ABSTRACT
Grouted steel-cement-steel connections have been used successfully for many decades in the offshore industry. Typical applications are grouting of an offshore pile within a pile sleeve for support of subsea or jacket structures. Such connections are dominated by simple compressive and shear load transfer at the steel boundary via welded shear connectors or well beads on the steel boundary surfaces. The length diameter ratio for such joints have generally been larger than 7. Grouting has also been used for large piles drilled into rock. For lateral loading a length diameter ratio down to 2.5 has been used. The grout used has been simple cement systems. Recent years there has been an increasing use of dynamically loaded grout connections for structures such as offshore windfarms and for sleeve/shaft connections on fixed offshore structures in the oil and gas industry. In general the grout joints have done their jobs. But there are examples of unforeseen behaviour. For instance, slip surfaces have been observed resulting in axial displacements between grout and steel. In more extreme cases gaps have occurred in the grout annulus. The typical length/diameter ratio for these connections is 1.5. Examples of this type of connections and the typical sealing systems are presented in this paper.

It is shown that if the stress flow is completely through the grout in a grout joint exposed to bending then there will invariably be created tension stresses, which may debond from the steel surfaces and cause cracks. This can lead to sliding between grout and steel. The cracks may develop further and the grout may ground down to aggregate and pulverized cement. As long as the pulverized grout is confined it will still transfer stresses. If unconfined, for instance due to a detachment of the grout packer, these cracks will further develop and eventually the joint will lose strength. Proposals for strong grout packers are presented.

KEY WORDS: grouted connections; monopile; monotower platforms; offshore windfarms; structural FEM analysis.

INTRODUCTION
In recent years more demanding applications for grouted steel-cement-steel connections have been developed compared with the traditional connections for pile jackets. The connections are now being used for foundation design in the offshore oil and gas as well as in the offshore windfarm industry. The grouted connection has the advantage to take care of installation problems relating to fabrication tolerances; however there are some drawbacks due to differences in material property grout/steel and also degradation of grout compounds. The development of these structural connections is relying on use of modern high strength grout compounds. The applications are mainly for cylindrical shaft-sleeve connections where the grouted annulus transfers the main axial and bending loads from the topside structure to the foundation. The new type of connections generally has a short length/diameter ratio around 1.5-2.5 and no shear keys or weld beads are applied.

The transverse loads and deflections are generally of a cyclic nature, therefore more demanding than traditional grouted connections such as grouted offshore jacket piles or cemented offshore well conductor/casing systems where load is predominantly axial. Various work has been carried out for structural evaluation of the new type of grouted connections. In the present paper a brief presentation of typical connections is given, the layout of steel-grout interface and the confinement systems used are described. Some experience based on knowledge today is presented and discussed to the extent that the information is in the open domain. Various structural FEM analyses of typical composite steel-cement-steel system are presented and discussed especially considering the different material/elastic properties of steel and grout. Factors such as grout adhesion, geometrical tolerances, end effects and mechanical grout break down are considered. Finally, some possible improvements of existing methods and alternative designs are proposed.

TYPICAL DESIGN OF GROUTED CONNECTIONS
The typical application is to use the grouted connection for fixation of a super structure (topside structure) to a foundation placed or driven into the seabed. Below typical examples are presented.

Example 1, Driven monopile foundation for offshore windturbine
The monopile foundation is driven into the seabed by a hydraulic hammer. A transition piece is landed on top of the pile and supported