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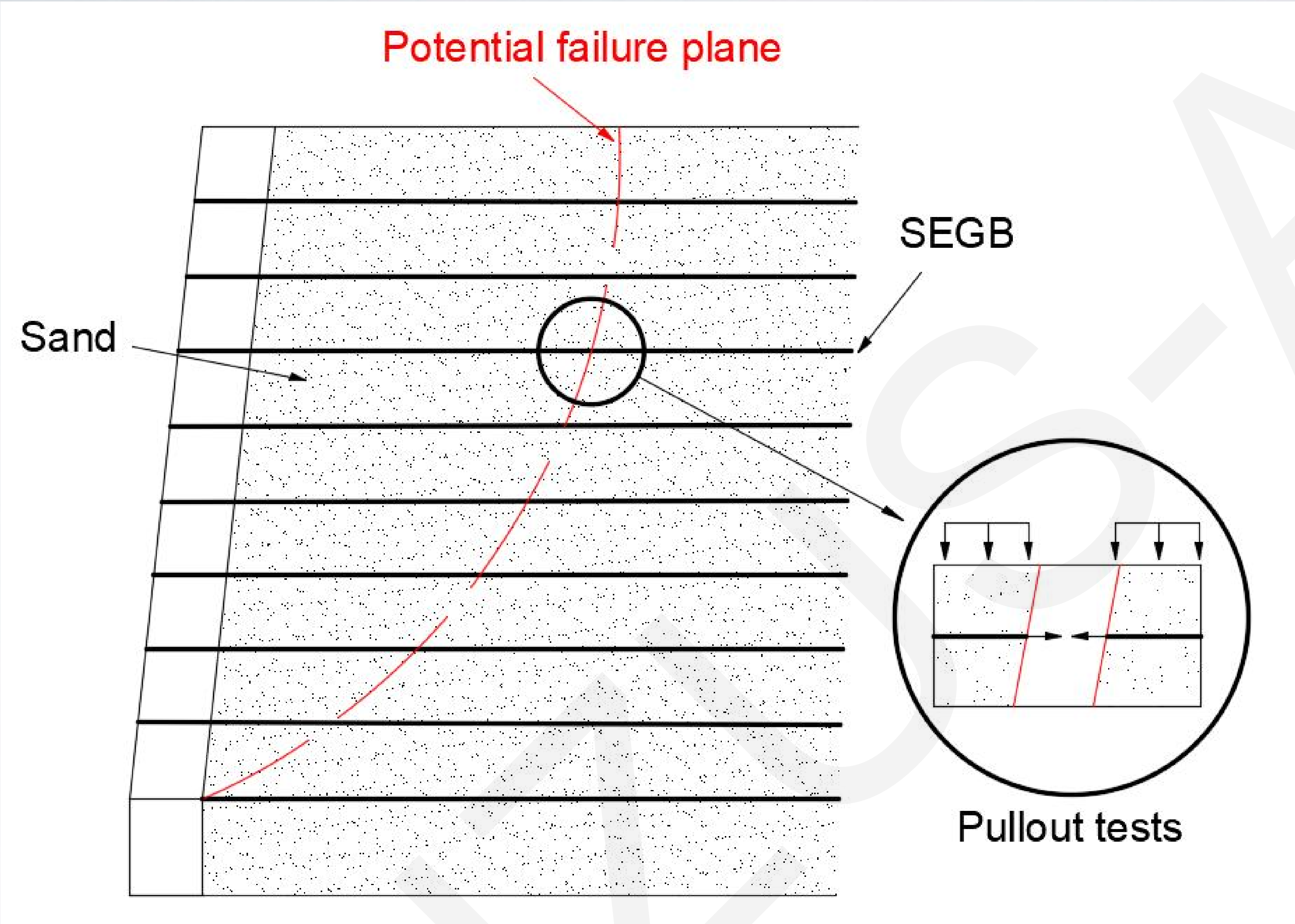
Deformational characteristics of sensor-enabled geobelts incorporating two failure modes in reinforced sand

Key words:

Geosynthetics; Sensor-enabled geobelts; Failure mode; Deformation characteristics; Pullout tests

General Idea



The objective of this paper:

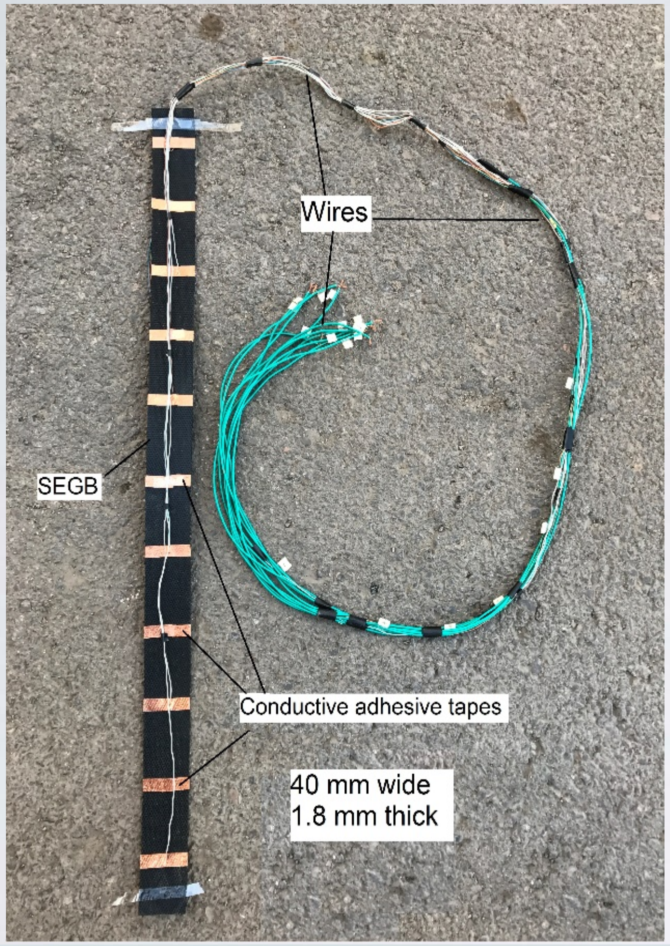
i):report a series of pullout tests of various lengths in sand under different normal pressures and to discuss these in the context of long-term monitoring of reinforced soil structures.

ii): aims to proposing a method for preliminary prediction of failure mode based on observed pre-failure behaviour.

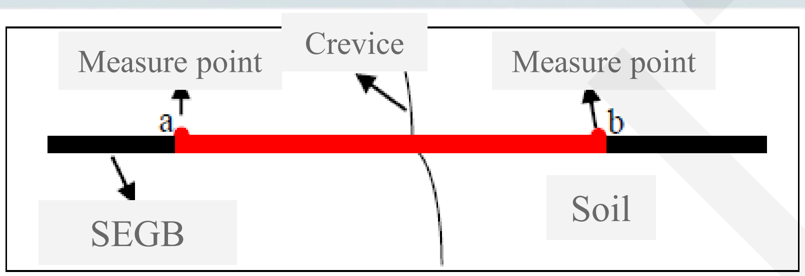
Most of the geosynthetics near the failure plane in GRS could be equivalent to pullout tests on geosynthetics.

There is a paucity of information addressing the deformation characteristics of geosynthetics considering failure from the perspective of long-term monitoring of performance

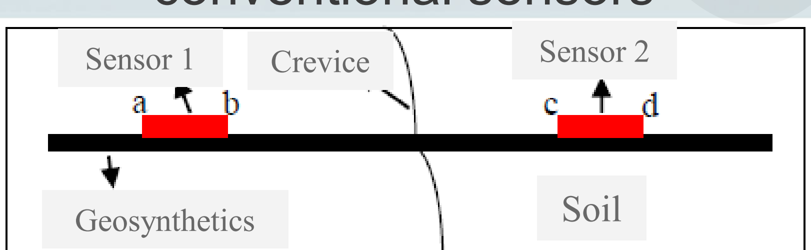
Sensor-enabled geobelts (SEGB)



Distributed Measurement of SEGB

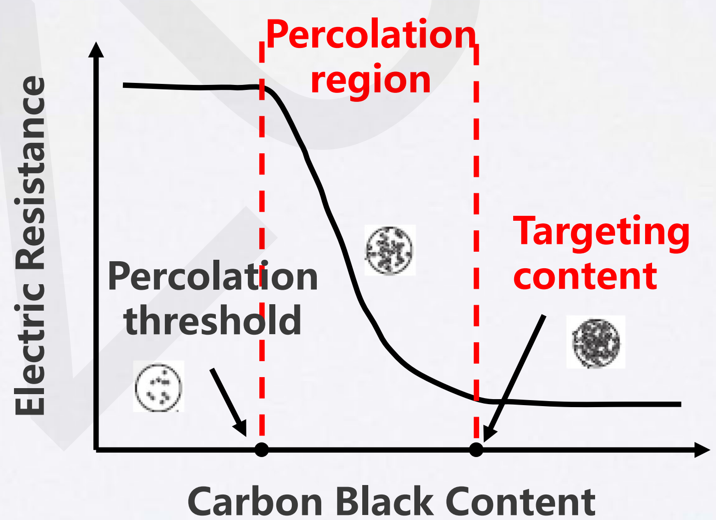


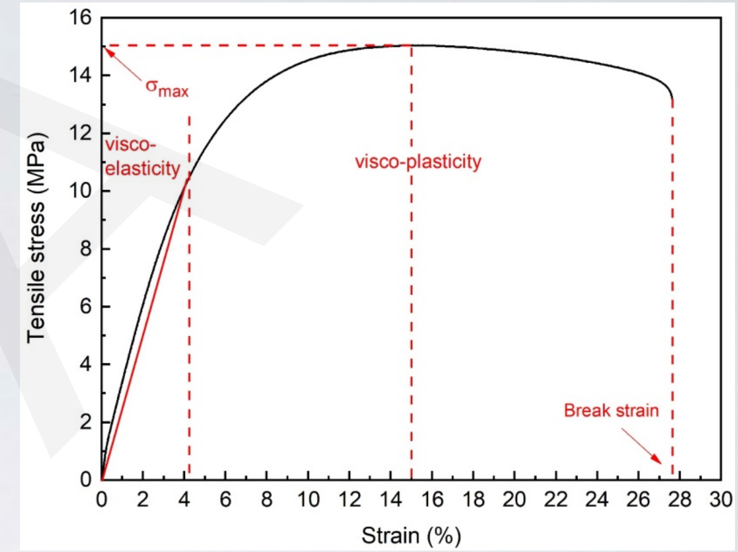
Non-distributed Measurement of conventional sensors



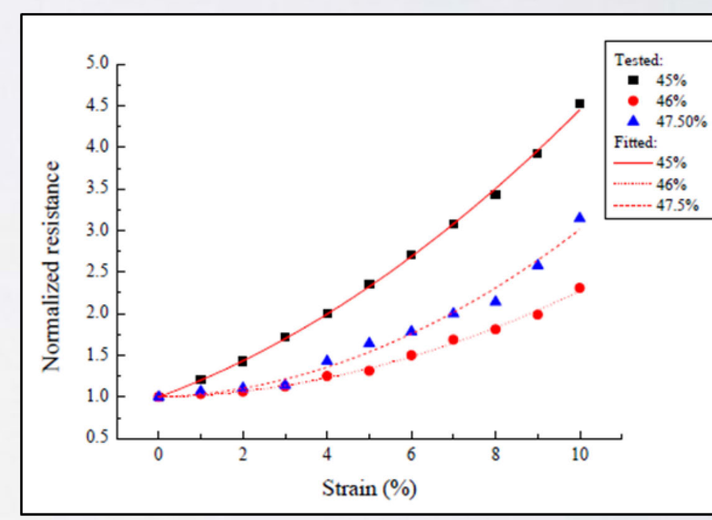
Conductive polymer: HDPE + Carbon Black

Percolation Phenomenon





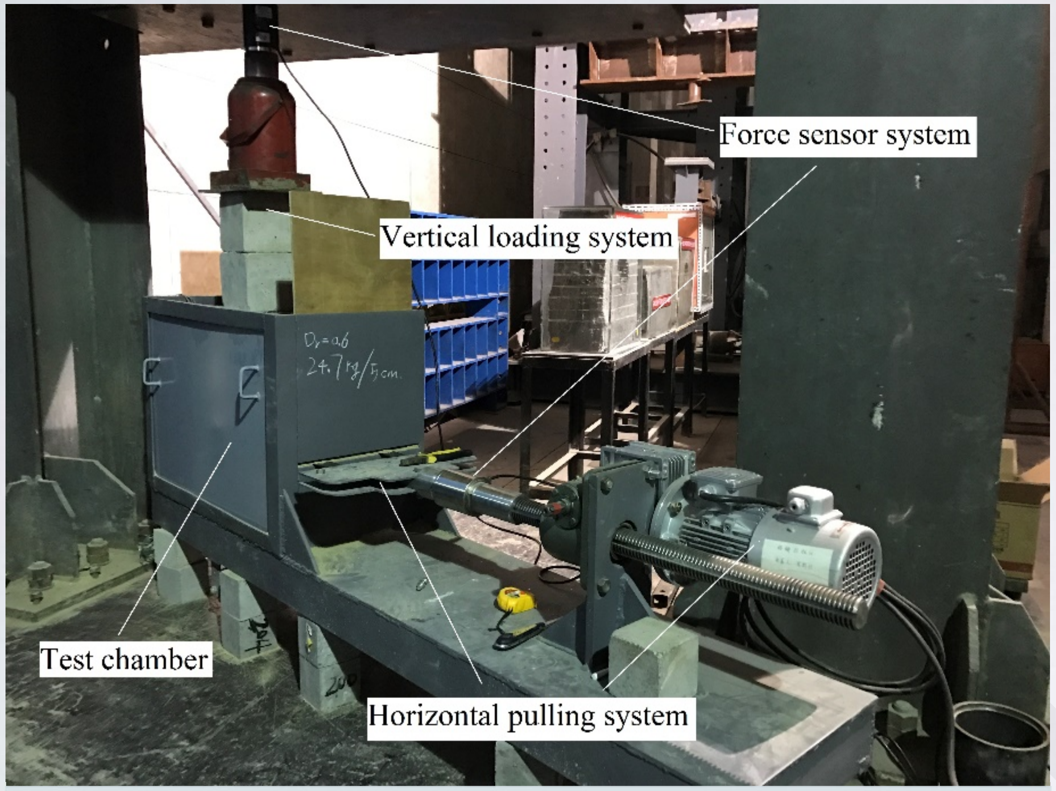
Mechanical Property:
Tensile strength: 15 MPa
Breaking elongation: 27.5%



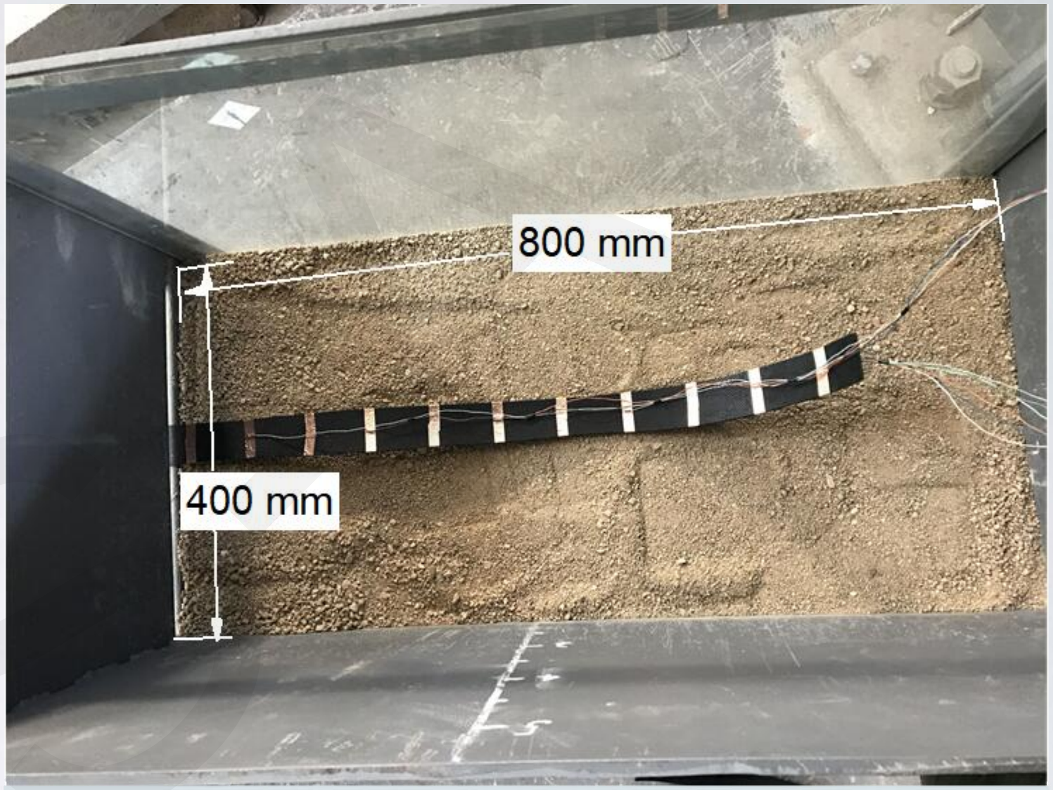
Tensoresistivity:

$$\frac{R_s}{R_0} = \alpha\varepsilon^2 + \beta\varepsilon + 1$$

Pullout tests setup



Pullout test device



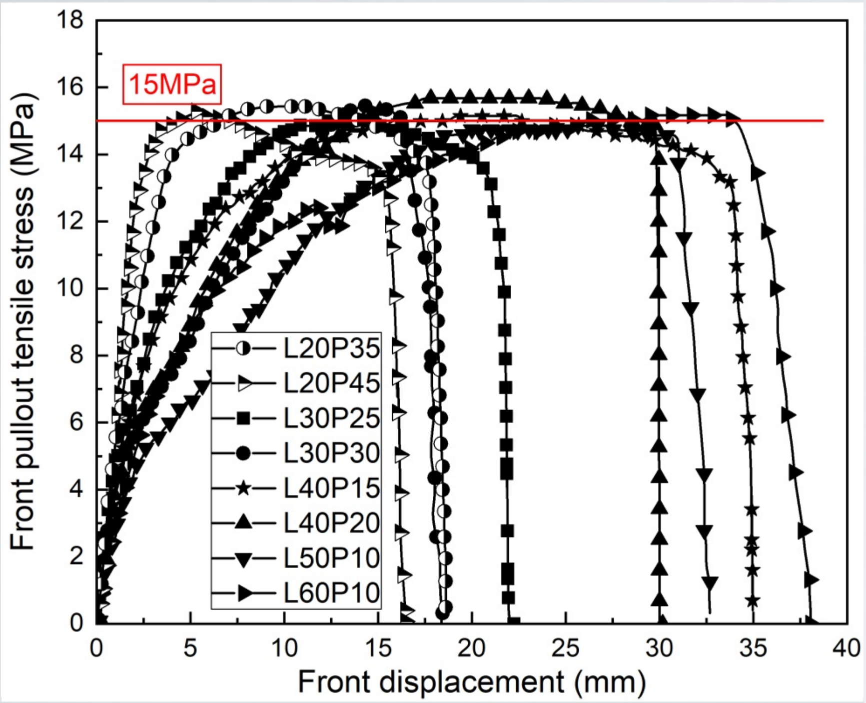
Pullout test preparation

Pullout test cases

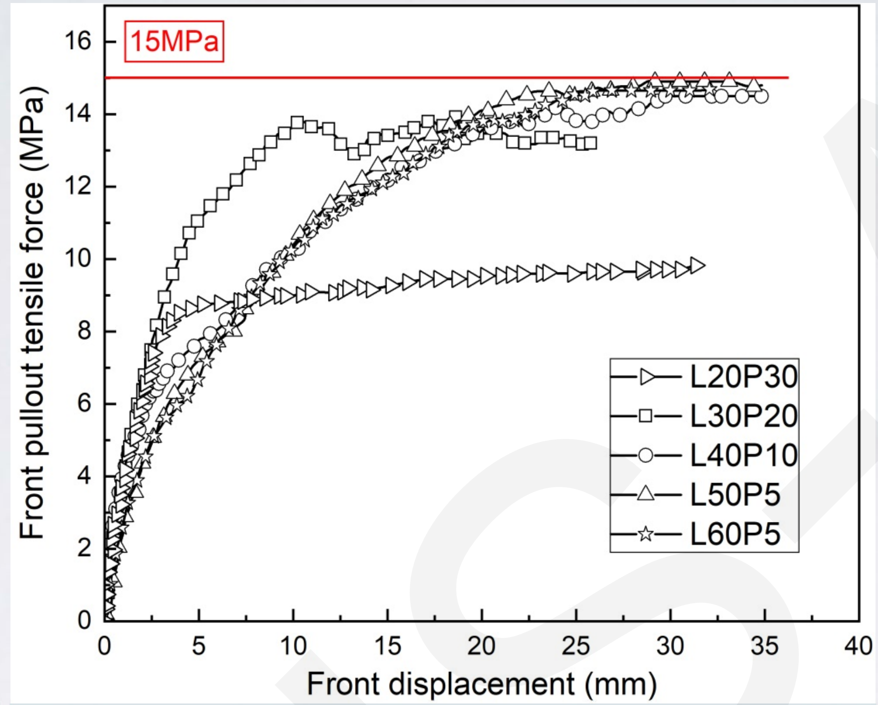
Effective length l (cm)	Normal pressure σ_v (kPa)
20	50, 45, 40, 35, 30
30	30, 25, 20
40	20, 15, 10
50	10, 5
60	10, 5

- For each effective length of specimen, sufficiently high normal pressure was applied to ensure that geobelt tensile failure occurred
- Normal pressure was then decreased in subsequent tests until the specimen reached pullout.
- Pullout failure cases were carried out twice with the same normal pressure and effective specimen. Average values of two iterations were recorded.

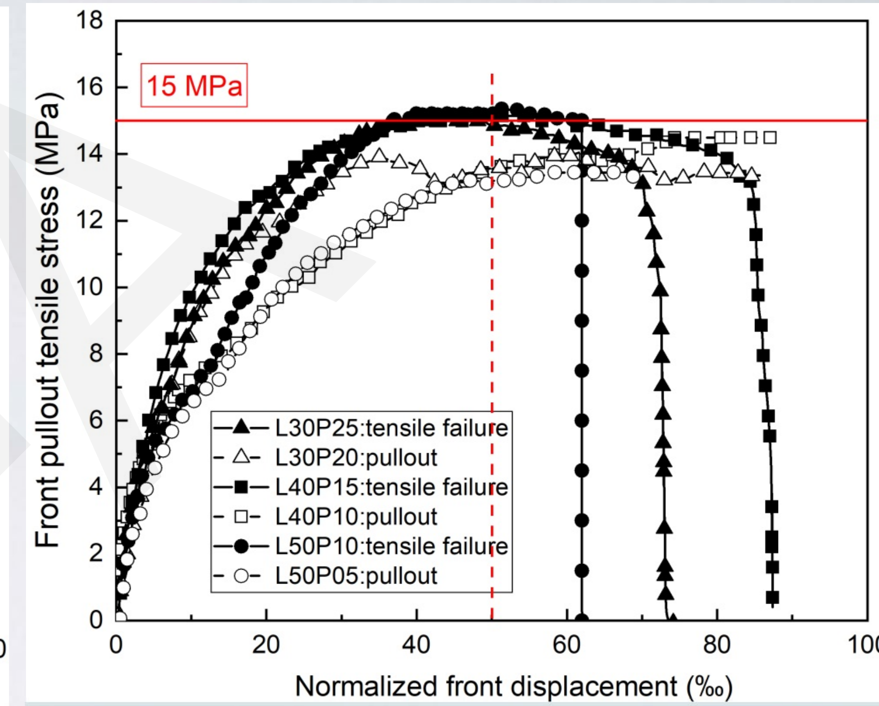
Test results analysis



Tensile failure cases



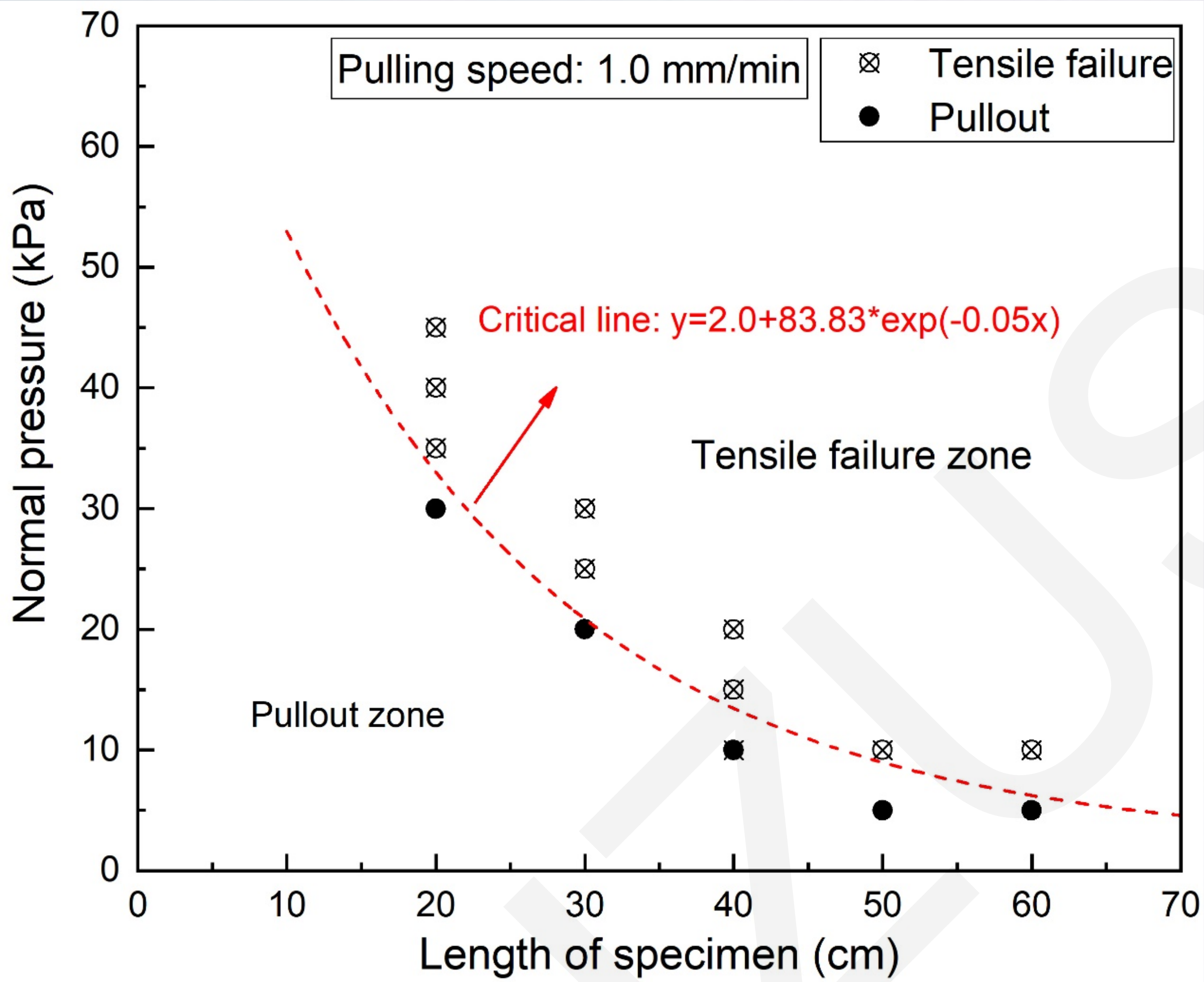
Pullout failure cases



Comparison of two failure cases

- In most tensile failure cases, pullout force increased monotonically with front displacements until tensile strength (about 15 MPa) was reached
- In most pullout failure cases, the ultimate constant value was close but lower to 15 MPa, indicating that full tensile capacity had not be mobilized yet.
- Peak values for all tensile failure mode cases occurred at around 5% of normalized front displacement. Thus, at a given normal pressure for the geobelt and sand tested, specimens reached material tensile strength when front displacement reached about 5% of the specimen length.

Critical line between failure modes



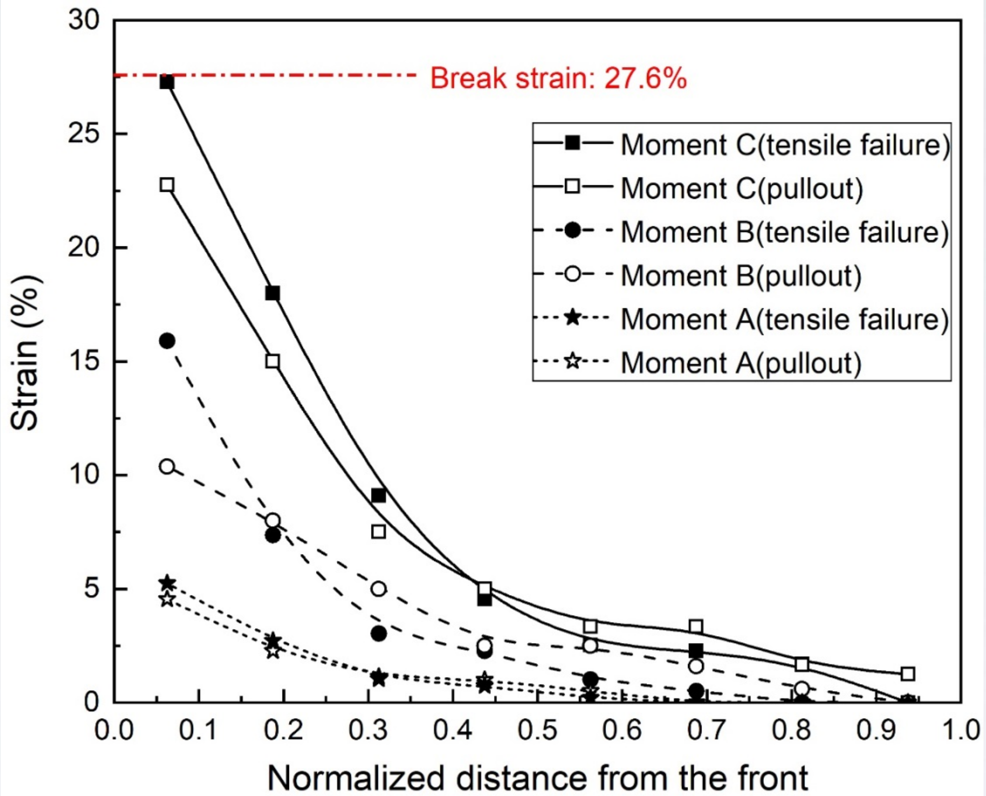
Critical state between two failure modes

- The critical line between two failure modes could be described:

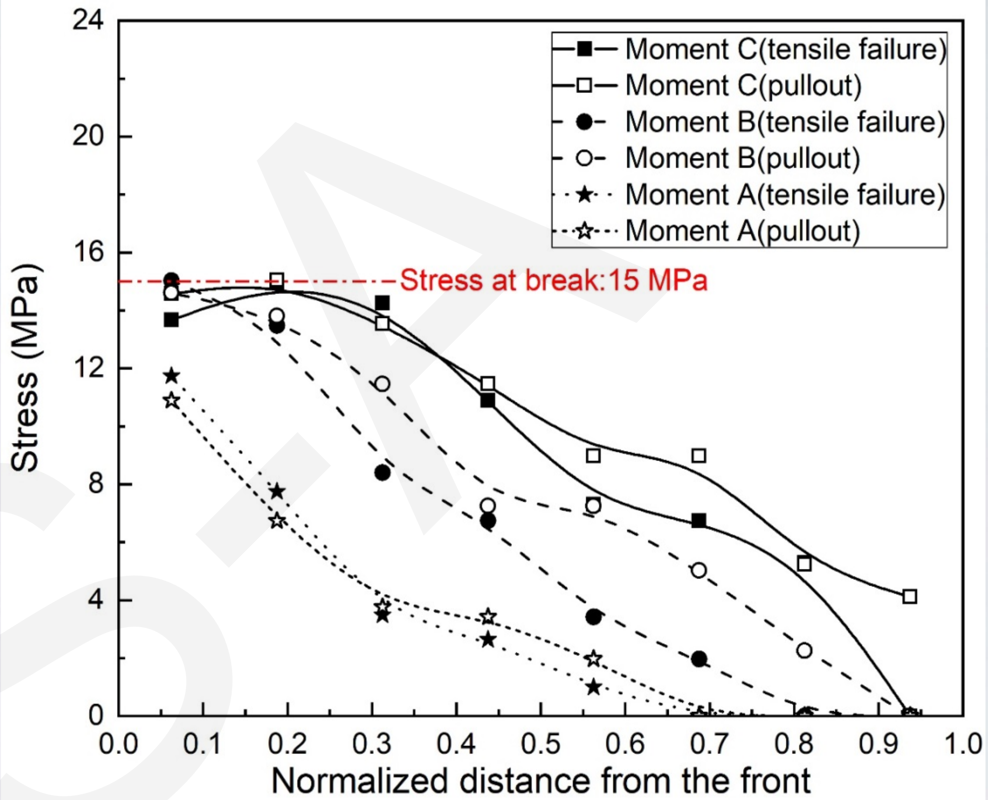
$$\sigma_v = a + b\exp\left(-c \times l\right)$$

- This critical line can be used as a map or index for preliminary judgement about failure mode as it simply depends on length and confining pressure.
- Although derived from pullout tests, the critical line was applicable for geosynthetics-reinforced structures

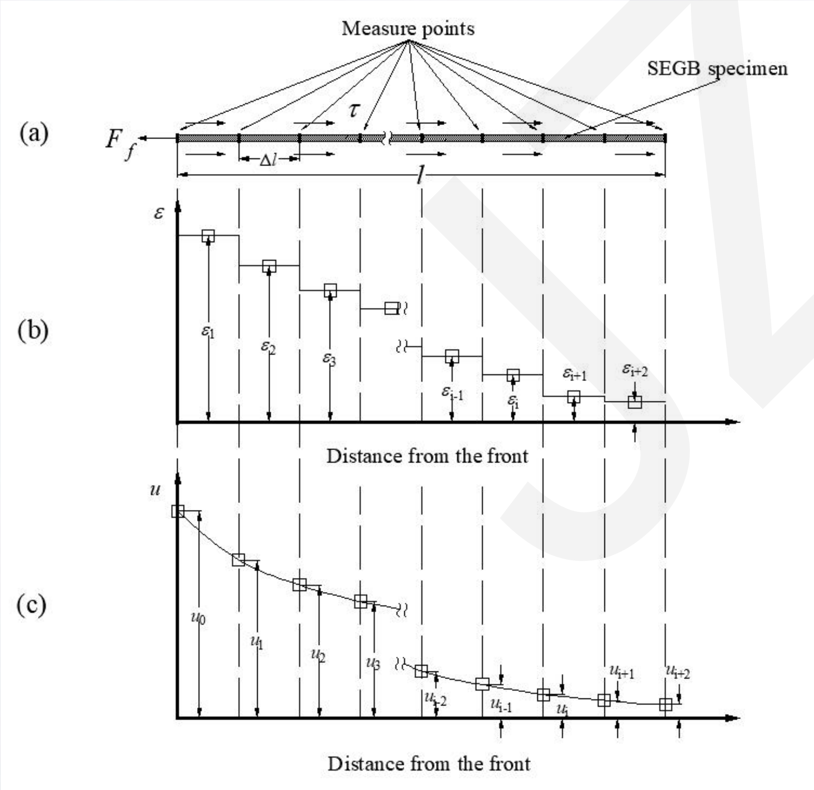
Distributed Measurements of SEGB

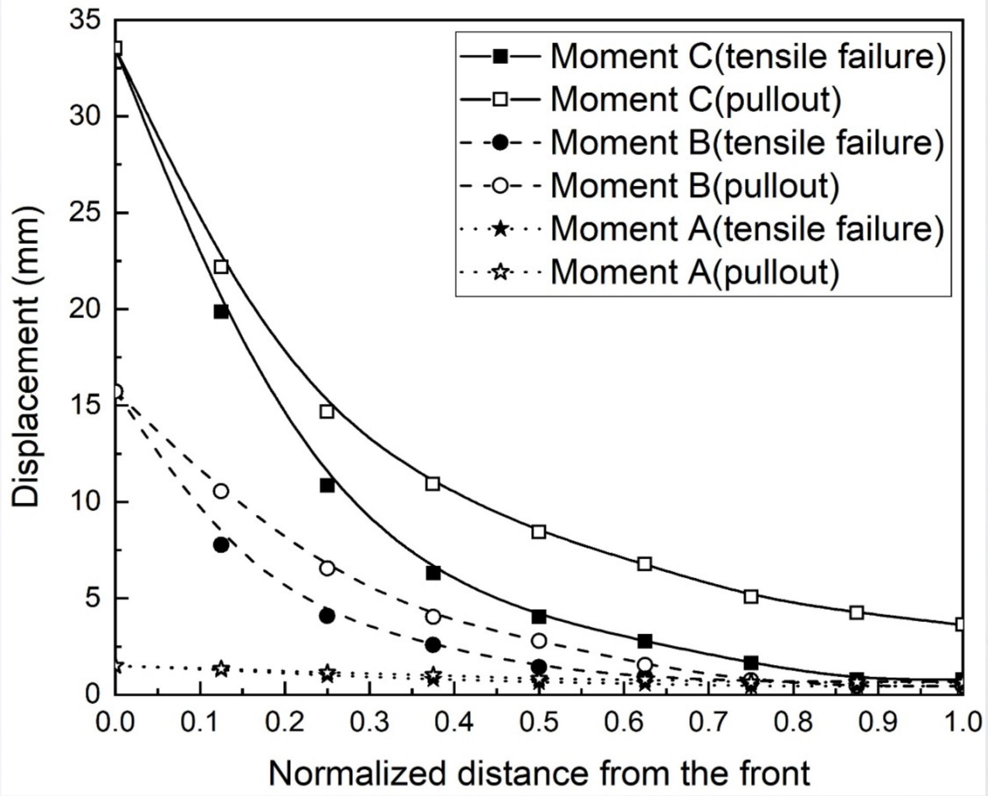


Distributed strain measurement



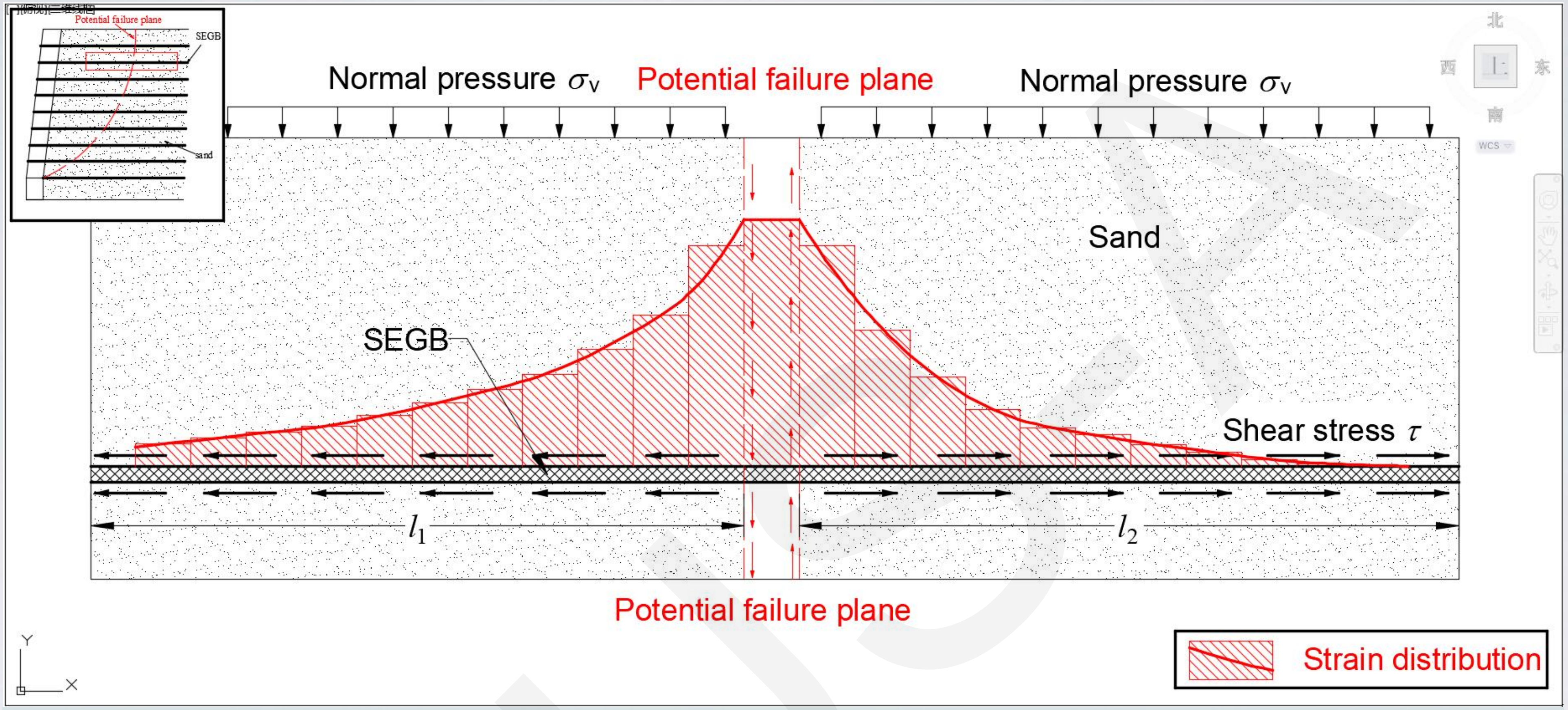
Distributed stress measurement





Distributed displacement measurement

SEGB failure mode criteria



Critical state between two failure modes

- Once the strain distribution along the geobelt reached a peak value, the potential failure plane could be prejudged.
- A geobelt can be divided by the potential failure plane into two parts with length of l_1 and l_2, respectively. The failure mode of the geobelt could be preliminarily predicted according to the critical line.
- At the beginning, the strains at tail zones should be zero. Once the strains at tail zones were no longer zero, the geobelts were prone to be pulled out.
- If the peak strain at failure plane reached the level of tensile strength of specimens, the geobelts were prone to be geobelt tensile failure eventually.

Conclusions

- A critical line considering the length of SEGB and confining pressure was proposed to describe the transition between two failure modes—geobelt tensile failure and pullout. The critical line could be utilized for preliminary pre-diction of failure mode of SEGB.
- On the basis of strain distribution from the self-measurement of SEGB, warning criteria for the failure modes of SEGB was established. The strain distribution along the geobelt showed a peak value where the potential failure plane occurred, and the mobilization of the strain was transferred from the failure plane to either side. Once the strains at tail zones were no longer zero, the geobelts were prone to be pulled out. If the strains at tail zones remained to be zero but the peak strain at failure plane reached the level of tensile strength of specimens, the geobelts were prone to be geobelt tensile failure eventually. The warning criteria could be utilized for preliminary recognition and judgment of the potential failure modes during service life.