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13–16 March | Sheraton Dallas Hotel | Dallas, Texas USA

Determination of shear strength parameters of Municipal Solid Waste by means of static plate load tests

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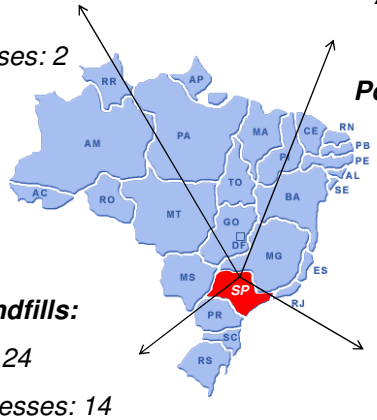
State of Sao Paulo:

Waste to energy plants

Operating: 0

In regulatory processes: 2

Source: CETESB, 2011



Area: *248,196 km²*

Cities*: 645*

Population*: 41 million*

Source: IBGE , 2011

MSW large landfills:

Operating: 24

In regulatory processes: 14

Source: CETESB, 2011

MSW production*:*

51,426 ton per day

Source: ABRELPE, 2009

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FACTS:

•The State of Sao Paulo has a **high production of waste**;
•There is **scarcity of adequate available sites** near the urban areas of big cities;
•Environmental protection systems in a landfill demands an **expensive infrastructure**.

CONSEQUENCES:

Disposal centralization of MSW in large ventures for a better usage of area and of the expensive necessary infrastructure

LANDFILLS BECOME HIGH

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Large MSW landfills need:
Prediction of geotechnical stability
Geotechnical monitoring

Stability analysis

•MSW failure may be represented by a **Mohr-Coulomb envelope**

•**Limit-equilibrium** slope stability methods

Shear strength parameters
(cohesion - c and friction angle - φ)

•Obtained by means of **back-calculation of real failures** or **laboratory tests**

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Sitio São João landfill – City of São Paulo

Height: more than 150 meters (492 ft)

Failure in 2007: 220,000 m³ of MSW
(no victims)

Satellite view of Leuwigajah landfill - Indonesia

Failure in 2005: 2,700,000 m³
of MSW
(147 people died)

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DETERMINATION OF SHEAR STRENGTH PARAMETERS

Back-calculation of failures: **uncertain** events

Laboratory tests: **lack of representativeness of collected samples**

Recently: **large scale laboratory tests**.

This research: **determination of shear strength parameters by means of *in situ* tests**

OBJECTIVE

In situ tests in a large sanitary landfill to contribute to the evaluation of shear strength parameters of MSW.

Results of static plate load tests aplied to **Terzaghi's bearing capacity formula** (Azevedo et al. 2006, Ribeiro 2007).

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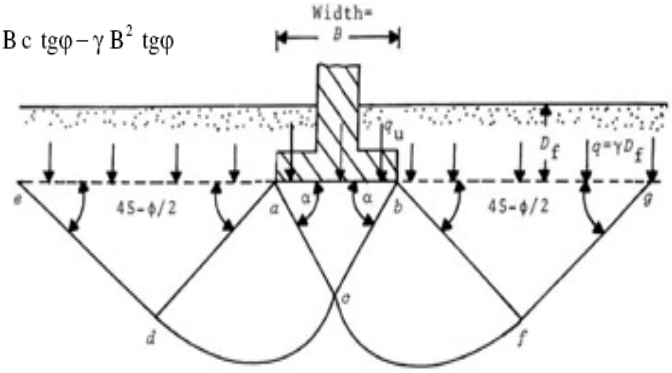
BEARING CAPACITY

1943: Terzaghi presents a method to evaluate **bearing capacity of strip footings**.

Assumptions: **soils have a rigid-plastic behavior**, equilibrium of forces at the imminence of failure, the resistance offered by the weight of the soil and by the surcharge can be evaluated independently, and a particular failure configuration.

TERZAGHI'S MODEL TO EVALUATE BEARING CAPACITY

$$Q_r = 2\,P_p + 2\,B\,c\,tg\varphi - \gamma\,B^2\,tg\varphi$$



$$q_r = 1{,}3\,cN_c + q_0 N_q + 0{,}3\,\gamma\,B\,N_\gamma$$

Unit weight=γ
Cohesion=c
Friction angle=ϕ

PLATE LOAD TEST

Determination of the bearing capacity and the stress-strain behavior of the soil under a shallow foundation

Brazilian (NBR 6489-84) and ASTM (D1194-94) standards to normalization of plate load tests are very similar

Failure stress: Load under which the soil fails, or the load correspondent to a maximum deformation criterion (a common value is 10% of plate diameter).

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CASE STUDY - Itapevi Waste Management Center

- Located about 42 km of the city of Sao Paulo
- Attends 8 municipalities on the west side of Sao Paulo metropolitan region.
- Certified for 1,200 tons per day of MSW in co-disposal policy with non-hazardous industrial waste.
- Landfill operation: 100,180 m²
- Volumetric capacity: 3.2 million tons

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PLATE LOAD TESTS IN MSW LANDFILL

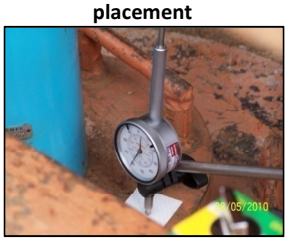
Step 1: Removing soil cover

Step 2: Surface regularization

Step 3: Plate and knee-cap placement

Step 4: Hydraulic jack placement

Step 5: Gauges placement



Step 6: Gauge measure

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PLATE LOAD TESTS IN MSW LANDFILL

Truck carried with soil or crushed stone to react against the jack

Maximum plataform loading: 30 tf

Test ends when the heterogeneity of waste causes the tilting of plate (dangerous for the operators).

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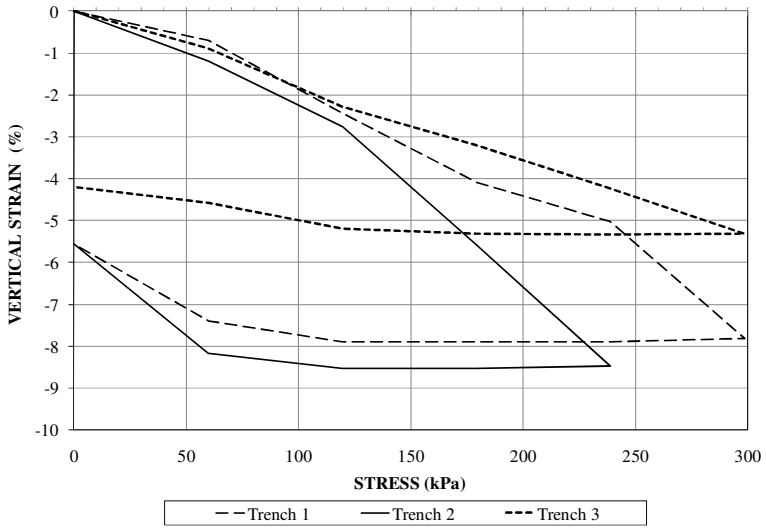
RESULTS



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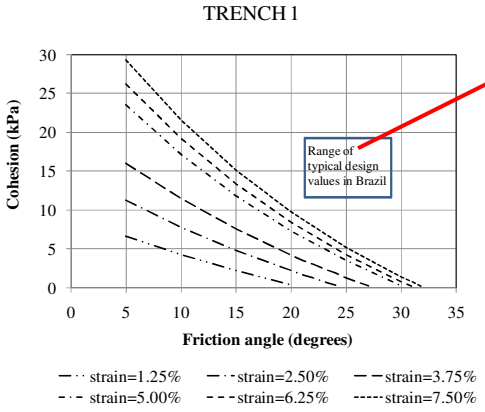
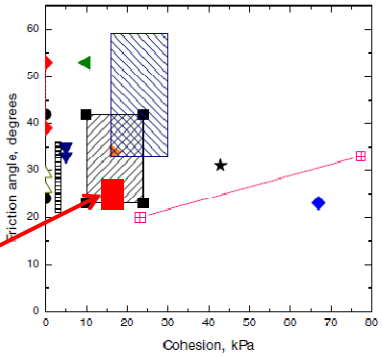
RESULTS

$$q_r = 1{,}3\,cN_c + q_0N_q + 0{,}3\,\gamma\,B\,N_\gamma$$





Adapted from Kavazanjian, 2010

- Stoll (1971)
- Landva and Clark (1986, 1990)
- Siegel et al(1990)
- Withiam et al. (1995)
- Gabr and Valero (1995)
- Houston et al (1995)
- Vilar and Carvalho (2002)
- Kavazanjian et al. (1999) direct shear
- Kavazanjian et al. (1999) simple shear
- Pelkey (1997)
- Caicedo et al (2002)
- Mahler and Delamare Netto (2003)

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COMMENTS

Static plate load tests **are not an adequate method to obtain shear strength parameters** of MSW.

Physical limitations do not allow to reach high strain and failure does not occur (necessary for Terzaghi's bearing capacity method).

Loaded region and confining stresses are **more representative** than laboratorial triaxial tests.

Values of cohesion and friction angles **are probably more accurate** than laboratorial tests.

Continuation of the research: **representativeness** of elastic-plastic or visco-elastic-plastic models to the MSW behavior

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Questions are welcome.

Thank you for your interest.

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