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Composites: from Theory to Practical Applications

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Introduction

Composites are already widely used in aerospace and sport industry and they are getting to be accepted more and more in various fields of civil engineering. This is due to the good properties of the material, such as high strength to weight ratio and corrosion resistance.

Designers working with traditional materials face problems which are well explored in engineering. However, designers working with composites must face new, surprising challenges, and must apply the knowledge of several fields of science and engineering to avoid undesired behavior during the service of composite structures. In this lecture we will address these questions through four practical examples.

Strengthening of masonry walls by FRP

Historic unreinforced masonry structures are widespread all over the world. A great number of historic, valuable masonry structures are located in seismically active regions such as the Mediterranean, California, or Japan. Unreinforced masonry structures are vulnerable to earthquakes, hence they must be strengthened. FRP is an excellent candidate for reinforcing, because it is easy to use (as a "wall-paper"), and has high tensile strength. A model for designing FRP strengthened masonry structures are presented in [1, 2]. In the application special attention must be paid to the fact that composites are brittle, not ductile, and, in addition, the design is much stronger influenced by the "details", than usual.

Retaining walls

Economic retaining walls may be built with the aid of reinforcing strips. These are placed perpendicular to the wall and applied in a uniform pattern to strengthen the soil and reduce the earth pressure. One end of each strip is attached to the wall and the other end is anchoraged in the soil. The first walls were built with steel strips, which may be sensitive to the corrosive environment of the soil.

To avoid this shortcoming a large amount of retaining walls were built using GFRP strips in the last decade. However, designers did not pay attention to two important differences between steel and FRP.

Steel is an elastic-plastic material, but composites are perfectly elastic until failure, and exhibit *brittle behavior*. Designers of steel and reinforced concrete rely, in many cases, on the plasticity of the materials: moments are redistributed, plastic hinges are assumed, etc. This is not valid for composites. For example, in some cases the uneven settlement of the soil caused brittle failure of composite strips and the fall of the retaining wall.

Steel is sensitive to the "deicing salt" and to acids, but alkaline environment may protect steel from corrosion. However, glass fiber reinforced composites are not alkaline resistant. In the case of retaining walls the GFRP were intensively investigated for the acid environment of the soil, but not for the alkaline environment close to the concrete wall. This second error lead to the failure of some walls which survived the settlement of the soil.

Fiber optic sensors

To measure strains in composite materials fiber optic sensors seem to be advantageous: we must change only one of the fibers to an optical one, and the strains at several locations along the optical fiber can be measured at the same time. However, the measurement is influenced by the strain in the fiber direction, as well as by the other strain components and the temperature [3]. Do we really know what we are measuring? What are the limitations of the measurement? We will give an answer for these questions in the lecture.

Designing of alpine skis

In alpine skis a core is sandwiched between the FRP layers. In the "optimal" design the geometrical properties (length, width, thickness, sidecut, and camber), the layup (construction), and the material can be varied. It is known that the ski must be tailored according to the skier's ability and according to the skiing conditions (snow, path, and speed).

Consequently, in the design of skis, we must consider not only the mechanics of the ski, but the ski-snow interaction and the skier dynamics as well. In the talk we will face this challenge [4, 5], and show how can we come up with an optimum design.

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