Continuing Education Course #242
What Every Engineer Should Know
About Reinforcement Corrosion in Concrete Highway Bridges

1. Of the approximately 600,000 bridges with spans of 20-feet or more in the U.S., this percentage was judged in 2014 by the Federal Highway Administration (FHWA) to be structurally deficient:
- a. 3%
- b. 15%
- c. 10%
- d. 20%

2. A 2001 FWHA report estimated that the direct cost of corrosion-induced damage to U.S. bridges was $8.3 billion. The indirect cost of this damage was estimated as:
- a. About the same
- b. Up to10 times as much
- c. 5 times as much
- d. About have as much

3. Among traditional rebar and concrete plus prestressed concrete U.S. bridges, larger numbers of structurally deficient (SD) bridges exist in:
- a. The southern and far western states
- b. The northeastern and far western states
- c. The northeastern and Midwestern states
- d. The southern and Midwestern states

4. The electrolyte in a corrosion cell during active corrosion of steel in concrete:
- a. Is able to be ionized
- b. Is the anode
- c. Prohibits ion movement
- d. Prohibits electron movement

5. During corrosion of bare steel reinforcement in concrete, the following statement is true:
- a. The oxidation reaction occurs at the cathode
- b. The reduction reaction occurs at the anode
- c. The oxidation and reduction reactions occur at different rates
- d. Electrical DC flows from the steel surface at a rate directly proportional to the rate of corrosion

6. The four essential “components” necessary for corrosion of bare steel reinforcement in concrete are:
- a. Anodic sites, cathodic sites, a metallic path between the two sites (the steel) and the electrolyte (through which DC moves via ions)
- b. Flowing electrical AC, a high pH concrete, a cathodic corrosion potential and the steel
- c. Flowing electrical DC, a rapid anodic reaction, a slow cathodic reaction and the steel

○ d. Low pH concrete, equal rates of anodic and cathodic reactions, poor quality steel and poor quality control during casting of the concrete

7. Small cracks in the concrete immediately around corroded steel rebar are formed due to:
○ a. Highly alkaline (high pH) concrete
○ b. An undesirably low w/c ratio in the concrete mix
○ c. Hydroxyl ions produced by the corrosion
○ d. The wedging action caused by the large volume of hydrated iron oxide corrosion products

8. Embedded steel corrosion by carbonation occurs:
○ a. Primarily because CO_2 gas diffuses into the concrete and mixes with water there
○ b. Only on bonded, post-stressed strands
○ c. Most commonly on rural highway bridges
○ d. Primarily because the amount of water in the concrete is minimal

9. Corrosion of coated structural steel freely exposed to the atmosphere in the superstructure of a bridge might occur due to all of the following factors with the <u>likely exception</u> of this one:
○ a. Poor surface preparation was used prior to applying the coating
○ b. The bridge is located in a fully, sun-shaded area most of the day
○ c. Poor design details were used, e.g., many unsealed crevices existed
○ d. The bridge is located in a heavy industrial area with many acid gases in the atmosphere

10. Weathering steels used in the superstructures of structural steel bridges instead of regular coated steel resist corrosion:
○ a. Best in areas where there is heavy use of deicing salts on the highways
○ b. Because their chemical compositions with copper and other elements permit a protective patina to form and become stable with time
○ c. Because they are more corrosion resistant compared to regular coated steels in all environments
○ d. Best when local conditions permit them to remain wet most of the time

11. Bridges with pre-tensioned concrete reinforcement include:
○ a. Traditional rebar steel that is galvanized
○ b. High strength steel strands inside grout-filled ducts
○ c. High strength steel strands directly exposed to and bonding with the concrete
○ d. Fabrication of concrete members at the job site

12. In the bonded, post-tensioned reinforcement bridge configuration, a void can be generated in the grout if:
○ a. Poor quality grout is used and “bleeding” occurs
○ b. Traditional rebar is used
○ c. The concrete’s w/c ratio is too low
○ d. The concrete’s outer surface is not properly sealed

13. Two well-known factors that minimize corrosion of steel reinforcement in the traditional rebar configuration of structural members are:
○ a. Use of chemical corrosion inhibitors and a high w/c ratio in the concrete
○ b. Use of stainless steel rebar and a high w/c ratio
○ c. Specifying a low w/c ratio for the concrete and a minimum concrete cover thickness (and not less) that are used
○ d. Use of epoxy coated rebar on the outer mat of rebar and bare steel on the second mat further into the concrete

14. Superplasticizers are a type of admixture used with concrete in order to:

○ a. Interact with the anodic corrosion reaction and decrease the rate of attack
○ b. Interact with the cathodic corrosion reaction and decrease the rate of attack
○ c. Increase the flow ability of a low w/c ratio concrete
○ d. Permit the use of a high w/c ratio concrete

15. Hydrogen embrittlement of the steel used for prestressed construction, either pre or post-tensioned, may occur if:
○ a. Molecular hydrogen, H_2 embrittles the strands
○ b. The steel's strength is too low
○ c. Atomic hydrogen, H^0, generated by the acid pickling process prior to galvanizing enters the steel and that galvanized steel is used in the application
○ d. The steel is exposed to "bleed" water from the concrete

16. The electrical resistivity of concrete indicates the capacity for corrosion of steel reinforcement to occur. Therefore the following is true:
○ a. Resistivity data, independent of other factors, always indicate whether or not active corrosion is occurring
○ b. Measured resistivity values are directly proportional to the rate of corrosion occurring
○ c. Most admixtures in concrete decrease its resistivity and thus decrease the rate of corrosion
○ d. Measured resistivity values are inversely proportional to the rate of corrosion that may occur

17. Measuring meaningful corrosion potential values of embedded steel in concrete requires that:
○ a. The concrete cover thickness be 4-inches or more
○ b. A reference electrode, such as a copper–copper sulfate type, and a high impedance multimeter are used
○ c. The steel have an epoxy coating
○ d. The concrete's resistivity value is high

18. ASTM C876 that applies to measurements of the corrosion potential of steel in concrete states that:
○ a. All embedded rebar must be electrically continuous
○ b. A six inch distance between adjacent measurement locations must be maintained
○ c. The concrete must be thoroughly dry
○ d. Reference electrodes should be re-calibrated before every fifth corrosion potential survey

19. The best use of corrosion potential surveys for assessing the possibility of corrosion of embedded steel is accomplished by:
○ a. Using the measured values to establish real time corrosion rates
○ b. Completing multiple corrosion potential surveys on a regular repeating cycle and looking for trends over time
○ c. Emphasizing this assessment technique with little attention to other evaluation methods
○ d. Using a technician that is certified as qualified for this work by the ACI to complete the surveys

20. A restraining issue in attempting to measure the rate of corrosion of embedded steel in real time is that:
○ a. Lab measurements done prior to field work do not provide reliable results
○ b. There is no electrochemical measuring technique that is typically used
○ c. It is difficult to establish the specific surface area of the embedded steel being measured in the field and that value must be used in the necessary calculation of corrosion rate
○ d. Every state DOT uses a different measuring technique in their regular attempts to obtain rate data but there is no agreement on which method is most reliable

21. A remedial plan of action for an existing bridge that has known or suspected damage from corrosion should always:
○ a. Follow the standardized remedial plan established by the ACI for all bridges
○ b. Use a team of persons with the specific knowledge and experience needed
○ c. Limit the number of possible assessment techniques to current structural integrity evaluations
○ d. Understand that most repair actions will provide long-term mitigation of corrosion

22. ECE and ER remediation techniques for concrete bridges have all of the following characteristics except:

- a. They involve the application of direct electrical current to the embedded steel
- b. They lower the concentration of chloride ions and raise the concrete's pH, respectively
- c. They provide long-term (up to about 40 years) resistance to corrosion
- d. If not well controlled, they may cause hydrogen embrittlement of the high strength steel used in the pre-tensioned category of prestressed construction

23. The ER technique is generally effective in minimizing this form of corrosion-induced damage to bare steel reinforcement:

- a. Carbonation
- b. The concrete is too alkaline, i.e., its pH is too high
- c. The depth of concrete cover over the steel is too large
- d. Corrosion is being caused by voids formed in the concrete due to 'bleeding" of concrete used with traditional rebar construction

24. Comparison of the sacrificial anode CP method to impressed current CP (ICCP) indicates that:

- a. The sacrificial anode variety has higher initial and higher monitoring costs than ICCP
- b. ICCP can provide an adjustable output of voltage and thus current to the steel
- c. ICCP can only be accomplished with one type of anode
- d. The sacrificial anode method can function with a wide variety of anodes

25. In performing discounted life-cycle cost analyses it is frequently true that establishing this vital input information is the most difficult to define :

- a. The proper interest rate to use in defining the discount factors
- b. If an engineer or a finance person should independently complete the analysis
- c. When the several possible future costs will occur
- d. The proper rate of inflation that will apply to future costs