



# FUGRO PILE DRIVING MONITORING SERVICES

**Pile Driving Monitoring is the best and most economic way to ensure a safe and successful installation of foundation piles and monopiles both in marine and land environments.**

Dynamic pile driving monitoring (PDM) and high strain dynamic loading have been used for testing offshore and onshore piles for several decades. Whereas most testing measures hammer performance and pile stresses, Fugro’s approach focuses on delivering accurate pile capacities and estimates of soil resistance during driving as part of a geoconsulting approach to site characterisation.

## SERVICES

FUGRO performs PDM tests during driving on pilot or production piles, taking advantage of the high strain impact provided by the driving hammer. Force and velocity sensors are mounted near the pile top and we record the reflected waves to evaluate the soil response along the shaft

and at the tip. We often also recommend re-strike tests to evaluate the long term capacity of the pile.

## FIELD APPLICATIONS

- Control in real-time of the driving stresses to prevent pile damage and propose optimized driving sequences.
- Evaluation of pile capacity using the signal matching method (CAPWAP®) to validate or re-evaluate the design capacity.
- Use of recorded data and subsequent geotechnical assessment to better characterise the dynamic and static response of the soil and refine pile design and hammer selection through an adjusted wave equation model (GRL-WEAP®).



*PDM services are of use for offshore wind jackets and monopiles*

# SERVICE FLYER



## OPERATIONS

Fugro installs strain and accelerometer sensors directly on site, which avoids affecting the installation planning. Standard piles are equipped with two strain gauges and two accelerometers located below the hammer sleeve whereas this quantity is doubled for very large diameter monopiles. Sensors are connected to a remote data acquisition monitor via wifi or connection cable. The monitoring kit can be waterproofed allowing the monitoring of underwater pile installation.

The PDM instrumentation can also be implemented on conductor pipes, cast in-place piles, piles driven with a follower and sheet piles, both in a marine and land environment. Fugro's team has the operational and engineering experience to adapt the services to meet the Client's objectives.

## DATA PROCESSING

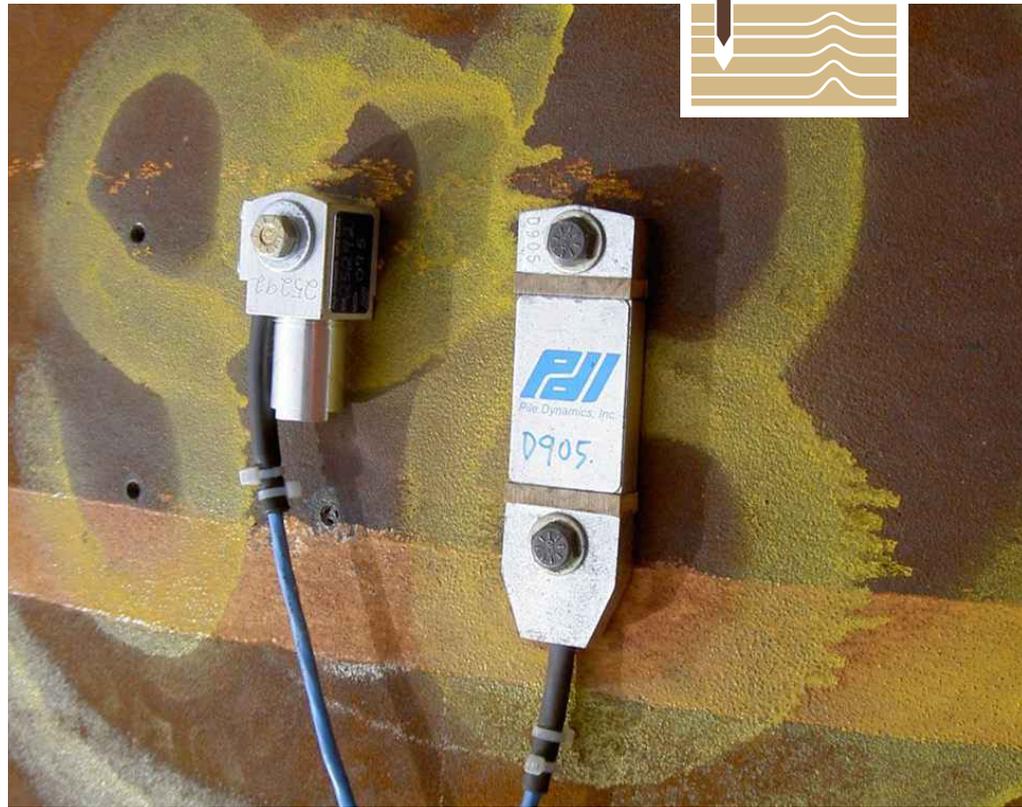
During driving, the PDM acquisition monitor records and displays in real time:

- The maximum compressive and tensile stresses in the pile, the tension envelope and an estimate of the stress at the pile tip;
- An estimate of the pile capacity during driving using the CASE method;
- The actual energy received by the pile (ENTHRU) to evaluate the hammer efficiency;
- The set per blow and number of blows per increment of penetration.

At the end of the driving sequence, the force and velocity data of one or several hammer blows are analysed using the rigorous "signal matching" program (CASE Pile Wave Analysis Program or "CAPWAP<sup>®</sup>") to extract wave equation-like soil model results, including soil resistance distribution along the shaft and at the toe and the dynamic resistance parameters. CAPWAP<sup>®</sup> has demonstrated good correlation with static load tests. Signal matching is considered "state-of-practice"

ask@fugro.com

**WWW.FUGRO.COM**



Strain and accelerometer sensors installed on a steel pipe pile (bolted type).

and many codes require this CAPWAP<sup>®</sup> signal matching for the final capacity evaluation.

Results of the CAPWAP<sup>®</sup> analyses are used on site to support our Client in validating the foundation capacity as well as evaluating the pile's long term capacity when a re-strike test is performed.

## BUILDING EXPERIENCE FOR 20 YEARS

Pile monitoring data form a very valuable component of overall site characterisation knowledge. The accurate characterisation of the soil dynamic resistance to driving and its ability to develop static resistance with time allows for refining future pile and soil design. Accurate GRL-WEAP<sup>®</sup> models, where CAPWAP<sup>®</sup> results have been integrated, will allow for optimised hammer selection and driving sequences to reduce the installation time, and risk of refusal.

Over the last 20 years Fugro has gathered pile monitoring data and CAPWAP analyses worldwide, with a strong offshore experience. Its geotechnical experts provide state-of-the-art consultancy services to help our Clients reduce the risk of pile installation and to improve significantly the geotechnical site characterisation of the area.



Marine application of pile monitoring services for tubular steel piles of a four-legged jacket.



Refined GRL-WEAP<sup>®</sup> Modelling using soil parameters from PDM test results.



Marine application of pile monitoring services for large diameter monopiles.