OBJECTIVE SHEET

STRUCTURAL REPAIR 2

INTRODUCTION

Epoxy injection is one of the most widely used methods of structural repair in the construction industry. Epoxy adhesives are the most commonly used adhesives for crack repair, and are usually used through the injection process. Epoxies offer excellent adhesion properties because of relatively low shrinkage during curing, and are also attracted molecularly to a wide variety of substances. Structural composites or fiber wrapping is a technique being used in the repair of bridges, columns, beams, and slabs. Glass cloth, Kevlar, or even carbon fiber to which resin has been applied is wrapped around or attached to the surface. This technique has been very useful in not only repair, but in retrofitting to meet code changes.

FOCUS ASSIGNMENTS

FOCUS ASSIGNMENTS

1. Use the Internet or current publications to investigate types of injection equipment. Be sure you find information on manual, electric, and pneumatic systems.
2. Write a brief description of one of the systems and a situation in which it would be most appropriate for use.


Reading


Writing


Critical Thinking


Technology

UNIT OBJECTIVE

After completing this unit, you will show the following competencies by mastering the activities on the Assignment Sheet and Job Sheets and by scoring at least 85% on the Written Test.

SPECIFIC OBJECTIVES

1. State basic safety hazards concerning epoxy.
2. Identify types of repairs.
3. List conditions associated with cracks.
4. List considerations when evaluating a job site.
5. Identify types of seals.

6. Name types of ports.

7. List types of materials used for ports.

8. Name factors to consider when selecting a seal system.

9. Identify types of injection equipment.

10. Identify factors affecting the choice of epoxy.

11. Determine appropriate equipment and techniques to use in concrete repair. (Assignment Sheet).

12. Identify uses of fiber wrapping in concrete repair.

13. List materials used in fiber-wrapping repair.

14. List steps in the process of applying fiber wrapping.

15. Prepare a surface and seal a crack. (Job Sheet 1)

16. Install ports for the manifold injection system. (Job Sheet 2)

17. Inject a crack using the port-to-port method. (Job Sheet 3)

OBJECTIVE 1

State basic safety hazards concerning epoxy.

CAUTION: Review MSDS for characteristics of all materials before using them.

WORDS YOU SHOULD KNOW	
polymer	a relatively large molecule formed from smaller molecules made possible by the building reactions of simple units
solvent	a typically liquid substance in which another substance can dissolve
reactivity	the ability of two substances to interact

- **Fire** — All polymer products that contain solvents are flammable. The binder resins may also be flammable, especially in the liquid state.

  CAUTION: You must also be aware of the flash point of particular epoxies. This is defined as the temperature at which the vapor of a substance will ignite in the presence of flame.

  CAUTION: Air monitoring is very important when working in confined spaces especially when working with epoxies and solvents that are flammable.

- **Explosion** — an explosion can occur when the entire air vapor volume reacts simultaneously. If the volume of solvent vapor in the air is sufficient, a spark or flame may be enough to ignite the vapor, causing an explosion. Ventilation when using flammable substances is extremely important. See the terms below for a more complete description of explosive concerns.

  - ❏ Explosive range — the percentage of solvent vapor in the air at which an explosion will occur in the presence of a spark or flame. The explosive range is between the Lower Explosion Level (LEL) and the Upper Explosion Level (UEL).

- **Evaporation rate** — is the rate at which a material will vaporize (evaporate, change from liquid to vapor) compared to the rate of vaporation of a specific known material. This quantity is a ratio, therefore it is unitless.

  Evaporation rate can be useful in evaluating the health and fire hazards of a material. For example, a substance with a high evaporation rate will readily form a vapor which can be inhaled or explode.

  Evaporation rates generally have an inverse relationship to boiling points; i.e. the higher the boiling point, the lower the rate of evaporation.

  ✔ **NOTE:** Evaporation rates have advantages and disadvantages. For example, a low evaporation rate will result in a slower buildup of the explosive limit, but will also result in the epoxy staying wet longer, which increases flammability hazards.

  CAUTION: Always follow the Code of Federal Regulations for confined space standards in construction and general industry before conducting any inspections or performing work.

- **Solvent Vapor Density** — most solvents are heavier than air, which means that in an enclosed area they will concentrate in the lower portion of the space, potentially creating a zone of vapor above the explosive limit.

- **Reactivity** — epoxies can develop a substantial amount of heat when resin and hardener are mixed. Hardener and resin should not be left standing in any volume for extended periods. They should be stored separately when not being used.

- **Health hazards** — for proper health protection the proper protective equipment should always be used. It is essential to ventilate areas of application, store all chemicals properly, and allow only trained personnel to handle epoxies.

OBJECTIVE 2

Identify types of repairs.

WORDS YOU SHOULD KNOW	
adhesive	a substance capable of maintaining attachment between two or more surfaces
adherent	a body which is held to another by an adhesive
bonding agent	a substance applied to create a suitable bond between it and a succeeding layer

- **Rock pockets** — an area where paste did not consolidate around the aggregate at the time of concrete placement. (Figure 1)

FIGURE 1

- **Delamination** — this occurs when the adhesive properties of the bonding agent fail. A void is created when the adhesive and the adherent do not bond properly. (Figure 2)

FIGURE 2

Photo courtesy of Lily Corporation.

- **Rebar shadowing** — occurs when rebar is moved while the concrete has initial set but is still plastic, making the hole unnecessarily larger than the rebar itself.

- **Post-tension strand voids** — after stretching the cables within concrete to the correct tension, the ends are removed to a position within the concrete, creating voids on the exterior surface edges. These must be filled to avoid any structural damage over time.

OBJECTIVE 3

List conditions associated with cracks.

- **Wet** — water often finds its way into cracks in a variety of ways. It is important to remove all moisture from the cracks before injection.

- **Dirt** — wind and erosion are the most common reasons for dirt in cracks. Dirt must be removed before injecting any crack.

- **Painted surface** — some pumping systems create more pressure than certain types of paint can withstand. If this is the case, you will need to remove the paint from the affected area before epoxy injection.

- **Oil saturated** — concrete floors are the most typical place to find oil in cracks. Since concrete floors tend to absorb oils, substances such as motor oil can often be found in these cracks.

- **Hydrostatic head** (water flowing through the crack) — standing water against a wall or a structure creates pressure which can effectively infuse water into existing cracks or expand them.

OBJECTIVE 4

List considerations when evaluating a job site.

WORDS YOU SHOULD KNOW	
pot life	the working time after mixing during which a material may be used without difficulty
set	to convert an adhesive into a fixed or hardened state by chemical or physical action
creep	deformation of concrete as a result of a sustained load over a period of years
seal	material used to fill crack voids and protect cracks against further deterioration

- **Safety problems** — always evaluate the environment of the site for safety before any work proceeds. Foremost among the considerations should be the people in the area and the structural integrity of the concrete being repaired.

  ✔ **NOTE:** Always follow the safety precautions listed in Objective 1.

- **Public considerations** — noise, odor, traffic flow obstructions, and knowledge of the basic environment are all good examples of typical public considerations. There are many public considerations when evaluating a site, however most of them will depend on the specific site itself.

- **Containment** — when evaluating the site you need to be sure that the material to be injected can be contained in the spaces desired.

- **Crack width and depth** — crack width (Figure 3) and depth (Figure 4) should always be taken into account when evaluating a site. They should be evaluated based on their potential for current and future structural damage, considering load conditions. It is also important to consider crack width and depth when determining which methods of repair to use.

FIGURE 3

Photo courtesy of Lily Corporation.

FIGURE 4

Photo courtesy of Lily Corporation.

- **Choice of injection resin** — the choice of resin is a critical one, as it will affect the durability of repairs directly over time. Both the cured and uncured properties of the resin must be considered. Some considerations are structural properties (strengths, modulus, creep) and some are environmental (temperature, humidity, exposure). Many different

combinations of these qualities are possible, so it is important that the cement mason consider all of these qualities before making a resin selection.

- **Choice of seal** — the type of site you are working will always affect the type of seal you use. Factors to consider before choosing a seal include pressure, architectural finish, and environmental factors.

  EXAMPLE: if your job site is a historical building, you may need to consider appearance of the seal very carefully.

OBJECTIVE 5

Identify types of seals.

WORDS YOU SHOULD KNOW

cap/seal the material applied over a crack to contain an injection until it has cured

Photo courtesy of Lily Corporation.

- Cementitious mortar
- Rubber seal
- Decorative seal
- Fast setting
- Slower setting
- Temperature control

OBJECTIVE 6

Name types of ports.

WORDS YOU SHOULD KNOW	
port	the entry point where resin is injected into a void

- **Port/surface** — surface adapters are generally connected to the concrete surface with a hollow stem connected to a flat base. This method is preferred because it does not require drilling a hole. However, resin injection may be obstructed if debris from paint removal, grinding, or sanding has entered the fault. (Figure 5)

FIGURE 5

Photo courtesy of Lily Corporation.

- **Socket** — by drilling into concrete, an adapter known as a socket adapter can be used for resin injection. The hole created should be at least one inch deep and ½-inch in diameter. The sockets will usually be slightly larger. There are several different drilling methods to choose from, and impacted debris should always be considered when choosing a drilling method. (Figure 6)

FIGURE 6

Photo courtesy of Lily Corporation.

OBJECTIVE 7

List types of materials used for ports.

- Tape (Figure 7)

FIGURE 7

Photo courtesy of Lily Corporation.

- Tubes
- Pipe nipples
- Packer
- Straws
- Press-to-connect tube fittings (Figure 8)

FIGURE 8

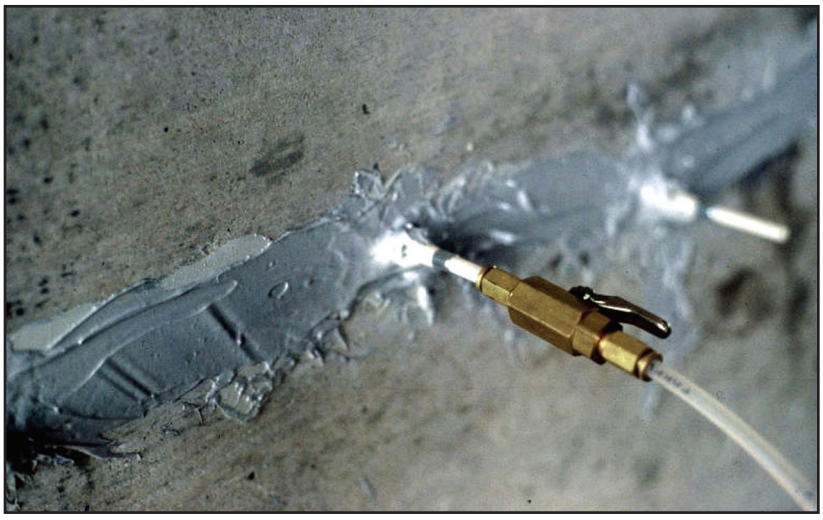


Photo courtesy of Lily Corporation.

OBJECTIVE 8

Name factors to consider when selecting a seal system.

- **Pressure of injection** — high pressure systems and low pressure systems are better suited for different circumstances. High pressure systems are more often used for deep, fine cracks while low pressure systems are preferable for surface treatments such as delaminations.
- **Surface conditions** — surface conditions such as moisture, grout, and dirt all affect the type of system that is preferred.
- **Cost** — the type of job and the budget will probably be the top considerations when determining acceptable costs.
- **Architectural appearance** — as noted in Objective 4, different types of buildings require different types of seal and seal systems. For example, a parking garage might call for an entirely different seal system than a museum.
- **Odor** — odor may be of no consideration in remote areas, while in urban areas they may affect the choice of seal system directly.
- **Slump pump** — a stepped process of crack injection when the backside of the concrete structure cannot be sealed (i.e. retaining walls, dams). Inject in normal fashion, wait for an initial set to take place (see pot life for estimate), re-inject to replace the material that has slumped out of the unsealed backside. Repeat until confident the crack is full.

OBJECTIVE 9

Identify types of injection equipment.

WORDS YOU SHOULD KNOW	
manifold	injection into numerous ports
injection	simultaneously

- **Manual** — a hand held gun for injecting epoxy. It may hold a cartridge of pre-mixed epoxy or use two containers that are mixed as they are dispensed. (Figure 9)

FIGURE 9

Photo courtesy of Lily Corporation.

- **Proportioning dispensers** — these dispensers are useful because of their ability to control and correct epoxy mixtures within the equipment itself. The mixture can thus be controlled without ceasing operations.

  - ❑ **Electric dispenser** — driven by electricity (Figure 10)

FIGURE 10

❑ **Pneumatic dispenser** — air powered (Figure 11)

FIGURE 11

Photo courtesy of Lily Corporation.

- **Single air-driven pump** — unlike proportioning dispensers, single component pumps can only deliver pre-mixed epoxy resin. They have low operating costs, but pre-mixing the epoxy resins leads to pot life concerns in some cases. (Figure 12)

FIGURE 12

Photo courtesy of Lily Corporation.

OBJECTIVE 10

Identify factors affecting the choice of epoxy.

- **Viscosity** — the thickness of a liquid or gel; its ability to flow, or resist flow. High viscosity substances are thick and do not flow easily, while low viscosity substances flow more easily. Typically, lower viscosity resins are used for small cracks. However, the strength of such resins must be considered before simply choosing the lowest viscosity available.

- **Size of crack** — the size of the crack to be repaired directly affects all other factors, such as cap, choice of epoxy, machine, etc. For example, a smaller crack may call for the use of a lower viscosity resin.

- **Ambient temperature** — this is the temperature of the surrounding air as opposed to the temperature of a substance or element. For example, not the temperature of the concrete, but the temperature of the air surrounding the concrete. Air temperatures directly influence the bonding properties of epoxy materials.

- **Concrete wetness** — ideally concrete should be completely dry at the time of injection. However, if that is not possible, wetness should be considered because it affects other factors such as viscosity and bonding.

- **Confinement/containment** — whenever using injecting equipment, always be sure to fully understand your surroundings before choosing an epoxy for use. The area of effect should always be under control, in other words confined and contained. Failure to control the area of effect can have unfortunate results.

- **Modulus** — The strength of the bond and material is an engineering consideration for the segments being bonded.

- **Pot life** — The set time of an epoxy can be a critical issue when considering depth of a crack ambient temperature or other factors that affect length of the operation.

OBJECTIVE 11

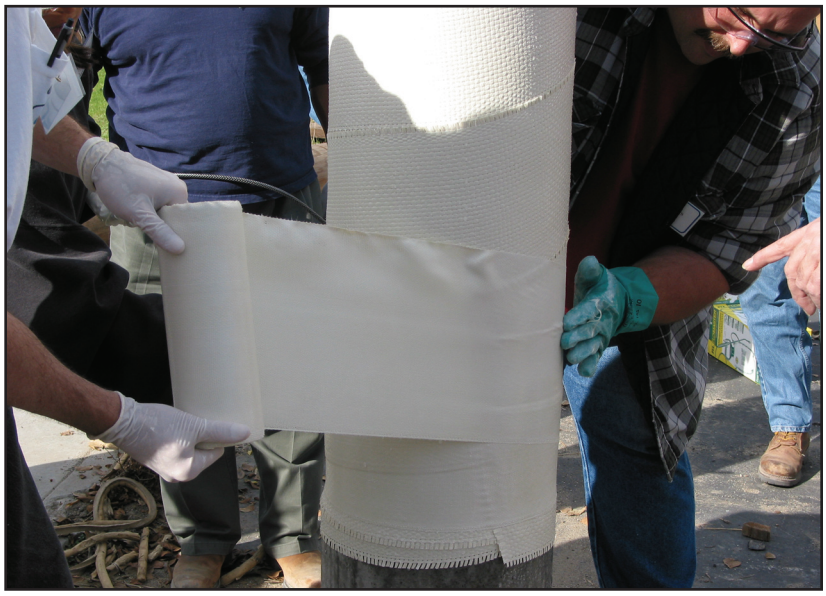
Complete the Assignment Sheet.

OBJECTIVE 12

Identify uses of fiber wrapping in concrete repair.

Structural composition fiber wrapping is a construction technique that can be used to significantly increase the strength of a variety of concrete and masonry structures. It comes in the form of a fabric that is bonded to the surface of the existing structures using specially developed epoxy, polyurethane, or polyesters. The fabric is generally made of carbon or glass fibers weaved together in a single or multiple directions. (Figure 13)

FIGURE 13



Fiber wrap is most commonly used in:

- Column repair
- Beam repair
- Wall repair
- Slab repair
- Un-reinforced masonry and block walls

  ✔ **NOTE:** A single layer of fiber wrapping, only 1/16 inch thick is equivalent to six-inch thick concrete with No.6 bars at 6-inch on center.

- Bridge repair
- Reinforcing
- Earthquake repair and reinforcing

- Code changes

  ✔ **NOTE:** Municipal code changes often require more strength in concrete structures than previously required. In this case, fiber wrapping can be used to upgrade the structure to code, eliminating the need for reconstruction.

OBJECTIVE 13

List materials used in fiber wrapping repair.

Safety Materials

✔ **NOTE:** Those involved in using epoxy compounds should always be well-informed of the characteristics and hazards of the particular materials they must handle. Materials Safety Data Sheets (MSDS) should be carefully reviewed and pertinent information should be passed on to each worker.

- Rubber gloves

- Disposable suit

  ✔ **NOTE:** Disposable suits and gloves, available from many suppliers of work garments, are suitable for this application. Gloves should be tested for resistance to resins and solvents. Disposable rubber or plastic gloves are recommended and should be discarded properly after each use.

- Safety glasses

  ✔ **NOTE:** Safety eyeglasses or goggles are strongly recommended when handling epoxy compounds. As with most chemicals, materials should be stored below eye level.

- Respiratory equipment

  ✔ **NOTE:** Work in a well-ventilated area. Careful attention should be paid to the work area's ventilation and respiratory protection should be considered if the area is not properly ventilated.

Materials

✔ **NOTE:** Materials may be dry and have resins applied either before or after being placed on the structure, or they may come preimpregnated with the resins.

- Glass cloth

- Kevlar

- Carbon Fiber

  ✔ **NOTE:** Carbon fiber is eight times more expensive than glass.

- Resins

Tools (Figure 14)

FIGURE 14

- Basic finishing tools (trowels)
- Rollers
- Squeegees

OBJECTIVE 14

List steps in the process of applying fiber wrapping.

1. Prepare Surface

✔ **NOTE:** The surface should be free from loose or unsound concrete. Sand- or waterblast the substrate to completely remove all coatings, paints, grease, oils, and other foreign materials. Repair all damaged concrete and fill uneven surfaces. The contact surface should be as dry as possible. All square corners should be rounded to a two-inch radius.

2. **Mix Epoxy**

   ✔ **NOTE:** Follow the mixing instructions listed in the product specifications.

3. **Apply fiber wrapping** (Figure 15)

   FIGURE 15

   ✔ **NOTE:** Refer to job specifications for instructions as to which direction fiber should be run, how many layers to apply, etc.

4. **Cure fiber wrapping**

   ✔ **NOTE:** Curing times and temperature for fiber wrapping must be maintained for the designated formulation used, according to the instructions supplied with the materials from manufacturer. The cured composite should have a uniform thickness and density, and lack porosity.

5. **Apply protective coating**

OBJECTIVE 15 **Complete Job Sheet 1.**

OBJECTIVE 16 **Complete Job Sheet 2.**

OBJECTIVE 17 **Complete Job Sheet 3.**

ASSIGNMENT SHEET

STRUCTURAL REPAIR 2

Name _____Score_____

OBJECTIVE 11

Determine appropriate equipment and techniques to use in concrete repair.

BASIC SKILLS


Critical Thinking


Employability


Technology

EQUIPMENT AND SUPPLIES

- Pen or pencil
- Paper

INSTRUCTIONS

Read the following scenarios and write a brief description of how you would approach the repair to each of the structures. Be sure to include appropriate equipment and techniques in your description.

1. You are called to repair cracks in a 250 feet x 250 feet slab, six inches thick constructed with standard rebar. You are able to drive right up to the site, however, there is no power. There are approximately 120 lineal feet of cracks ranging from 10 to 15 millimeters in width. It is a clean slab.

2. You are repairing the slab described above. In this case a building was constructed upon it and it has burned, leaving the cracks contaminated with dirt and ashes.

3. You are called to a museum to repair a small crack in a red granite wall.

4. You are called to repair a crack in a retaining wall 10 feet high and 8 inches thick with water running through the crack.

5. You are to repair a crack in the wall of an active office building. The wall is covered in plaster.

6. You are to repair a crack in the side of a manhole.

7. You are called to repair an overhead crack in an active parking garage.

8. You are called to repair a crack in the south retaining wall near an overpass. Temperatures range from 50 degrees in the morning to near 100 degrees in the late afternoon.

JOB SHEET 1

STRUCTURAL REPAIR 2

Name _____Score_____

OBJECTIVE 15

Prepare a surface and seal a crack.

BASIC SKILLS


Reading


Science


Critical Thinking


Employability

EQUIPMENT AND SUPPLIES

- Wire brush
- Hand tools for cleaning
- Water or cleaning solution
- Compressed air or neutralizing agent
- Seal components
- Mixing containers and equipment
- Personal protective equipment

✔ **NOTE:** Refer to CFR (Code of Federal Regulations) 1926 Construction Industry Safety and Health Regulations.

PROCEDURE

Yes No

❑ ❑ 1. Clean all surfaces to be capped. Make sure that all of these surfaces are sound and dry.

✔ **NOTE:** The surface should be free of frost, curing membranes, waterproofing treatments, and all other materials which may inhibit bonding. Usually a wire brush is the preferred method of cleaning.

❑ ❑ 2. Clean the cracks to be injected by vacuuming or flushing with water or a cleaning solution.

❑ ❑ 3. Flush the water or cleaning solution out of the crack with compressed air and a neutralizing agent if necessary.

✔ **NOTE:** If this option is not available, allow enough time for the cracks to air-dry.

Yes No

❑ ❑ 4. Install ports.

❑ ❑ 5. Batch the seal paste.

✔ **NOTE:** Batching to achieve high-modulus qualities requires measuring components by weight or volume to achieve good molecule linkage. Weight ratios are usually different than volumetric ratios.

❑ ❑ 6. Mix the seal paste.

✔ **NOTE:** Closely follow the resin supplier's recommendations for mixing procedures. For best results, mix the paste components in one container and then transfer them to another container for final mixing. Be careful not to contaminate either compound with the other. The components must be thoroughly mixed to prevent seal failure.

❑ ❑ 7. Apply the seal.

A. Apply the seal before the paste begins to stiffen.

B. Cover the entire length of the crack to be sealed. Carefully trowel epoxy around ports.

C. Avoid seal failure by keeping the components cool and spreading the paste to a maximum depth of ¼-inch immediately after mixing.

D. Be sure that the seal has properly bonded to the surface materials before injecting epoxy.

❑ ❑ 8. Have the instructor check your work.

❑ ❑ 9. Clean the work area and return tools and equipment to proper storage.

SKILL TEST RECORD

PRODUCT EVALUATION

Evaluator note: Rate the student on the following criteria by circling the appropriate numbers. Each criterion must receive a rating of "3" or higher to demonstrate student mastery. (See Key below.) A student who is unable to demonstrate mastery should review the material and submit another product for evaluation.

Criteria:

Safety	4	3	2	1
Use of tools	4	3	2	1
General appearance	4	3	2	1
Overall performance	4	3	2	1

AVERAGE RATING

Evaluator note: To obtain an average rating for the Profile of Training Mastery, total the points in Product Evaluation and divide by the total number of criteria. Circle the rating on the Key.

KEY

4 **Skilled** — Can perform job with no additional training
3 **Moderately Skilled** — Has performed job during training program; limited additional training may be required
2 **Limited Skill** — Has performed job during training program; additional training is required to develop skill
1 **Unskilled** — Is familiar with process, but is unable to perform job

EVALUATOR'S COMMENTS

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JOB SHEET 2

STRUCTURAL REPAIR 2

Name _____Score_____

OBJECTIVE 16

Install ports for a manifold injection system.

BASIC SKILLS


Reading


Critical Thinking


Employability

EQUIPMENT AND SUPPLIES

- Wire brush
- Hand tools for cleaning
- Water or cleaning solution
- Compressed air or neutralizing agent
- Seal components
- Mixing containers and equipment
- Insertion ports, surface adapters, or socket ports
- Personal protective equipment

✔ **NOTE:** Refer to CFR (Code of Federal Regulations) 1926 Construction Industry Safety and Health Regulations.

PROCEDURE

Yes No

❑ ❑ 1. Follow the procedures listed in Job Sheet 1 to prepare the surface for porting.

❑ ❑ 2. Select the best type of port for your work area. (See Objective 6)

❑ ❑ 3. Locate the ports.

A. Port spacing is influenced by the width of the crack, required injection pressure, and the viscosity of the resin.

B. Ports should be placed as far apart as possible to decrease costs, and not closer than 8 inches apart.

✔ **NOTE:** Positioning adapters to allow maximum resin flow into the void is more important than exact spacing.

C. Remember that narrower sections of a crack fill more quickly.

❑ ❑ 4. Install the ports.

✔ **NOTE:** When installing surface ports be careful to center ports on the crack. When applying epoxy to the base of the port be sure not to seal the hole at the center of the base.

SKILL TEST RECORD

PRODUCT EVALUATION

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EVALUATOR'S COMMENTS

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JOB SHEET 3

STRUCTURAL REPAIR 2

Name _____Score_____

OBJECTIVE 17

Inject a crack using the port-to-port method.

BASIC SKILLS


Reading


Critical Thinking


Employability


Technology

EQUIPMENT AND SUPPLIES

- Measuring equipment
- Porting equipment
- Seal
- Epoxy components
- Injecting equipment
- Personal protective equipment

✔ **NOTE:** Refer to CFR (Code of Federal Regulations) 1926 Construction Industry Safety and Health Regulations.

PROCEDURE

Yes No

❑ ❑ 1. Select a porting method.

❑ ❑ 2. Install the ports.

✔ **NOTE:** Ports should be spaced the thickness of the wall away from each other.

❑ ❑ 3. Install the surface seal.

❑ ❑ 4. Let the seal cure adequately.

PROCEDURE

Yes No

❑ ❑ 1. Perform a pressure/ratio test of the injection equipment.

❑ ❑ 2. Inject the crack until refusal.

A. The injection should be started at the lowest port.

B. Continue the injection until the next adjacent port is reached.

✔ **NOTE:** Monitor the epoxy consumption and use common sense.

C. Seal the first port and continue the process until the injection is complete.

D. Allow the epoxy to harden.

❑ ❑ 3. Remove the ports and seal.

❑ ❑ 4. Finish to specifications.

❑ ❑ 5. Clean and put away all equipment and supplies.

SKILL TEST RECORD

PRODUCT EVALUATION

Evaluator note: Rate the student on the following criteria by circling the appropriate numbers. Each criterion must receive a rating of "3" or higher to demonstrate student mastery. (See Key below.) A student who is unable to demonstrate mastery should review the material and submit another product for evaluation.

Criteria:

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General appearance	4	3	2	1
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AVERAGE RATING

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EVALUATOR'S COMMENTS

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_____