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FOUNDATION EROSION OF HOUSES DUE TO ACTION OF WIND

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Abstract:

The paper presents results of a pilot study into the wind-induced erosion of non-cohesive soil within densely grouped, single storey building structures in South Africa. The study comprised of site visits and assessment of structural damage to houses, analysis of climatic information pertinent to the area, a literature survey and limited wind-tunnel tests. It was established that the erosion of houses was triggered by a combination of soil founding conditions, climatic characteristics (in terms of seasonal prevalence of wind and rain) and also the character of aerodynamic wind flow distribution developing over a grouping of 'bluff-bodies' (i.e. houses) in close proximity of each other. Initial results of the study indicate the feasibility of investigating and identifying the remedial measures to reduce the problem and confirm the relevance of respective wind-tunnel technology.

1 INTRODUCTION

Several complaints of sub-standard house construction and structural defects were received by local and national authorities regarding a mass-housing, low-income development project in Delft on the Cape Flats (in Cape Town). Initial site investigations undertaken by structural engineers revealed the underlying reason for the structural damage to be wind-induced erosion of loose and unsaturated soils forming the land cover of the area under consideration.
A pilot study on the erosion patterns within densely grouped, one-storey buildings has been subsequently launched. The study comprised of site visits and assessment of damage, analysis of relevant geotechnical and climatic data, literature survey and initial wind-tunnel tests.

2 RESEARCH ON WIND EROSION

A literature survey revealed that no information is available on wind-induced erosion of soils within densely-spaced, single-storey housing developments. Several references were found on sand and snow drift, its modeling, measurements techniques and prevention (e.g. Refs. [1] or [2]).
Ref. [3] considers buildings in dusty environments while Ref. [4] describes a study based on full-scale sampling and subsequent laboratory testing of sand deposition at selected locations within a city.

3 THE SITE

The township of Delft is located on a plane with slightly undulating dunes, approximately 3 kilometres east of Cape Town International Airport. Further away, it is flanked by two mountain ranges (to the east and west), with elevations of up to about one kilometre above sea level.
From a geo-morphological point of view, the area of Cape Flats once constituted a shallow seabed separating both mountain ranges, and was eventually formed as a result of intense sediment activity which took place about ten thousand years ago, and more recently by a deposition of wind-blown sand dunes [5].

4 CLIMATIC CONSIDERATIONS

The erosion and transportation of loose soils is governed by two dominant climatic influences, namely, the amount of precipitation and windiness. (Non-cohesive soil particles in a saturated condition do not get airborne because of the increase in their weight and cohesion forces generated between neighbouring particles).
Table 1 presents a comparative summary of selected data on monthly rainfall and wind speed occurrence for Cape Town. It can clearly be seen that very little rainfall occurs between November and March and an opposite trend is evident in the data on wind speed occurrence. This results in a situation in which a substantial portion of the year is characterised by dry and windy-weather. Such a circumstance enables and promotes the propagation of erosion of unsaturated and loose soils, within densely spaced houses, which from an aerodynamics point of view, form a set of ‘bluff-body’ objects.

5 SITE INSPECTIONS: WIND INDUCED EROSION, TRANSPORTATION AND DEPOSITION

The development of housing in Delft consists of about two thousand low-income units divided into large clusters of buildings spaced in a regular pattern, typically based on an orthogonal grid. Interviews with residents of a recently established part of Delft (Roosendal), confirmed that the erosion, transportation and unwanted deposition of sandy soil constitute significant factors which negatively affects the lives of local community.

Several properties and open spaces contained wind-borne dunes of substantial sizes (Fig. 1a). In some places, the height of the deposit was up to 2 metres above the original ground level, and some sections of tarred roads were also totally covered by sand. According to residents, the process of unwanted accumulation of huge volumes of sand was typically very rapid, making any removal efforts fruitless. Several houses affected negatively by the erosion process were observed. Fig. 1b presents a complete failure of floor slab with worn-away supporting soil, which subsequently also triggered the collapse of walls.

Table 1:Comparative data on precipitation and wind speed occurrence; derived from data measured at Cape Town International Airport (1961-1990)

Months ↓	Average number of mm of rain per month	Average number of days with rainfall ≥ 1mm	Average % of time with mean hourly wind speed >10,8 m/s
January	15	3.2	8.1
February	17	2.8	6.9
March	20	2.8	4.1
April	41	5.9	1.6
May	69	7.8	1.4
June	93	10.1	2.4
July	82	9.0	2.6
August	77	9.4	3.9
September	40	7.2	2.8
October	30	5.0	4.3
November	14	2.9	8.6
December	17	3.6	7.9
Total →	515	7.0	4.2

a)

b)

Figures 1a to 1b: Effects of sand deposition and erosion

6 WIND-TUNNEL MEASUREMENTS

A wind-tunnel pilot study has been undertaken with the objective of assessing the feasibility of application of wind-tunnel technology to investigate the phenomenon of wind erosion within low-rise densely grouped buildings. The measurements were undertaken in a boundary layer wind-tunnel. A geometric scale of 1:100 was adopted and two generic layouts of houses were investigated, namely:

- orthogonal, in which houses were arranged in straight line in both directions, and
- staggered, in which every second row of houses was 'shifted' by half a stand length.

Typical size of low-cost houses was adopted as 6,5x8,5x2,5 m and an area of about 55 m^2 (in full-scale).

The investigation was carried out using a sand-scour technique. The erosion patterns which were obtained for both experimental arrangement of houses and for various wind directions were documented photographically. A sample of such a pattern is presented in Fig. 2.

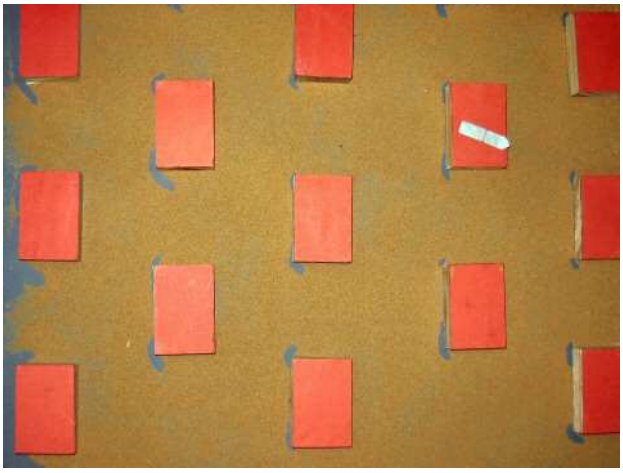

Figure 2: A sample of erosion pattern

A general confirmation of the full-scale observations was apparent in respect to the role of open, undeveloped spaces. The photographic documentation obtained from tests was subsequently digitised and converted to a graphical form. The full paper presents samples of the erosion patterns and quantitative analysis of the respective results.

7 CONCLUSIONS AND RECOMMENDATIONS

The paper presents an integrated multi-disciplinary approach to investigate wind-induced erosion around densely spaced houses which, from aerodynamics point of view, form a set of 'bluff-bodies' distributed in a regular pattern.

Results of the study demonstrate the applicability of wind-tunnel technology as a practical tool, which can be applied to predict the extent of the erosion and to investigate the optimal methods and remedies to reduce the negative impact of wind in dense mass-housing developments located on loose soils.

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