Chapter 1
Introduction

1-1. Purpose

This engineer technical letter (ETL) provides basic information and references on background, evaluation, and design of fiber-reinforced plastic (FRP) materials to assist structural design engineers who are considering the use of FRP on civil works projects. This information will help the engineer evaluate the suitability of FRP materials for structural applications, and will be useful in preparing performance specifications for procurement of suitable composite components and structures.

1-2. Applicability

This ETL applies to HQUSACE elements and USACE commands having responsibilities for the design of civil works projects.

1-3. References

Required and related references are listed in Appendix A.

1-4. Discussion

a. Applications. FRP composite materials are becoming more affordable and more widely used in consumer products, industrial applications, and construction. For example, many gratings, handrails, and storage tanks are currently made from FRP materials. Applications investigated and used by the Corps of Engineers are described in Appendix B. FRP composites offer potential advantages in weight, strength, and corrosion resistance. These must be balanced against the possibility of higher initial cost and lower stiffness and other differences in material behavior, when compared to more traditional materials. Much of the basic information necessary for an initial evaluation of composites as an alternative material for civil engineering applications is provided herein. Engineers considering use of composites should review the information provided and that in the referenced publications. Since composites technology is evolving rapidly, engineers should also review the latest literature. As technology and applications evolve, additional Corps of Engineers guidance will be developed for use of FRP materials.

b. Standards. Currently, there are no national consensus standards for design of composites; however, there are many military specifications and American Society for Testing and Materials (ASTM) standards concerning FRP materials. These provide minimum requirements for various fibers and resins, for some processed composite materials, and for testing of material coupons to obtain basic material properties. Development has started on an ASTM standard for FRP composites for use as concrete reinforcement. Final properties of FRP are more dependent on the production process than some other materials. Properties of FRP are also dependent on the thickness, because surface materials experience a different processing environment than the interior materials. For these reasons, designers must be careful when specifying materials requirements. Because of the lack of design standards, procurement of FRP components will usually be based on a performance specification, possibly including verification testing.

1-5. Background

a. Composite materials, as discussed herein, refer to fiber/matrix combinations such as fiberglass/epoxy and are commonly referred to as fiber-reinforced plastics (FRP). This ETL is intended for use by design engineers who are considering the use of composite materials on civil engineering projects. Structural applications are the primary focus of the ETL.

b. This ETL identifies potential advantages of using FRP. It lists applications where composites may be suitable for use on Corps of Engineers projects. It presents background on the development and use of FRP. It includes data on the properties and behavior of selected component materials and several generic fiber/matrix combinations. A key element of this ETL is the list of references (Appendix A), which a designer must consult to obtain detailed information.

c. Composite materials take advantage of a combination of materials with different properties to result in a designed material with desired overall properties. Civil engineers have been using more traditional composites for years. These include laminated wood, reinforced concrete, and steel/concrete bridge girders. These materials have gained wide acceptance and have proven performance. FRP composites are currently gaining wider acceptance in civil engineering applications as they are proving to be effective on numerous demonstration projects.

d. Civil engineers are accustomed to using consensus design standards such as building codes and steel and concrete design codes. Similar standards for composites are not yet available. Therefore, designers cannot use a traditional civil/structural design approach when designing with FRP. This ETL provides some of the information required to develop a performance specification for procurement of suitable FRP components and structures. Quality assurance is more critical in the design, production, and construction process for FRP than for steel or concrete. This is true for several reasons. Designers and contractors have less experience with these materials; there is less extensive performance history; failure mechanisms for infrastructure applications are not yet thoroughly researched; there is a much greater choice of materials and properties; final properties are dependent on the production process; and the anisotropic properties of FRP require unique design considerations. This ETL provides information on appropriate quality assurance methods during the design and construction process.

1-6. Scope

a. Applications.

(1) Nonstructural applications. Composite materials may be used in appropriate nonstructural applications. This includes the purchase and use of existing commercial products.

(2) Secondary structural applications. When composite materials offer cost or performance advantages, they may be used for secondary structural applications. Generally such applications should be relatively small, inexpensive, and easily replaceable. Examples of such applications include handrails, grating, ladders, light posts, large pipes, small gates, and minor temperature reinforcement in thin concrete sections. Components such as these may be included in construction contracts as performance specified items, to be designed and certified by the supplier. The performance specification should identify the functional requirements, exposure conditions, durability requirements, and any restrictions on material selection. Generally, the designer should specify generic products based on consultations with several potential suppliers to determine the availability and suitability of products for such applications.

(3) Critical structural applications. Composite materials shall not be used for critical structural elements except in consultation with and as approved by CECW-E. This includes any application where failure of the composite would significantly impact life safety, or the overall structural integrity or function of the project. Examples include large gates or hybrid girders of wood/FRP or concrete/FRP. Since there are no national design codes for composite materials, each design is unique and will require special studies and design procedures, and possibly special contracting methods. This will require the involvement of suppliers, contractors, designers, and reviewers during development of the design. The project management plan should include appropriate funds and schedule for this special design effort, including appropriate expert consultation. A reliable quality assurance plan is essential for design, fabrication, and erection. To ensure acceptability of the final product, specific verification, testing, and monitoring requirements should be developed.

b. Procurement specification.

(1) Design requirements. The performance specification, along with the contract drawings, must clearly identify the following requirements for any FRP component: (a) size and shape limits, (b) strength or loading, (c) durability under given exposure conditions for a given length of time, (d) restrictions on material selection, (e) reference standards for materials and testing, and (f) design factors of safety. Because of potential property variations, design factors of safety should be relatively large. An example of a performance specification is provided in Appendix C.

(2) Design quality assurance. Due to the lack of consensus design standards, each supplier may have a unique approach to design of FRP components and structures. Generally, this approach will be based on previous test data for similar materials and joint configurations. It is critical that the supplier submit the assumptions and methods used for design, including the appropriate test results, so that the Corps can ensure there is an adequate technical basis for the design. These test results should include data from durability testing under appropriate environments to ensure long-term adequacy, and the basis for extrapolating short-term or accelerated testing results to predict long-term behavior.

(3) Fabrication quality assurance. Since FRP properties are very dependent on processing parameters, it may also be appropriate to perform verification testing on actual materials produced for the contract. For nonstructural or for secondary structural applications, quality assurance may usually be limited to a manufacturer's certification that specified shapes, materials, properties, or strengths have been provided. For critical structural applications, the design engineer must develop a more thorough quality assurance plan, sufficient to verify the adequacy of the FRP in terms of life safety or overall project function. This plan must include coupon tests of materials and connections, or verification tests of

completed structures. In addition, once the FRP has been placed in service, there should be a plan to monitor performance at appropriate intervals. The level of detail of the testing and inspection program should be adjusted to conform to the complexity and degree of importance of the FRP application. The designer should rely on an expert consultant for assistance in developing an adequate quality assurance plan for critical applications.