UNITED STATES MARINE CORPS
COMBAT ENGINEER INSTRUCTION COMPANY
MARINE CORPS ENGINEER SCHOOL
PSC BOX 20069
CAMP LEJEUNE, NORTH CAROLINA 28542-0069

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26 Jan 01
(00 POI)

STUDENT HANDOUT

CONCRETE CONSTRUCTION

1. Purpose: This period of instruction is to provide you with the basic knowledge necessary to construct concrete projects.

2. Learning Objectives:

a. Terminal Learning Objective(s):

(1) Provided a mission, construction site, specifications, appropriate power tools, power source, and references, construct concrete form to conform to design specifications per the references.(1371.01.11)

(2) Provided a mission, construction site, specifications, engineer masonry tools, cement, gravel, sand, water source, specified mix ratio, and references, mix concrete to ensure batches of concrete are of uniform quality, conforming to the specified mix ratio and safety precautions observed at all times per the references. (1371.01.05)

(3) Provided a mission, construction site, specifications, engineer masonry tools, reinforcing materials, mixed concrete, and references, pour concrete to produce a tight bond between the paste and course aggregate, and fill the forms completely per the references. (1371.01.07)

(4) Provided a mission, construction site, specifications, engineer masonry tools, reinforcing materials, mixed concrete, and the reference, finish concrete to produce the desired finish per specifications and the reference.(1371.01.08)

b. Enabling Learning Objective(s):

(1) Provided a mission, construction site, tools, lumber and fasteners, as a member of a team, without the aid of references, prepare the subgrade to conform to design specifications per the references. (1371.01.11a)

(2) Provided a mission, construction site, tools, lumber and fasteners, as a member of a team, without the aid of references, construct concrete forms to conform to design specifications per the references. (1371.01.11b)

(3) Provided a mission, construction site, tools, lumber, fasteners and reinforcing steel, as a member of a team, without the aid of references, install reinforcing steel in the formwork to conform to design specifications per the references. (1371.01.11c)

(4) Provided a mission to mix concrete, specifications, and a concrete masonry tool kit, without the aid of references, select concrete tools that will satisfy the mission specifications per the references. (1371.01.05a)

(5) Provided a mission to mix concrete, specifications, a specified mix ratio, a concrete masonry tool kit, cement, gravel, sand, and water source a construction site, as a member of a team, without the aid of references, proportion wet and dry concrete materials to conform to the specified mix ratio per the reference. (1371.01.05b)

(6) Provided a mission to mix concrete, specifications, a specified mix ratio, a concrete masonry tool kit, proportioned cement, gravel, sand, and water source, a construction site, as a member of a team, without the aid of references, mix concrete to ensure batches of concrete are thoroughly mixed, of uniform quality and conform to the specified mix ratio per the reference. (1371.01.05c)

(7) Provided a mission, specifications, a construction site, concrete masonry tools, formwork and mixed concrete, as a member of a team, without the aid of references, pour concrete to produce a tight bond between the paste and course aggregate, and fill the forms completely per the reference. (1371.01.07a)

(8) Provided concrete mix poured into a form and a screed board, as a member of a team, without the aid of references, level the concrete to ensure that all visual voids are filled and no humps or depressions are present per the reference. (1371.01.07b)

(9) Provided a mission and specifications, without the aid of references, state, orally, the types of concrete finishes per the references. (1471.01.08a)

(10) Provided concrete mix poured into a form and float, without the aid of references, float the concrete per the reference. (1371.01.08c)

(11) Provided concrete mix poured into a form and trowel, without the aid of references, trowel the concrete per the reference. (1371.01.08d)

(12) Provided concrete mix poured into a form and an edger, without the aid of references, edge the concrete per the reference. (1371.01.08e)

(13) Provided concrete mix poured into a form and jointer, without the aid of references, cut joints in the concrete per the reference. (1371.01.08f)

(14) Provided specifications, concrete mix poured into a form and broom, without the aid of references, broom the concrete (if required by specifications) to obtain a non-skid surface per the reference. (1371.01.08g)

(15)Provided specifications and concrete mix poured into a form, without the aid of references, cure the concrete to achieve the desired end state per the specifications and the reference. (1371.01.08h)

OUTLINE

1. CONCRETE

a. General: Concrete is artificial stone. It consists of a mass of fine and course materials known as aggregate, which are surrounded and held together by a hardened cement paste.

(1) It contains 7% to 14% cement. Cement mostly contains limestone.

(2) Concrete contains 15% to 20% water. The water causes a chemical action known as hydration, causing the concrete to harden and set.

(3) It contains 66% to 78% aggregate

b. Concrete as a building Material

(1) Advantages

(a) Economical, versatile and readily available.

(b) Can be easily handled and placed in forms and can be cast into any desired shape.

(c) Produces structures, which are lasting, pleasing in appearance, and require comparatively little maintenance.

(d) Concrete has a high degree of compressive strength. If placed correctly, it will support almost any weight.

(2) Disadvantages

(a) Concrete has a low tensile strength. Concrete pads, columns or foundations are subject to tensile stress must be reinforced with rebar or engineer stakes as available alternate.

(b) Concrete contracts and expands under various conditions of moisture and/or temperature.

(c) Concrete is porous to a degree and cannot be completely waterproofed. This is important in areas where the structure is exposed to freezing and thawing.

c. COMPONENTS OF CONCRETE

(1) CEMENT: There are 5 different types of cement. The type of cement you use is dependent on what the specifications are for your mission. Type I cement is the cement most commonly used.

(a) TYPE I NORMAL CEMENT

1 General purpose Portland cement

2 Suitable for most projects

a Paving

b Sidewalks

c Buildings

d Bridges

3 Prior to mixing, it must be stored in a watertight shed or building.

(2) AGGREGATE

(a) Aggregate consists of fine (sand) and course (gravel) materials. The difference between sand and gravel is determined by size.

1 Sand will pass through a 1/4" sieve, yet be retained on a #200 sieve.

2 Gravel will pass through a 3” sieve yet is too large to pass through a 1/4" sieve.

(b) Purpose of Aggregate

1 Aggregate is added as filler for strength and to cut down on expense.

2 It minimizes the shrinkage of concrete as it sets.

(c) Natural Sources of Aggregate

1 Stream and riverbanks: Finer aggregates will be washed downstream.

2 Alluvial fans and bars: This is where one stream or river enters into another, or a river enters into an ocean.

(d) Desirable Properties of Aggregate

1 Partially rounded. The smoother, rounder and more elongated the aggregate, the less paste required to cover each aggregate.

2 Hard. Concrete will set hard, but if the aggregate is weak it will collapse and affect the strength.

3 Durable. Hardened concrete is amazingly durable under constant heavy traffic. Poor quality aggregate will break down, reducing durability.

4 Well graded. The ideal aggregate should contain various size aggregate; the large particles will result in less cement used and smaller ones will fill the voids.

(3) WATER FOR MIXING CONCRETE

(a) Water is necessary to produce the hydration necessary to harden concrete.

(b) A good mix has 1/2 of its water for hydration and 1/2 for workability.

(c) The amount of water used in a mix is based on several factors, (i.e. moisture in the sand, desired strength, etc.). For best results, make a trial batch.

(d) Too much water will result in:

1 Loss of strength.

2 Loss of durability.

3 Lack of water tightness and leaks.

4 Cracks in cured concrete.

5 Excessive bleeding. (Water standing on the concrete.)

6 Dusting. Caused by cement at the surface that has dried on the concrete surface.

7 Long waiting time to finish.

(e) Too little water will result in:

1 A stiff mixture.

2 Concrete difficult to place and finish.

3 More time and more Marines required to finish the concrete.

(f) Water that is potable is most suitable.

1 It should be clean and free of oil, mud, sulfur, alkali and acid.

2 Salt water and sand found in water can be and is used in the construction of concrete.

a A reduction in strength will result.

b Use the following rule of thumb to determine the approximate loss of strength.

(1) Salt water only - 10% reduction in strength

(2) Salt water and salty sand - 20% reduction in strength

(4) REINFORCEMENT

(a) Although concrete is strong in compression, it is relatively weak in tension. But the reverse is true for slender steel bars. Therefore, when the two are materials are combined one make up the deficiency of the other.

(b) The design of a reinforced concrete structure consists mainly of predicting both the position and direction of potential tension cracks in concrete, and in preventing the cracks by locating sufficient reinforcing steel across their positions.

(c) Identification of steel

1 Deformed Steel Bars - Bars are available in 11 sizes designated by
numbers that range in size from 3/8 inch to about 2-1/4 inch in diameter.

2 Welded Wire Fabric - Its primary use is to control crack widths due to temperature changes.

a Used to prevent shrinkage cracks.

b Does not add reinforcement.

(d) Fabrication

1 Splicing - Because reinforcing bars are available only in certain lengths, you must splice them together for longer runs. If one bar is not long enough for the spans, never butt reinforcing bars. A common way to splice bars is to lap them.

a Principles.

(1) It is usually best to locate splices beyond the center of a beam.

(2) When possible, stagger the splices so that all of them do not fall at the same point.

b Methods.

(1) The Splicing Method is satisfactory when bar spacing is large, but do not use this method in a similar member having several closely spaced bares, or when the overlapping section interferes with the proper bar covering or form filling.

(2) Lapping bars in a horizontal plane is the most practical arrangement if the spacing provides enough clearance for aggregate to pass.

(3) Lapping bars in a vertical plane is used when the aggregate is too large for the horizontal plane method.

(4) Lap Welded Wire Fabric should be spliced and tied at one square plus 2 inches.

(c) Cut Reinforcing Steel with:

1 Bolt cutter

2 Hacksaw

3 Rebar Cutting Set

(d) Bending of bars - Hooks should be fabricated to meet dimensional requirements.

(e) Placement

1 Spacing is based on specifications. Check alignment and overlap.

2 There should be a minimum of 1 1/2 inches to 3 inches of clear space around the reinforcing steel depending on the of the size rebar used.

(f) Supports

1 All steel reinforcement must be accurately located in the forms and held firmly in place both before and during consolidation.

a Manufactured - High Chairs, Bolsters usually support the horizontal reinforcing bars and hold them in place during construction. Support horizontal bars at minimum intervals of 5 or 6 feet, and secure all bars to supports and other bars using tie wires not smaller than 18 gage. The twisted tie ends should project away from an interior surface.

b Field Expedient - Wire Fabric, Mortar Cubes

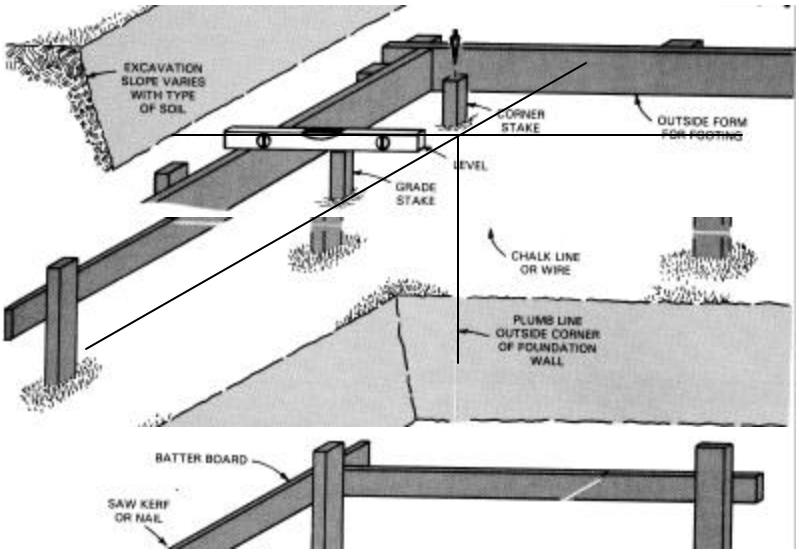
(1) Wire fabric is sometimes used to pre-assemble the reinforcing steel for concrete walls in place.

(2) Mortar cubes can be made from the mortar having the same consistency as the concrete, but without the coarse-aggregate. Spacer blocks are usually 1-1/2 inches to 4 inches square, varying in length as required. Cast tie wires into the blocks to secure them to the reinforcing bars.

2. CONCRETE FORMS

a. Layout: the first step in form construction.

(1) Batter Boards: A simple method using wood stakes, boards and string to identify the outside dimensions of the structure to be built. They are constructed using 2x4 stakes, with 1x3 boards nailed to them, to which a string is attached, as shown below



b. Site Preparation:

(1) Excavation: Footings and slabs should be placed on undisturbed soil having adequate load bearing capacity to support the designed structure and no vegetation. A footing must also be below the frost line.

c. Form Construction:

(1) Slab: The form is strong enough to hold the concrete. The form is made using 2X lumber, and Stakes will be placed every 2 to 4 ft as dictated by the size of the pour.

(1) Continuous wall foundations are constructed when heavy loads are to be carried, where the earth has low supporting strength and the structure is of permanent-type construction. Because of the time, labor, and material required to build them, this type of foundation is seldom used in the theater of operation.

(2) Forms must be Square, level, and straight. There are two methods to accomplish this:

(a) 3-4-5 Method: Using a Carpenters Square at the intersection of your sting lines. You measure three inches down from the corner on one line and 4 inches down the other line. Then measure the distance between these two Marks should be 5 inches.

(b) Diagonal Method: Measuring from one corner to the opposite corner, do the same between the other two corners and ensuring that the distance is the same between them. As shown below:

(2) Forms should be designed and constructed with some thoughts as to their removal without damaging the concrete.

(a) Ensure the face of the sheathing has a light coat of oil on it to keep the concrete from adhering to the form.

(b) Form nails (double headed) will be used, so they can be easily pulled out.

3. CONCRETE MIXING

a. Mixing by hand

(1) Ratio 1-2-3.

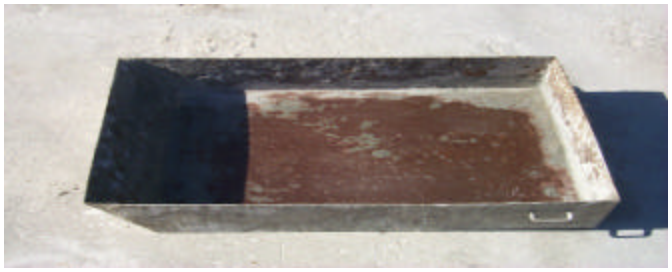
(a) One cubic foot of cement.

(b) Two cubic feet of sand.

(c) Three cubic feet of gravel.

(d) Measure the water with a 5 gallon bucket. And measure the dry ingredients by making a 1 cube and 2 cube box. The 2 cube box is shown below.

(2) Sand. Place a measured quantity of sand on a clean, watertight surface. A large mixing pan is shown below



(3) Cement. Spread the cement over the sand and mix it. Use a concrete hoe to mix one is pictured below

(4) Gravel. Add gravel to the dry materials a little at a time.

(5) Water is mixed with the dry materials a little at a time.

b. Mixing by machine. The Marine Corps has a machine designed to mix concrete, below are the characteristics of the mixer. Commercial units are also in use.

(1) 11S Mixer

(a) The 11s is a 4 wheeled, diesel engine driven, skip loaded concrete mixer with a capacity 11 cu. ft. The 11s mixer is equipped with a 12-gal water tank mounted on the top of the mixer. This water tank will allow a predetermined amount of water to be ejected into the drum.

(2) Commercial Mixers: Due to maintenance problems with the 11s Mixer a few Engineer units in the fleet are using various models of commercial mixers.

(3) Ready-mix: For large concrete projects, concrete may be purchased from a local cement company and the premixed concrete delivered by a ready mix truck(s). Timely delivery of enough concrete and placement of the concrete on large projects will require careful planning.

4. PLACE THE CONCRETE

a. To avoid segregation, place the concrete as near to its final position as possible.

c. Never allow concrete to free fall more than three feet.

b. In wall forms, place six to twelve inches of concrete along the entire form; then place a second layer on top of the first.

d. Consolidate the Concrete

(1) General: Done to prevent having rock pockets and air bubbles present and bring the fine materials to the surface for the desired finish. There are two methods that are used to consolidate Concrete.

(a) Vibration: This is the best method to use. A vibration attachment comes with the 250 cfm air compressor.

(b) By Hand: Known as Rodding the concrete. Using the a spade or puddling stick (rebar or broom handle), or various type of tampers.

(c) Whatever method is used to consolidate the Concrete pay particular attention around reinforcement materials, sides, and corners.

5. FINISH THE CONCRETE: Depending on the effect wanted, finishing might require many operations.

a. Screed the Concrete: Screeding is the process of attaining a preliminary surface level with the form without voids or excess.

(a) Begin screeding as soon as possible.

(b) Strike off the surface of the concrete by moving a straight edge (normally of 2" stock) back and forth with a saw-like motion across the top of the form. Keep a small amount of concrete ahead of the straight edge to fill in low spots and maintain a level surface. This is shown in the picture below.

(c) For efficient screeding, do not go beyond ten feet wide.

(d) In normal operations, screed the concrete a second time, to remove the surge of excess caused by the first screeding.

b. Floating: Floating is used to embed the large aggregate beneath the surface; to fill up the hollows and iron out the humps left after screeding. It gives an even, yet gritty, nonslip surface often desired for sidewalks, driveways, and some floors.

(1) Float the concrete immediately after screeding while the concrete is still plastic and workable.

(2) Do not overwork the concrete or you may bring an excess of water and fine aggregate to the surface.

(3) When a float finish is desired (sidewalk finish), float the surface a second time after it is partially hardened.

(4) Hand floats are made in two types 1-inch thick wood and Aluminum Magnesium. The Aluminum floats will give the concrete a much smoother finish. Below are pictures of Hand Floats

(5) Bull floats are used on large pads where the center can't be reached with a hand float. Below is a picture of a bull float.

b. Troweling: Troweling produces a smooth, hard, watertight surface.

(1) TROWEL: Steel hand trowels come in many different sizes.

(1) 10" to 20" long

(2) 3" to 4-3/4" wide

(2) The Troweling should begin after the water sheen has disappeared from the concrete surface and the concrete has hardened enough to prevent water and fine material from working to the surface.

(3) The Concrete has hardened enough to trowel it when thumb pressure barely dents the concrete surface.

(4) Troweling early or excessively can cause:

(a) Cracks

(b) Dusting

(c) Scaling

(5) Too long a delay before troweling results in a surface too hard to finish properly.

c. Brooming

(1) Brooming is using a hair broom on the concrete before it has partially cured, usually after floating and troweling to produce a nonskid surface.

(2) Whenever severe scoring is required, use a street broom.

(3) Draw the broom over the surface at a right angle to the direction of traffic.

d. Edging

(1) Produces a rounded edge on a slab or a wall to prevent chipping or damage to the edge and to improve appearance.

(2) After floating, run the edger back and forth until a finished edge is produced. An edger is shown below:

(3) If marks left by edger are not desirable, remove them by floating or troweling.

e. Jointing

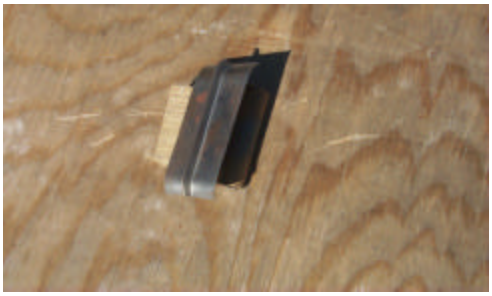
(1) Jointing is used to predetermine the location of any possible cracks caused by shrinkage or heaving of frozen ground. Joints are placed in sidewalks and driveways at intervals equal to the width. On large slabs place the joints at not more than 20 feet intervals.

(2) It consists of cutting a joint partially through fresh concrete.

(3) The resulting joints are called contraction or control joints.

(4) Begin jointing after floating.

(5) Lay a 2″x 4″ from form to form where the joint is to be to act as a straight edge. Run jointer along the edge to create a groove in the concrete. A jointer is pictured below:



(6) Remove marks left by the jointer, if not desirable, by floating or troweling.

f. Expansion joints

(1) Consist of both space and filler to permit expansion movement of concrete.

(2) Used in pavements and slabs less than 10" thick.

(3) Used when pouring a slab next to an existing one.

(4) Used at intersections and around all structures in contact with slab.

(5) Expansion joint filler

(a) Many different materials may be used as expansion joint fillers.

1 Building tarpaper triple folded

2 tar impregnated fiber board

3 Tar or mastic and shingles

4 1X lumber (least desirable)

6. CURE THE CONCRETE

a. Curing is the most important operation in the manufacture of good quality concrete. Curing consists of steps necessary to keep concrete moist and near 70 degrees, until it is strong enough to do the job for which it was intended.

b. Methods of curing

(1) Additional Moisture:

(a) Spraying. Spray water on the concrete surface either continuously or as often as necessary to keep it moist. Start as soon as the concrete has set enough that the spray will not mar the surface.

(b) Moist covering. Cover the surface with burlap, straw, sand, or earth and wet down the covering.

(2) Preventing Moisture loss

(a) Watertight covering. Use any watertight material to keep moisture in and the drying air out. (e.g. plastic, roofing paper, etc.)

(b) Curing Compounds. Slows the evaporation of moisture, it is sprayed directly on the surface of the concrete after final finish is applied.

c. Improper curing

(1) Never sprinkle dry cement or a cement-sand mixture on the concrete to absorb the water.

(2) Fine materials form a layer on the surface and are likely to cause dust or hair cracks when the concrete hardens.

7. FORM REMOVAL: It is generally advantageous to leave the forms in place throughout the required curing period. However, it may be necessary to strip forms as early as possible to permit their immediate reuse, therefore here are some steps to consider when removing forms;

a. Forms must not be removed until the concrete is strong enough to carry its own weight and any other loads that may be placed on it during construction.

b. The forms must be stripped carefully to avoid damage to the surface of the concrete.

REFERENCES:

FM 5-742	Concrete and Masonry
FM 5-426	Carpentry