# Stability problems of landfills – The Payatas landslide

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**Abstract**: Stability of landfills for MSW has been a problem for years. In July 2000, a slope at the Payatas dumpsite (Philippines) failed. More than 200 people were killed. Supported by the Asian Development Bank a forensic evaluation has been conducted. One major reason for the landslide could be identified: The waste density was too low. The low density allowed a high rate of water percolation instead of getting drained by surface flow. The water reduced the shear strength by mobilizing pore water pressure and triggered finally the failure. The reasons for the low waste density are a combination of lack of development (poverty) and industrial production creating a very light waste („American waste“), which is reluctant to conventional compaction methodes. As a keystone measure a biological pretreatment has been proposed to improve the geotechnical situation at Payatas dumpsite.

**Keywords:** landfill stability, biological treatment, settlements, water balance, dranage system

## Introduction

Stability of landfills is one of the major geotechnical tasks in landfill design and operation. Stability has been a problem for years. Inhomogenious waste composition, difficulties in determining waste strength parameters and a lack of knowledge about the principles of waste mechanics resulted in considerable uncertainties in stability calculations. In the early 90ies the German government has spent a lot of efforts to investigate waste mechanics. Meanwhile, the landfill stability in Germany seems to be a solved problem, even extreme slope geometries were constructed during remediation and mining measures at German landfills. Nevertheless, several landslide events occurred in other countries the last years. Definitely, the most tragic case was the Payatas landslide in July 2000. This catastrophy generated the question of the influence of different climate conditions or the state of development on the stability of landfills for municipal solid waste (MSW).

## The landslide

The Payatas dumpsite is located in the North-East of Metro Manila within in the boundaries of Quezon City on Luzon, the major island of the Philippines. About 1000 t municipal solid waste per day are delivered to the site, some 15-20% of the total amount of municipal solid waste (MSW) generated in Metro Manila. Around the dumpsite, the City of Payatas B houses 80.000 people, many of them working in waste business like in junk stores or as waste pickers (scavengers). The scavengers, who have the worst job in this micro-economy often have to live directly on the open waste surface of the dumpsite. Figure 1 illustrates the housing situation at the Payatas dumpsite before the landslide.

Figure 1: Housing situation at Payatas dumpsite before the landslide

Figure 2: Collapsed slope at the day after the failure

On July 10th around 5 A.M., a slope of the landfill failed and 1.2 Mio $m^3$ waste slid down burying both cottages of the scavangers and a part of Payatas B under 10 m of waste. In front of the toe of the slope an area of around 30.000 $m^2$ was completely covered by waste and debris. Figure 2 shows a part of this area at the day after the landslide in front of a remaining slope, where still huts of wastepickers can be seen. Rescue actions were hindered by landfill gas, which created several fires. More than 220 people were found dead in the plastered area. 4 weeks after the landslide, rescue works were suspended. There was no longer hope to find survivers, and even the dead bodies were heavily degradated, which made the identification impossible. Therefore, estimated 200 to 800 people are still missed. The area was leveled and secured by simple measures (peripheral trench, block lines)

## Forensic evaluation

A specific and detailed forensic analysis of the Payatas landlide has not been conducted, yet. Both, the authorities and the operater, the public agency MMDA (Metro Manila Development Agency), focused on analyses for the remaining landfills in Metro Manila, at first the San Mateo landfill. This procedure seems to be inappropriate, since new stability calculations without any enhanced input by forensic analyses are supposed the bring the same results as before. 4 weeks after the failure, Dr. Koelsch Geoenvironmental Technology came in place to make a visual evaluation of the case. Figure 3 show the collapsed slope at that time.

Figure 3: Broken slope at Payatas dumpsite – August 2000

Basically, a landslide happens in case a slope is constructed steeper than the shear strength of the material is sufficient to bear. Since the strength of waste is not well-known and is usually not being investigated in the laboratory, the waste is placed due to common experiences. It seems that the geometry of the Payatas dumpsite has met these experiences showing slopes of about 1:3 with a height of 25 m. However, some specific conditions, which show up in tropical developing countries, apparently have not been considered, thoroughly.

- **Low density of waste** due to
  a high portion of light plastic materials and an insufficient waste compaction
- **Unlimited water percolation**
  The water percolation is usually adjusted by paper. The observation has shown a lack of paper due to an outstanding high recycling ratio
- **Extremely high rates and non-uniform distribution of rainfall**

The major reason for the landslide is the low waste density. The low density reduced the surface flow of rainfall water and resulted in a high rate of water infiltration into the waste. The leachate water decreased the shear strength by mobilizing pore water pressure and triggered finally the failure. Waste settlements, which come along with a high content of organic materials, were driving this effect. The major reason for the low waste density was due to the composition of waste delivered to the Payatas dumpsite. The composition was characterized by a high portion of plastics and organics and an absence of certain other materials (paper, glass, metals). MSW composed in this matter is reluctant to conventional compaction methodes, even by using heavy equipment. The waste composition in Manila is typically for urban areas in developing and emerging economy countries. Basically, it results from an extraordinary consumption of plastics as package material, a lack of recycling systems for organic waste and an outstanding recyling rate for reuseable materials.The high recycling rate primarily reflects the poverty of the country, which enforces people to earn their living by segregating waste at dumpsites. The impact of the low density on the landfill stability was amplified by heavy rainfalls which are characteristical for the tropical location.

Anyways, stability problems are not restricted to the tropics, a troubled water balance jeopardizes the landfill stability, even in temperate climate areas, as long as the waste composition leads to a low waste density at the landfill. The Rumpke landslide, which occured 1996 in Cincinnati (USA), demonstrates, that US-landfills are more jeopardized than European ones. The reason is the extraordinary large portion of light waste (plastics) combined with disturbed water balances due to leachate circulation.

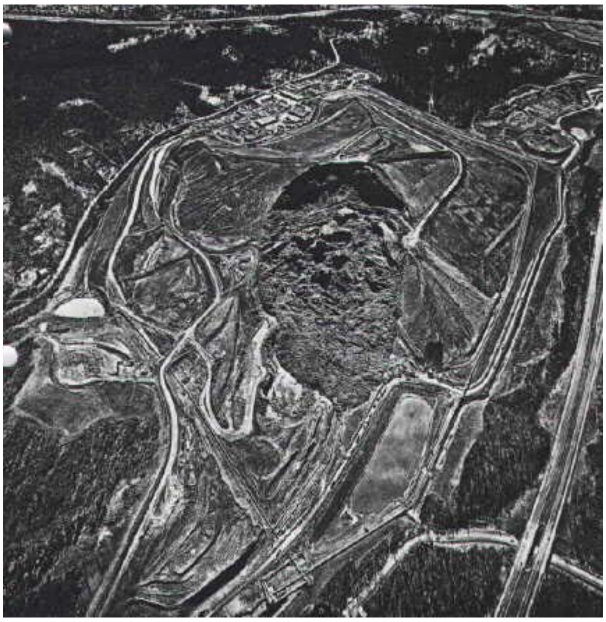

Fig.4: Rumpke landslide 1996 – air view

## Technical measures

Generally, the blocked water percolation is the major cause for landfill failures. Some design and operation measures should be considered in order to support a proper water percolation. The measures aim on reduction of water infiltration, improving of leachate dranage and minimizing of settlements. Usually, paying attention on these measures might avoid stability problems.

| **Aim** | **Measure** |
|---|---|
| Increasing of waste density | Biological pretreatment<br>Segregation of light materials and bioorganics |
| Improving of leachate dranage | Construction of dranage system<br>Continuous maintenance (control, cleaning) |
| Minimizing of settlements | Biological stabilization of organics (biotreatment)<br>Effective waste compaction |

Biological pretreatment is the technical keystone to improve stability. For the Payatas dumpsite, a simple treatment plant has been proposed. The plant should operate by the chimney-effect system like shown in figure 5 **(Koelsch, Reynolds, 1999)**.

Figure 5: Chimney-effect system at Meisenheim landfill (Germany)

Finally, technical aspects were not of prime importance. It was the governments intension to shut the landfill operation at Payatas down. From a technical view, there was no advantage from that decision. The shut-down of the landfill will worsen the ecological situation at the site leaving the place as an abandoned contaminated site. The site remediation will become easier by appropriate operating the dumpsite rather than by leaving and forgetting the place. Further, it has unclear and still unsolved social consequences. The implementaion of a biological pretreatment system would have created new and much more comfortable jobs at the landfill and would not have left people without their jobs.

## Stability calculation

Nevertheless, the geometry of the landfill or the conditions of a site may require exact stabilty analysis. Stability analysis for MSW-landfills are considerably different from stability calculations in soil mechanics. Primarily, MSW behaves like an reinforced material and has usually a higher shear strenght than soil. The shear strength results from friction (between the granular parts) and tensile forces (mobilized by fibrous materials like plastics). Evaluating the shear strength of MSW requires either laboratory tests with appropriate methods or a specific analysis of waste compositon. The waste analysis must include an identification of the shape of waste particles (granular, fibrous, 3-dimensional), the materials (plastics, paper, wood, metals a.s.o), the size and the overall biological condition (determined as oxygene demand). Due to the waste analysis, material values for the shear strength of MSW can be estimated slightly exactly.

Figure 6:Landfill mining at Goettingen Deiderode – steep slope

However, considering the reinforcement effect requires special calculation methods, but finally the described procedure will deliver a realistic evaluation for the slope stability.Additionally, an appropriate stability analysis may enable to make use of the waste strength in order to build steep temporary slopes or to expand the maximum landfill height – provided the landfill is in a good geotechnical shape. Both utilizations can be helpful in mining or construction situations. Figure 6 shows a 75° steep and 25 m high slope, which has been constructed at the Goettingen landfill in Deiderode (Germany) during the mining of the „grandfathered“ landfill area. The slope was even calculated and designed for an slope angle of 90°. Unlike the original plan, the slope has been held open for almost 3 years without showing any stability or deformation problems.

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