DMS® 3D PLUS: a new automatic in-place instrument for geotechnical multiparametric monitoring

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SUMMARY: The paper deals with the new DMS® 3D PLUS in-column monitoring system developed from the experience of the DMS® 2D lines and DMS® 3D MP (C.S.G. S.r.l. patents). The DMS® 2D monitoring columns are mainly intended for x, y displacement monitoring of landslides and slope stability problems and they are installed inside cased boreholes; the DMS® 3D MP columns, on the other hand, are mainly intended for geotechnical monitoring in engineering works and they are installed directly in contact with the uncased borehole through the expansion of special packers (x, y, z displacement monitoring). The DMS® 3D PLUS was born from the necessity of having an instrument able to measure also the z displacement in active landslides, being moreover fully compatible with the DMS® 2D columns (in mechanical, electronic, hardware and software elements). The instrument, through a special telescopic case controlled by a linear displacement transducer, can measure in addition to the typical parameters of the 2D lines (x,y displacement, 3D acceleration, pore water pressure, temperature, etc.) also the z component as the DMS® 3D MP, with the addition of thin layer packers having anchoring and hydraulic seal functions. DMS® 3D PLUS can work inside boreholes specifically conditioned with extenso-assestimetric casing.

KEYWORDS: geotechnical monitoring, multiparametric monitoring, settlement monitoring, landslides, slope stability, DMS.

1 INTRODUCTION

DMS® (acronym of Differential Monitoring of Stability) is an automatic in-place multiparametric geotecnical monitoring system for stability monitoring of landslide, cuttings and engineering works, patented and produced by C.S.G. S.r.l. company.

DMS® 2D and 3D technology allows to monitor more parameters with the same apparatus

(multisensor module) and to connect easily one apparatus to the other one to form very extended columns, which constitute an instrument of site-specific continuous monitoring able to detect real deformations, movements, settlements, pore pressures, etc. of soil or rock mass in which they are installed (Giuffredi et al 2003, Lovisolo et al. 2003).

The paper illustrates the features of the new DMS® 3D PLUS in-column monitoring system, specifically developed to meet the need to have an instrument able to measure also the z component of displacement in active landslide, where are required very deep boreholes subjected to significant deformations, fully compatible with the DMS® 2D columns (in mechanical, electronic, hardware and software elements).

2 DMS® 3D PLUS INNOVATIONS

The new DMS® 3D PLUS was born from the experience learned by C.S.G. S.r.l. in geotechnical monitoring with the multiparametric DMS® 2D and DMS® 3D lines with the aim of monitoring the stability conditions of active landslides and areas subject to subsidence.

Specifically, DMS® 2D columns, which are installed inside cased boreholes, are mainly used to monitor landslides and slope stability measuring displacements in the x, y plane. These instruments are made of hard tubolar stainless steel (inox AISI 304/316L) elements which contain sensors, control electronic and digital communication, connected each other by flexible high resistance joints in reinforced rubber and centered inside the borehole casing using specific polyurethan centralizers (Figure 1).

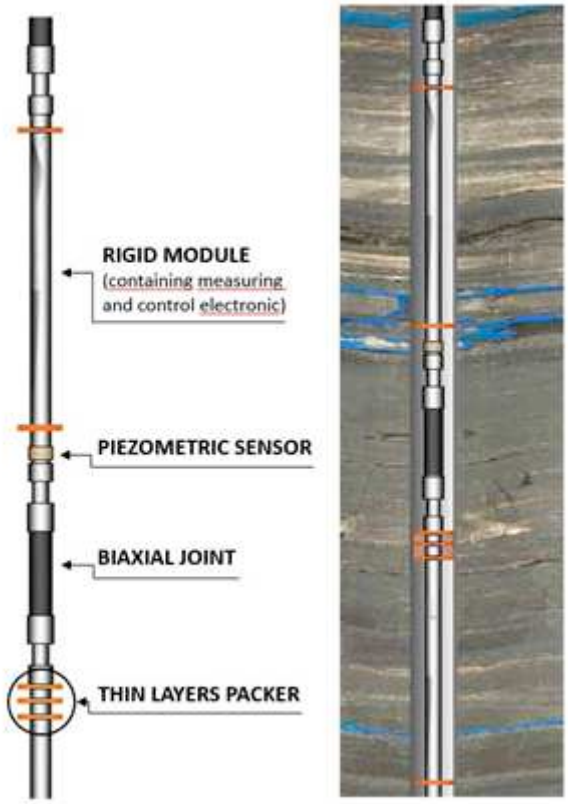

Figure 1. DMS® 2D column in cased borehole.

Each module is equipped with one or more of the following sensors: biaxial inclinometric sensor, piezometric sensor, temperature sensor, triaxial accelerometric sensor, digital compass. The DMS® 2D module length is 1 m; it comes from the need to have sufficient discretization of the vertical of investigation combining, at the same time, to the need to limit the propagation of measurement errors (Foglino et al. 2015).

DMS® 3D MP columns, installed directly in uncased borehole in contact with the ground or the rock, are instead intended for monitoring geotechnical parameters in combination with geotechnical engineering works (monitoring x, y, z displacements). These instruments are made up of rigid elements in 304 or 316L stainless steel to protect measurement and control electronics and digital communication, connected to each other by triaxial joints and constrained to the soil with the expansion of special packer against borehole (Figure 2).

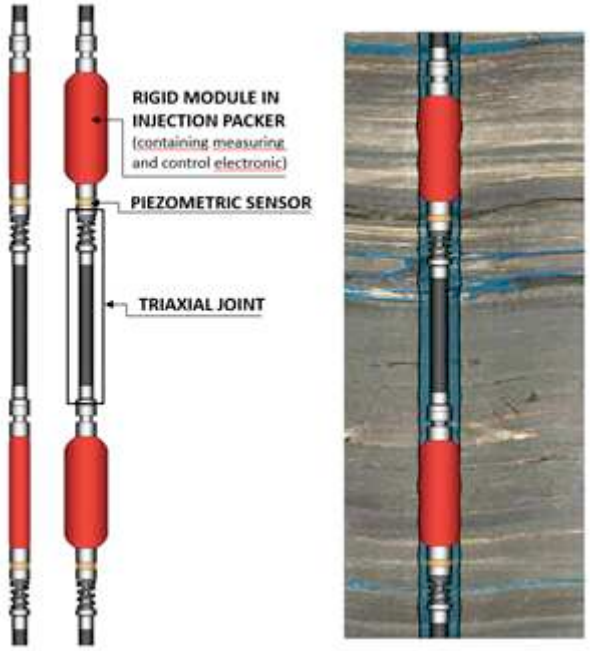

Figure 2. DMS® 3D MP in the uncased borehole.

Compared to DMS® 2D columns, the 3D modules are also equipped with a linear displacement transducer sensor for measuring displacements along the z axis.

The measurement of the displacement along the z axis takes place thanks to the constraint generated by the expansion of the packers against the walls of the uncased borehole that allows the column to lengthen or shorten following the behavior of the ground in which it is installed.

Due to the mechanical complexity of the instrumentation, specifically designed for local monitoring of the structure-soil interaction, the optimal measurement step is 1.5 m (module length).

The DMS® 3D PLUS monitoring system is an innovative instrument that allows to perform, automatically and continuously inside the same borehole, measurements of displacements along the x, y and z axes, variations of groundwater levels, accelerations, temperature. DMS® 3D PLUS is the missing link between the DMS® 2D series (specific for cased boreholes) and the DMS® 3D MP (specific for uncased boreholes) and is particularly suitable for monitoring kinematics of deep landslides where continuous monitoring of the "z" component is also required. Unlike DMS® 3D MP, DMS® 3D PLUS is fully compatible with DMS® 2D lines. This feature allows to monitor the movements along the z axis even only in some sections of the vertical of investigation where there are particular geological formations or geotechnical conditions, keeping the biaxial inclinometric measurement continuous along the entire borehole, with a consequent monitoring optimization and reduction of costs.

3 DMS® 3D PLUS MAIN FEATURES

The instrument, through a special telescopic case controlled by a linear displacement transducer, allows to measure, in addition to the usual parameters of the 2D lines (x-y displacement, temperature, acceleration, groundwater level, etc.), also the displacement along the z axis, such as

the DMS® 3D MP, with the combination of thin layers packers. In particular, the AISI 304 or 316L stainless steel telescopic module contains the sensors, the control electronics and the digital communication, while the bidirectional joint is similar to that of the 2D systems (Figure 3).

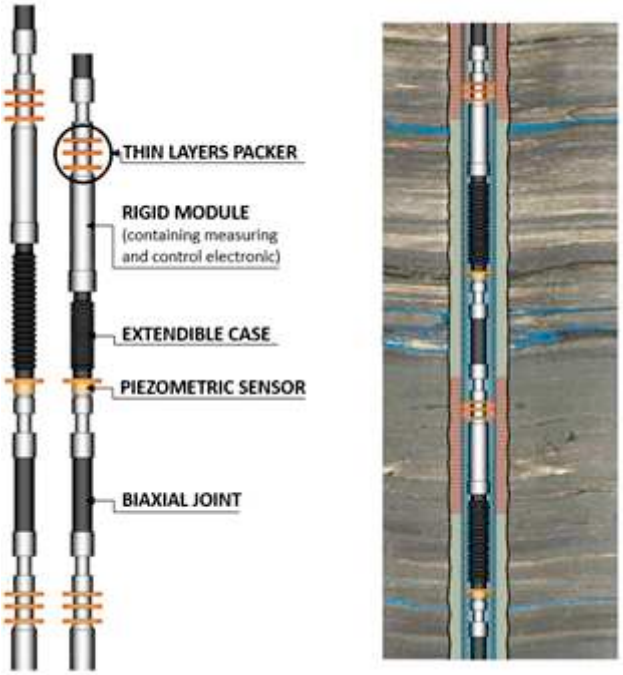

Figure 3. DMS® 3D PLUS.

The thin layers packers, made up of suitably sized polyurethane discs loaded with bentonite clay, produce the necessary constraints between the instrument and the casing in order to measure the possible lengthening/shortening of the casing directly related to soil movements; the thin layers packers can also perform the function of separation between different creeks. The DMS® 3D PLUS columns are generally installed in boreholes specifically conditioned with casing having extenso-assestimetric characteristics; if necessary in relation to the conditions of the monitoring site, they can also be installed in uncased boreholes. Like the DMS® 2D lines, the measurement step of this instrument is 1 m.

The standard production has the following characteristics:

- Telescopic module length = 0.90 ÷ 1 m
- Telescopic stroke = 100 mm
- Inclinometric sensor: range ±20°/±45°, resolution 0.001°
- Piezometric sensor: range 100/250 psi, resolution 0.02 psi
- Extensometric sensor: range 0-100 mm, resolution 0.01 mm
- Digital compass: range 0-360°, resolution 1°azimuth
- Accelerometric sensor: range ±2 g
- Temperature sensor: range -50°/+130°C, resolution 0.1°C

4 BOREHOLE, DRILLING AND CASING FEATURES

For the execution of exteso-assestimetric measurements, the borehole must be adequately prepared and conditioned to allow the natural development of the deformations in the x, y, z directions without altering the equilibrium of the acting forces. For this purpose, particular attention is recommended during the various boring phases.

Drilling should be made by continuous coring with core drill minimum diameter 114 mm and lining minimum diameter 127 mm maximum 152 mm; drilling diameters should be anyway

function of the external diameter of the casing chosen for the final conditioning that can vary from 2 "1/2 to 3". It is recommended to use the same drilling diameter when crossing the soft layer.

This type of measurement is carried out inside cased boreholes and so it's essential that the casing has got the suitable characteristics and that it is correctly installed in the borehole.

The DMS® PLUS columns are designed to work best with special single-wall corrugated pipes (INOX 304, 316L, 316T, HDPE, PVC). It can also be used traditional 3" inclinometric pipes connected to each other with telescopic sleeves or 3" piezometric pipes equipped with telescopic joints. In these cases the measurement of the displacements along the "z" axis will refer to the interval between a telescopic joint and the next one.

It will be necessary an accurate measure of the position of the telescopic sleeves/joints to correctly install the instrumentation with the telescopic parts at the same level of the telescopic sleeves/joints.

Using special flexible corrugated pipes the monitoring along the "z" axis is certainly more detailed: the casing can interact entirely with the ground and the movement measurement is not constrained to the position of the telescopic sleeves. In addition, this type of pipe, according to the particular corrugated structure of the wall, has good qualities of crush strength and flexibility (Figure 4).

Figure 4. Installation of corrugated pipe.

For the absence of reference grooves, the use of this pipe is not allowed for the execution of inclinometric measures with the traditional probes, while it is perfectly compatible for the DMS® series that, thanks to the special anti-rotational joints, maintain the mechanical alignment of the axes even without grooves (Foglino et al. 2015, Lovisolo & Della Giusta 2005).

5 CONCLUSION

The DMS® multi-parametric columns with DMS® 3D PLUS modules allow the detection

continuously, automatically and in real time of x, y and z displacements and other important parameters simultaneously along the entire vertical of investigation.

Local settlements along a vertical survey can be successfully monitored with the use of DMS® 3D PLUS columns to be installed inside boreholes equipped with corrugated or telescopic pipes able to copy the ground deformations. The new instrument provides the detection of another one important parameter for the comprehension of the kinematics of instability in addition to x-y displacements, groundwater levels, accelerations, temperature. The correlation between different parameters at the same time in the same borehole is important for the identification of risk scenarios and the validation of geotechnical models and also to support the technicians in Early Warning decision-making phases (Blikra et al. 2013).

The DMS® 3D PLUS main features of modularity and mechanical, electronic, hardware and software compatibility with the DMS® 2D columns make it usable in landslides, in mining or in civil engineering works even up to high depths of investigation.

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