Polymer Composites as Construction Materials

Application Summary Sheet 1

Title: Composite Piles

Target Audience: Geotechnical engineers, marine engineers and architects.

Keywords: piles, jetties, poles, recycled, marine works, durability, sheet piling

Overview of application:

Composite plastic/GRP reinforced piles can be used for marine applications such as quays, dolphins, jetties etc., as an alternative to driven timber, steel and reinforced concrete.

Although composite plastic piles do not have a long track record for use in civil engineering, their use can overcome problems with corrosion of steel and marine borer attack in timber piles. There are also environmental concerns over the use of creosote and Copper Chrome Arsenic treated timber in water. Composite piles have been used successfully in a number of large waterfront developments in North America.

Seapiles (TM) by Seaward International Inc. are made from 100% post-consumer recycled HDPE, coextruded with fiberglass or steel rods for strength. The piling has a high-density outer skin 5 mm thick and a lower-density foamed core. The standard product is 330mm in diameter and up to 32 m long, with eight 25 mm thick reinforcing rods. A square product called Seatimber(TM) for horizontal applications such as cross beams and fenders is also produced. Seapiles have been used by Hampshire County Council on the Hamble River, serving as channel markers. The piles were manufactured with green and red co-extruded outer skins, obviating the need to re-paint timber piles.

Marker Pile

Creative Pultrusions Inc produce a circular section pile plus a composite sheet pile for bank protection and retaining walls etc.

Hardcore Composites produce large-diameter FRP monopiles in diameters up to 8 feet (2.4m) and continuous lengths in excess of 100 feet (30m), as alternative to multiple groups of timber piles, for higher loads and structural applications. The piles can be driven by standard impact, vibratory or jetting methods, either open-ended or with a driving shoe. Similarly with tubular steel piles, after installation they can be filled with concrete.

Review of alternative/existing technology and potential market:

Timber, in particular, has been the favoured material for marine works because of its ability to absorb impacts, its ease of handling over water, and the poor performance, historically, of cast iron, steel and reinforced concrete. Untreated timbers are liable to attack by marine borers, around the British Isles principally the mollusc *Teredo* (the shipworm) and crustacean *Limnoria* (the gribble) leading to severe weakening. Although tropical hardwood timbers such as greenheart, ekki, balau, kauri and jarrah are resistant to marine borers, these timbers are not available with FSC certification. Creosoted Baltic pine was formerly used extensively, however several European countries have imposed a ban on the treatment method. Creosoted timber is also restricted for use in waterways in several American States. Freshly creosoted timber tends to cause the formation of an oil sheen on the surface of the water. Copper Chrome Arsenic (CCA) treated Douglas fir is also suitable for marine works. Although CCA is being replaced as a timber treatment by a non arsenic and chromium formulations for many applications such as garden fencing in the UK, it can still be used for industrial applications such as marine piles. In USA and Canada southern pine is used extensively and timber piles are considered the mainstay of foundation engineering. In Canada alone over 30,000 cubic metres of treated wood piling is produced annually. In Austrailia turpentine is the favoured timber for both marine and on shore piles.

Contrast with UK situation:

Tropical hardwoods from sustainable certified sources are still favoured for marine works in the UK, mainly due to their resistance to abrasion and also when replacing like with like on a structure with historical significance. Timber is very infrequently used for on shore works today as a piling material, although prior to 1900 many buildings were placed on timber piles (eg Old London Bridge). In softer ground on-shore, pre-cast concrete sectional piles and continuous flight auger piling is mainly used. Large marine structures in the UK tend to be founded on pre-cast concrete piles with well-protected steel or non-ferrous reinforcement. Steel can be coated with plastic or resin to provide corrosion resistance, or alternatively designed with service life and corrosion rates in mind. The uptake of a GRP/composite pile for lighter marine works such as marinas and on sensitive freshwater sites is likely to be significant.

FRP piles may find be used with timber for pier decking, boardwalks, handrails etc. on the grounds of its aesthetic appeal over plastic.
Hollow FRP piles can be filled with concrete.

Impact of Application

Financial:

Higher initial costs but lower through-life costs through improved durability (resistance to marine borers and corrosion)
Non-degrading
Low inspection costs in service

Environmental:

Some types of pile utilise recycled plastics
Non-toxic in use, no leeching of timber preservatives (such as creosote or CCA/copper chrome arsenic into seawater)
Creosoted timber also presents an environmental disposal problem
Alternative to tropical hardwood from rainforests
Note that softwood timber piles can also be produced in a sustainable manner on plantations.
FRP sheet piling offers alternative to steel (high energy costs associated with steel manufacture)

Engineering:

Lightweight - easy to handle over water
Flexible - avoids damage to ships
Durable - imperious to marine borers and corrosion resistant
Abrasion resistant
Easy to drill and fix on site.
Drivability of composite piling may limit applications, although for hollow section piles driving using an internal drop hammer onto a robust shoe or concrete plug would be possible.

Robustness:

Products fully tested with numerous examples in service.

Future developments:

On shore piling, in particular for corrosive soils (eg high sulphate content, acid/alkali or free carbon dioxide).
Short driven foundation piles for structures (including composite bridges), where ground conditions appropriate.
Higher capacity loadbearing piles, particularly as replacement for groups of timber piles (already developed)
Composite timber/GRP jacketed piles
Marine defences such as groynes

Where to get further information:

Products:

Seapiles by Seaward International, Inc. http://www.buoys.com/seapile.htm

Sheet piling and Fender Piles by Creative Pultrusions Inc.
http://www.pultrude.com/pfender.htm
http://www.pultrude.com/mmarine.htm

FRP Monopile by Hardcore Composites
http://www.hardcorecomposites.com/marine.html

Applications:

http://www.buildinggreen.com/products/pilings.html

"Monopile replaces multiple timber piles" Composites Technology Mar/Apr 2000 p8.   www.compositestech.com

"The US Navy Currently spends £40-50 million annually replacing treated wood structures" source = Reinforced plastics June 2002

Review paper:

State of the practice review in FRP Composite Piling
Iskander, M. G., Hassan, M., (1998) Journal of Composites in Construction ASCE, 2(3) 116-120

Abstract: There are considerable problems associated with the use of traditional piling materials in corrosive soils and marine environments. The durability of concrete, corrosion of steel, and vulnerability of timber piles to marine borers are serious hindrances to construction in these environments. In the case of timber marine piling, the toxic chemicals used in their treatment, such as creosote, pose a threat to marine life. Creosote-treated timber is also a growing environmental disposal problem. Composite materials such as fibre-reinforced polymers (FRP) can offer performance advantages when compared to steel, concrete, or timber. Composites can be designed to perform according to the required specifications for piling in adverse environments. However, composites face obstacles because they do not have a long track record of use in civil engineering structures. A comprehensive review of the American experience in research, testing, design, and practice of composite piles is presented in this paper. The technical and economical viability of composite piles is discussed. Emphasis is given to material properties, durability, drivability, and soil-pile interaction.

Research:

Composite fender and sheet piles in marine front systems

Mayer, M.H., et al. (1996) Proc. Fibre Composites in Infrastructure, Dept Civil Eng Mech, University of Arizona, Tucson 665-675.

Abstract: This paper reports on the progress of an ongoing research at Rutgers University on the modelling and testing of composite plastic fender and sheet piles in marine environments. The use of composite plastic materials eliminate the problem of attack by marine organisms, and the environmental consequences of creosote treatment of timber piles. The interaction of composite piling system with soil is investigated in the study by conducting a comprehensive analytical/experimental program. The paper reports on the analytical modelling of pile and sheet pile interaction with soil under different loading conditions. The analysis takes into account soil non-linearity and its effect on soil-pile interaction. Important issues such as depth of penetration, point of fixity and general deformation characteristics of composite piles are presented.

Driveability of Glass FRP Composite Piling

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Journal of Composites for Construction, Vol 5, No.1, February 2001, pp. 58-60

Abstract: The low impedance of some glass fibre-reinforced polymer (GFRP) composite piles may limit their usefulness as bearing piles for structures due to drivability limitations. The high strength of glass fibers used in their manufacture makes the necessary pile cross-sectional area similar to that of a comparable steel pipe pile, while the compression wave velocity and mass density are much closer to that of concrete. This results in a very low impedance and limits the ability of the GFRP piles to be driven to high bearing capacities. A comparison of the drivability of four composite piles to conventional steel and concrete piles shows that all of the piles reviewed can be reasonably expected to attain design bearing capacities of 400 kN, but that the extremely low impedance of glass fiber-reinforced matrix composite piles limits the ultimate capacity that can be achieved through impact driving.

Load-Deflection response of transversely isotropic piles under lateral loads Han, J. and Frost J.D. (2000) Int. J. Numer. Anal.Meth.Geomech. 24:509-529

Review: The paper discusses the effect of the assumption that pile materials such as FRP, timber and reinforced concrete are isotropic and presents solutions based on Timoshenko Beam Theory to derive deflections. If the effect of shear deformation is neglected on these transverse anisotropic materials, pile deflections will be higher than anticipated.

Accelerated degradation of recycled plastic piling in aggressive soils
Hassan M, Iskander M G (2001)
Journal of Composites in Construction vol 5 issue 3 pp 179-187

This paper presents the preliminary results of an experimental study conducted to assess the durability of piling made of recycled plastics in aggressive soils. An accelerated testing protocol permitting prediction of the behaviour of plastic piles was developed. Specimens were exposed to solutions with fixed acidic, basic, and neutral pH at elevated temperatures. Compressive strength was used as an index to quantify the degradation of the specimens.

Cross references:

Heinz, R. (1993) **Plastic Piling** Civil Engineering , Apr. 63-65 (review of composite plastic/steel piles for marine structures with examples)