Claims

1. A soil displacement measurement device comprising:

a cylindrical hollow housing;

an outer ring-magnet slidably arranged on an exterior surface of the cylindrical hollow housing in a manner such that the cylindrical hollow housing is inserted through a central cavity of the outer ring-magnet;

an inner magnet disposed within the cylindrical hollow housing;

a suspension arrangement holding the inner magnet with respect to the cylindrical hollow housing so as to suspend the inner magnet within an interior space of the cylindrical hollow housing, wherein a portion of the suspension arrangement is fixed to a portion of the cylindrical hollow housing and a further portion of the suspension arrangement is extended into the interior space of the cylindrical hollow housing and the inner magnet is attached to the further portion of the suspension arrangement so as to be suspended;
and

a strain measurement element provided to a region of the suspension arrangement,

wherein relative movement between the outer ring-magnet and the cylindrical hollow housing along a longitudinal axis of the cylindrical hollow housing causes the outer ring-magnet to coact with the inner magnet in a manner such that a magnetic force between the outer ring-magnet and the inner magnet changes a corresponding strain at the region of the suspension arrangement, and

wherein the change in the strain is detected by the strain measurement element as a measure of the relative displacement of the outer ring-magnet along the longitudinal axis of the cylindrical hollow housing.

2. The device as claimed in claim 1, wherein the strain measurement element comprises fibre Bragg grating (FBG).

3. The device as claimed in claim 1 or 2, wherein the cylindrical hollow housing is filled with a fluid medium.

4. The device as claimed in any one of claims 1 to 3,

wherein the cylindrical hollow housing has a first partition and a second partition defining a closed section of the cylindrical hollow housing,

wherein the inner magnet is suspended with a first flat-surface of the inner magnet directed towards the first partition of the cylindrical hollow housing and a second flat-surface of the inner magnet directed towards the second partition of the cylindrical hollow housing, the first flat-surface being opposite the second flat-surface,

wherein the suspension arrangement comprises

a first suspension-line-segment extending along the longitudinal axis of the cylindrical hollow housing between a center of the first flat-surface of the inner magnet and a center of the first partition of the cylindrical hollow housing, and

a second suspension-line-segment extending along the longitudinal axis of the cylindrical hollow housing between a center of the second flat-surface of the inner magnet and a center of the second partition of the cylindrical hollow housing,

wherein the strain measurement element is disposed along the first suspension-line-segment.

5. The device as claimed in claim 4, wherein the first suspension-line-segment comprises an optical fiber.

6. The device as claimed in claim 4 or 5, further comprising an annularly shaped magnet-housing having a cavity in the center to accommodate the inner magnet, wherein an outer boundary of the annularly shaped magnet-housing is dimensioned to fit into the cylindrical hollow housing.

7. The device as claimed in any one of claims 1 to 3,

wherein the suspension arrangement comprises a cantilever structure which is aligned parallel to the longitudinal axis of the cylindrical hollow housing and which has a first end portion fixedly coupled to the cylindrical hollow housing and a second free-end portion,

wherein the inner magnet is fixed to the second free-end portion of the cantilever structure, and

wherein the strain measurement element is attached to the first end portion of the cantilever structure.

8. The device as claimed in claim 7, wherein the suspension arrangement further comprises a cantilever-structure-holder in the form of a circular panel fixedly mounted to an

interior wall of the cylindrical hollow housing, wherein the circular panel comprises a cavity in which the first end portion of the cantilever structure is fixedly fitted.

9. The soil displacement measurement device as claimed in any one of claims 1 to 8, wherein the soil displacement measurement device comprises a first soil displacement measurement sub-device along a first length portion of the cylindrical hollow housing and a second soil displacement measurement sub-device along a second length portion of the cylindrical hollow housing,

wherein the first soil displacement measurement sub-device is configured according to any one of claims 1 to 8,

wherein the second soil displacement measurement sub-device comprises

a first partition and a second partition along the second length portion of the cylindrical hollow housing to define a closed section of the second length portion of the cylindrical hollow housing,

a suspended-body of the second soil displacement measurement sub-device being held in suspension within the second length portion of the cylindrical hollow housing with a first suspension-line segment of the second soil displacement measurement sub-device extending from the suspended-body towards a center of the first partition of the second length portion of the cylindrical hollow housing and a second suspension-line segment of the second soil displacement measurement sub-device extending from the suspended-body towards a center of the second partition of the second length portion of the cylindrical hollow housing, and

a strain measurement element of the second soil displacement measurement sub-device disposed along the second suspension-line segment of the second soil displacement measurement sub-device in a manner such that a change in tilt angle of the cylindrical hollow housing causes a change in a strain of the second suspension-line segment of the second soil displacement measurement sub-device which is detected by the strain measurement element of the second soil displacement measurement sub-device.

10. The device as claimed in claim 9, wherein the strain measurement element of the second soil displacement measurement sub-device comprise fibre Bragg grating (FBG).

11. The device as claimed in claim 10, wherein an optical fiber for the FBG of the strain measurement element of the first soil displacement measurement sub-device and another

optical fiber for the FBG of the strain measurement element of the second soil displacement measurement sub-device are spliced together in a manner such that measurements from both the strain measurement elements may be transmitted via a single spliced optical fiber.

12. The device as claimed in any one of claims 9 to 11, wherein the suspended-body of the second soil displacement measurement sub-device has a shape having circular symmetry about a main axis passing through the suspended-body between a first surface-intersection-point and a second surface-intersection-point, and the suspended-body is disposed within the second length portion of the cylindrical hollow housing and suspended between the first partition of second length portion of the cylindrical hollow housing and the second partition of second length portion of the cylindrical hollow housing with the first surface-intersection-point directed towards the first partition of second length portion of the cylindrical hollow housing and the second surface-intersection-point directed towards the second partition of second length portion of the cylindrical hollow housing.

13. The device as claimed in claim 12, wherein the first suspension-line-segment of the second soil displacement measurement sub-device extend from the first surface-intersection-point of the suspended-body towards a center of the first partition of second length portion of the cylindrical hollow housing, and wherein the second suspension-line-segment of the second soil displacement measurement sub-device extend from the second surface-intersection-point of the suspended-body towards a center of the second partition of second length portion of the cylindrical hollow housing.

14. The device as claimed in any one of claims 9 to 13, wherein a ratio of a length of the first suspension-line-segment of the second soil displacement measurement sub-device to a length of the second suspension-line-segment of the second soil displacement measurement sub-device is equal or more than 1.

15. The device as claimed in any one of claims 9 to 14, wherein a single optical fiber extends from the center of the first partition of the second length portion of the cylindrical hollow housing to the suspended-body of the second soil displacement measurement sub-device, through the suspended-body of the second soil displacement measurement sub-device, and from the suspended-body of the second soil displacement measurement sub-device to the center of the second partition of the second length portion of the cylindrical

hollow housing, wherein the first suspension-line-segment of the second soil displacement measurement sub-device is a segment of the single optical fiber between the first partition of the second length portion of the cylindrical hollow housing and the suspended-body of the second soil displacement measurement sub-device, and wherein the second suspension-line-segment of the second soil displacement measurement sub-device is a segment of the single optical fiber between the suspended-body of the second soil displacement measurement sub-device and the second partition of the second length portion of the cylindrical hollow housing.

16. The device as claimed in any one of claims 9 to 15, wherein the first suspension-line-segment of the second soil displacement measurement sub-device comprises a metal wire and the second suspension-line-segment of the second soil displacement measurement sub-device comprise an optical fiber.

17. The device as claimed in any one of claims 9 to 16, wherein the closed section of the second length portion of the cylindrical hollow housing is filled with a fluid medium.

18. The device as claimed in any one of claims 1 to 17, further comprising a first connection fixture disposed on an exterior of the cylindrical hollow housing at a first end portion and a second connection fixture disposed on the exterior of the cylindrical hollow housing at a second end portion, wherein each of the first connection fixture and the second connection fixture comprises three or more attachment elements, each attachment element being configured to interlock with a flexible elongate link member.

19. A soil displacement measurement system comprising at least two soil displacement measurement devices as claimed in any one of claims 1 to 8 arranged in a series one after another.

20. A soil displacement measurement system comprising at least two soil displacement measurement devices as claimed in claim 18, wherein the at least two soil displacement measurement devices are interconnected via three or more flexible elongate link members, wherein each of the three or more flexible elongate link members has a first end interlocks with an attachment element of one of the at least two soil displacement measurement devices

and a second end interlocks with an attachment element of another one of the at least two soil displacement measurement devices.