   2. Adding a gas-forming agent
   3. Changing the mix proportions
   4. Increasing the mixing speed

5. An important preliminary step in the use of an admixture is to: 5._____

   1. Heat the mix water to 70° F. or above.
   2. Increase the amount of fine aggregate.
   3. Add a little organic matter to the mix.
   4. Make some trial mixes.

6. Admixtures containing which one of the following should not be used in prestressed concrete? 6._____

   1. Workability agents
   2. Pozzolans
   3. Soluble chlorides
   4. Accelerating agents

7. The most practical way to counteract excessive heat of hydration and prevent too-rapid hardening in a concrete mix is to: 7._____

   1. Use cool mixing water and cool aggregate.
   2. Increase the water-cement ratio.
   3. Use a retarding admixture.
   4. Avoid hot-weather concreting.

8. Which one of the following characteristics of a concrete mixture will be improved by the addition of an air-entraining agent? 8. ____

1. Workability
2. Early strength
3. Tensile strength
4. Density

9. Entrained air greatly improves the durability of concrete that is exposed to: 9. ____

1. Heavy traffic
2. Freezing and thawing
3. Compressive loads
4. Bending loads

10. The temperature of fresh concrete may be as high as how many degrees Fahrenheit? 10. ____

1. 50
2. 70
3. 80
4. 90

CONCRETE TESTS

TOPIC 6 – METHODS OF CONCRETE PLACEMENT

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. Ramps and runways over which fresh concrete must be transported in concrete buggies and wheelbarrows should be: 1. ______

   1. Nearly level
   2. Inclined no more than 10 degrees
   3. Vibrated
   4. Smooth

2. Ramps and runways that are over 3 feet high and that are used for wheelbarrows and hand buggies must be at least how wide? 2. ______

   1. 24 inches
   2. 30 inches
   3. 3 feet
   4. 5 feet

3. Under normal conditions, what is the maximum time that should elapse between adding the mix water and placing the fresh concrete? 3. ______

   1. 10 to 15 minutes
   2. 20 to 30 minutes
   3. 1 to 1½ hours
   4. 2 to 2½ hours

4. If more water is added to a concrete mix just before placement to increase workability, the concrete is likely to be: 4. ______

   1. Stronger but less durable
   2. More durable but not as strong
   3. More waterproof but somewhat less durable
   4. Adversely affected in every important characteristic

5. Concrete should be placed in: 5. ______

   1. Layers
   2. Small, separate piles
   3. One large pile
   4. The most convenient manner

6. Vibrators are used in concrete placement to: 6. ______

   1. Prevent segregation of the concrete.
   2. Complete the mixing operation.
   3. Settle the forms.
   4. Consolidate the concrete.

7. Where should concrete be placed first in slab construction? 7. ______

   1. At the slab center
   2. On a dry part of the subgrade
   3. At the most remote end of the slab area
   4. Around the entire perimeter of the slab area

8. Bleeding in concrete can be reduced by: 8._____

1. Using a high-slump mixture
2. Placing the mixture more slowly
3. Sprinkling cement on the wet concrete
4. Increasing the vibration time for the concrete

9. If vibrators are to be used in the placement of concrete in the forms, the slump of the concrete can usually be: 9._____

1. Increased by one-third
2. Increased by one-half
3. Decreased by one-third to one-half
4. Disregarded in proportioning the mix

10. The preferred maximum angle of slope for ramps is how many degrees? 10._____

1. 10
2. 15
3. 20
4. 25

CONCRETE TESTS

TOPIC 7 — MOVEMENT OF CONCRETE ON THE JOB

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. Whatever method is used for moving concrete from the mixer to the point of deposit, the concrete-moving equipment must be: 1.______

   1. Rented on a weekly basis
   2. Guyed to deadman anchors
   3. Given a maintenance checkup at least once a week
   4. Permanently maintained in first-class condition

2. The principal difference between a hoist and a crane is that a crane: 2.______

   1. Is always a stationary unit
   2. Can move and position loads horizontally as well as vertically
   3. Is a heavy-duty lifting device
   4. Has automatic positioning controls

3. Hoists, cranes, and construction elevators for moving concrete may not be used for moving: 3.______

   1. Dry cement
   2. Loose aggregate
   3. Any construction material
   4. Workmen

4. Which one of the following types of cranes is generally considered to have the greatest potential for accidents? 4.______

   1. Climbing crane
   2. Truck crane
   3. Gantry crane
   4. Crawler crane

5. The boom of a tower crane is usually: 5.______

   1. Hinged
   2. Cantilevered
   3. Short
   4. A vertical mast

6. Tower cable cranes are used mainly in the construction of: 6.______

   1. High-rise buildings
   2. Bridges and trestles
   3. Dams
   4. Culverts

7. The lifting range of portable tower hoists is usually not more than how many feet? 7.______

   1. 40
   2. 60
   3. 75
   4. 100

8. Concrete being transported from the mixer to the forms must be protected from undue jarring and vibration to prevent: 8.______

1. Hydration
2. Segregation
3. Air entraining
4. Premature curing

9. If bell or whistle signals are used to direct the operator of a hoist or a construction elevator, what signal would be given to stop the machine? 9.______

1. One bell or whistle
2. Two bells or whistles
3. Three bells or whistles
4. Four bells or whistles

10. The maximum number of feet that concrete can be pumped vertically is: 10.______

1. 150
2. 160
3. 170
4. 180

CONCRETE TESTS

TOPIC 8 — FINISHING OF A CONCRETE SLAB

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. The first step in finishing a slab is: 1. ______

   1. Bullfloating
   2. Darbying
   3. Consolidating the concrete
   4. Removing surface water

2. After being struck off to the correct grade, the concrete slab should be worked with what tool to produce an even, true surface? 2. ______

   1. Wood float
   2. Trowel
   3. Screed
   4. Darby

3. Where a smooth, dense surface is desired on a concrete slab, floating is followed by: 3. ______

   1. Steel troweling
   2. Dampening
   3. Sacking
   4. Jitterbugging

4. For a fine hair-broom finish, the slab surface should first be given: 4. ______

   1. A sprinkling with cold water
   2. A belt finish
   3. One or more trowelings
   4. A wood-float finish

5. If surface water is present on the fresh slab, what should the finisher do before proceeding? 5. ______

   1. Sprinkle the slab with dry cement.
   2. Sprinkle the slab with a mixture of cement and fine sand.
   3. Let the water evaporate.
   4. Apply a chemical waterproofing agent.

6. Screeding accomplishes which one of the following? 6. ______

   1. Prepares the concrete surface for troweling
   2. Brings the surface to the correct contour and elevation
   3. Dries out the surface
   4. Prevents surface checking

7. The concrete slab should be floated: 7. ______

   1. While it is still plastic
   2. After the troweling
   3. Before the screeding
   4. After partial hardening

8. When no mortar adheres to the edge of the trowel and a ringing sound is produced as the trowel is passed over the surface, the concrete is ready for: 8. ____

1. First troweling
2. Hand floating
3. Final troweling
4. A rubbed finish

9. Striking off is the same as: 9. ____

1. Screeding
2. Floating
3. Jointing
4. Consolidating

10. Excessive troweling of concrete can result in which of the following? 10. ____

1. Increased wear resistance
2. Increased workability
3. Contamination of aggregate
4. Cracking

11. The handle of a bullfloat must be: 11. ____

1. Nonconductive
2. At least 14 feet long
3. Swivel mounted
4. Made of wood

12. Control joints are generally located how many feet apart on concrete slabs on grade? 12. ____

1. 5 to 10
2. 8 to 12
3. 12 to 15
4. 15 to 25

13. What advantage is gained by using low-slump air-entrained concrete of adequate cement content for slabs on grade? 13. ____

1. Reduced bleeding
2. Increased workability
3. Greater freeze-thaw resistance
4. All of the above

14. Before refueling a gasoline-powered trowel on the job, the worker should always: 14. ____

1. Stop the engine.
2. Remove the machine from the slab.
3. Slow the engine to idling speed.
4. Check with the foreman.

15. All types of manually guided troweling machines are required to be equipped with a(n): 15. ____

1. Speed governor
2. "Deadman" control
3. Overload protector
4. Quick-reverse drive

CONCRETE TESTS

TOPIC 9 – CURING OF CONCRETE

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. Concrete hardens as the result of a chemical reaction called: 1._____

   1. Hydrolysis
   2. Fractioning
   3. Hydration
   4. Fusion

2. Strength, durability, watertightness, and other desirable properties of concrete will be adversely affected if during the curing period the concrete is not kept: 2._____

   1. Moist
   2. Chilled
   3. Covered
   4. Warm

3. Which one of the following types of concrete mixtures would require the longest curing period? 3._____

   1. A rich mix with Type I cement
   2. A lean mix with Type IV cement
   3. A lean mix with Type III cement
   4. A rich mix with Type III cement

4. Excessive loss of surface moisture in the early part of the curing period is most likely to produce what defect in concrete? 4._____

   1. Discoloration
   2. Overhydration
   3. Plastic shrinkage cracks
   4. Poor aggregate bonding

5. If mechanical barriers are used to retain moisture in fresh concrete, they should be placed as soon as the concrete has hardened sufficiently to prevent: 5._____

   1. Further hydration
   2. Change in volume
   3. Rise of laitance
   4. Surface damage

6. A disadvantage of using plastic film as a moisture seal to aid the curing of concrete is that the film may: 6._____

   1. Increase bleeding.
   2. Discolor the concrete.
   3. Stop hydration.
   4. Entrain air.

7. The most favorable temperature range for curing concrete is: 7._____

   1. 40° to 55° F.
   2. 45° to 70° F.
   3. 50° to 62° F.
   4. 55° to 73° F.

8. In curing, forms should be left in place and kept damp how long after the concrete has become strong enough to be self-supporting? 8._____

   1. At least 12 hours
   2. At least 24 hours
   3. At least 36 hours
   4. As long as practicable

9. Concrete is almost certain to suffer permanent damage if during the first 24 hours of the curing period it is: 9.____

1. Allowed to freeze
2. Covered with plastic sheeting
3. Exposed to direct sunlight
4. Exposed to warm air

10. Curing compounds should not be used on a concrete surface if: 10.____

1. A concrete bond will be required.
2. The concrete contains additives.
3. Air temperature is above 80° F.
4. A lean mix has been used.

CONCRETE TESTS

TOPIC 10 – REINFORCED CONCRETE

Decide which one of the four answers is correct, or most nearly correct; then write the corresponding number in the blank at the right.

1. Reinforcement is placed in concrete to: 1. _____

   1. Increase compressive strength.
   2. Increase tensile strength.
   3. Prevent cracking.
   4. Prevent expansion.

2. Which one of the following is not used as reinforcement in concrete? 2. _____

   1. Wire fabric
   2. Smooth bars
   3. Bars with lugs
   4. Steel tubing

3. In concrete beams, the reinforcement should be placed near the: 3. _____

   1. Bottom
   2. Sides
   3. Center
   4. Top

4. The reason for deforming a reinforcement bar is to increase: 4. _____

   1. Bar strength
   2. Concrete adhesion
   3. Bar flexibility
   4. Concrete flexibility

5. "Six-six-ten-ten" welded-wire reinforcement has: 5. _____

   1. 10-inch wire spacing
   2. 6-inch wire spacing
   3. Unequal wire spacing
   4. No. 6-gage transverse wires

6. Reinforcement is sometimes used to: 6. _____

   1. Separate aggregate.
   2. Reduce cracking.
   3. Stop cracking.
   4. Stop shrinkage.

7. Reinforcement when used in walls or slabs should always be placed at least how far in from the concrete surface? 7. _____

   1. ½ inch
   2. ¾ inch
   3. 1 inch
   4. 2 inches

8. Reinforcement bars should always be overlapped a minimum of how many inches at splices? 8. _____

   1. 6
   2. 8
   3. 10
   4. 12

9. If the job requires that some reinforcement bars be placed as close as 1 inch apart, the largest-diameter aggregate that should be used is: 9.______

1. ¼ inch
2. ½ inch
3. ¾ inch
4. 1 inch

10. The diameter of a No. 4 bar is: 10.______

1. ½ inch
2. ⅝ inch
3. ¾ inch
4. 1 inch

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