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Evidence of gas formation and venting in organic soils: experimental evidence and modelling approach

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Peatlands have been recognised to provide a natural carbon sink thanks to waterlogged conditions, which keep summertime temperatures relatively low, increase their water holding capacity, decrease the organic soil decomposition rate by creating anoxic conditions and eventually keeping high water table. However, unfavourable environmental conditions due to increasing temperatures and more frequent droughts will reduce water retention of peats and the summertime insulation, in turn increasing their temperature sensitivity and their decomposition rate [1]. As a result, peatlands may start inverting their positive cycle and emitting greenhouse gases, including CO_2 and CH_4 [2], which suggests better investigating how increasing climate stresses will affect the efficiency of peats in the greenhouse gases cycle and CO_2 sequestration.

Some evidence of gas production from increasing decomposition rate in the Netherlands is coming from continuous pore pressure measurements in saturated layers below the water table, which are monitored to assess the safety of the water defence and the transportation infrastructures. Increasing water pressure in closed piezometers compared to vented ones seem to suggest that gas is produced and capped in the ground, until the breakthrough pressure is reached and the gas vents from cracks opened in the soil matrix. Besides the environmental issues, increasing gas production from decomposition is becoming of concern for the stability of embankments made of organic soils, where the effective stress may be lowered to such an extent to endanger their stability. As a matter of fact, in the last ten years, gas overpressure has been claimed to be a triggering or a contributing factor in few small failures experienced by regional dykes in the Netherlands. In spite of the evidence [e.g. 3] and the risk increasing with heat waves and drought events, the role of gas on the coupled hydromechanical response of organic soils has been seldom investigated nor properly understood yet.

In the section of Geoengineering at TU Delft, a research effort has been undertaken in the last years to investigate in depth the role of gas formation and venting on the coupled hydro-mechanical response of organic layers in the subsoil of water defence embankments. Preliminary laboratory tests performed on peats to fill this gap showed the role of increasing gas content on their compressibility and on the mobilised shear strength at given strains [4, 5]. The volumetric response of peats including gas was tentatively interpreted with a simple non-linear elastic model, which proved able to model the experimental results [6].

A similar model was used to numerically investigate the relevance of gas production and venting on the response of a regional dyke in the Netherlands, where gas bubbles from venting were observed after excavating - unloading - the toe of the dyke during a stress test. Fully coupled three-phases hydromechanical numerical analyses were performed with CODE_Bright [7] to include gas overpressure. A gas content of 6% in volume was artificially generated in the peat layer, capped by a clay layer on top, and let reaching an equilibrium distribution, which depends on the stress-strain response of the different layers and their volumetric compressibility (Figure 1(a)). Gas venting is triggered by simulating excavation at the toe of the dyke, which allows gas escaping after the capping clay is removed.

The variation in the operative stress, on which stiffness and strength are assumed to depend [6], is shown in Figure 1(b) over gas generation and venting. In spite of the small amount of gas generated, the predicted overpressure is enough to bring the operative

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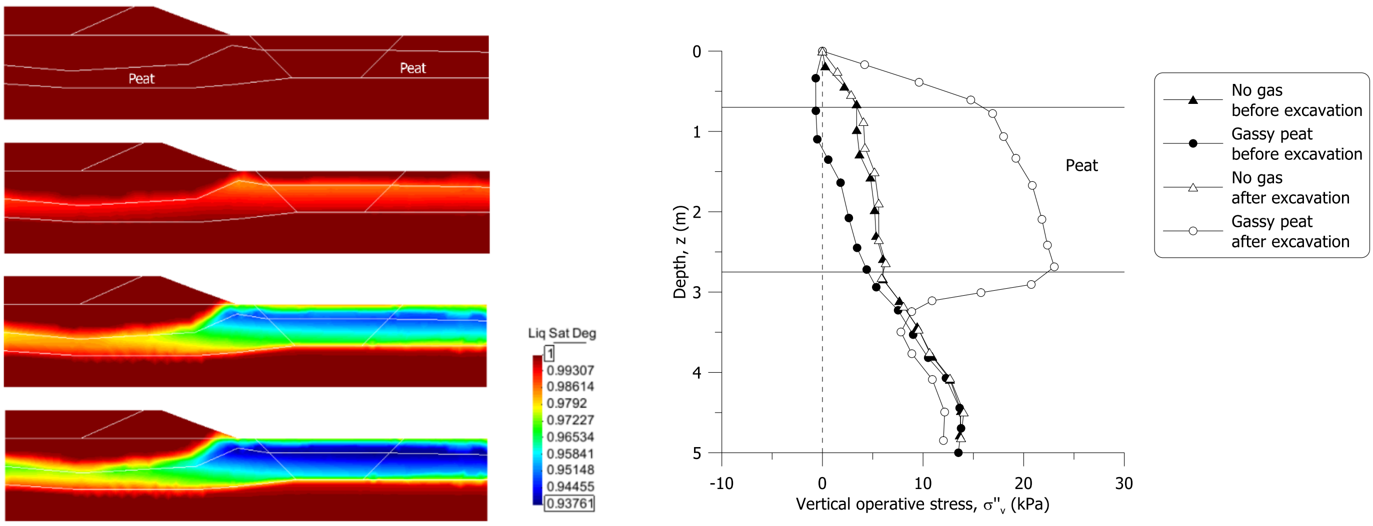
stress to zero in the upper meter of soil at the toe of the embankment due to the light weight of peat and cover soil, which temporarily reduces the factor of safety of the water defence against global stability. As soon as the gas overpressure is released, the operative stress increases above the effective stress which would characterise saturated conditions, bringing the system back to safer conditions.

These preliminary analyses are supporting an undergoing experimental and numerical thorough effort to better quantify the dynamics of gas generation and venting in organic soils to reduce the hazard associated with increasing climatic stresses.



(a) (b)

Figure 1: Illustrative numerical results: (a) evolution of the liquid degree of saturation and (b) variation of the vertical operative stress in peat upon gas generation and release.

Contributor statement

Inge de Wolf; experimental monitoring, modelling; Man Xu: numerical modelling; Cristina Jommi: conceptualisation, supervision, revision; Stefano Muraro: conceptualisation, supervision, writing

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