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Severe wind phenomena in Southern Africa and the related damage

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Abstract

This paper presents a review of the types and magnitude of strong and extreme wind events that develop over the southern portion of the African continent. The origin of such events is given, together with selected statistics and examples of damage. The differences in implications of these events on the built environment, in terms of the levels of engineering input and the context of formal and informal development, are discussed.

Keywords: Statistics on wind damage; Strong wind events; Southern Africa; Wind climate; Wind damage

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1. Introduction

All natural disasters, including those related to wind, have enormous socio-economic implications in terms of the sustainability of the human habitat and built environment. This issue is even more relevant to the African continent, where there is a chronic lack of appropriate infrastructure and adequate exploitation of resources on both national and regional level.

No statistics on windstorm disasters on the African continent as a whole, or even at national level, are readily available. This situation can be attributed to a lack of relevant systems of observations, communication, information transfer and storage as well as education and administration, while the low population density in some areas of the continent is also a pertinent factor.

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This paper considers the wind climate and related damage affecting built environment and its population for the countries which, from a geographical point of view, extend over the southern portion of the African sub-continent and include Namibia, Botswana, Zimbabwe, Mozambique, South Africa, Swaziland and Lesotho (see Fig. 3a).

2. Climatic considerations

The southern portion of the African continent has a diverse climate. South Africa alone is characterised by 24 climatic zones, ranging from arid desert areas to tropical zones. The climate is largely determined by the presence of the easterly trade winds, with four predominant climatic zones, namely the

- hot desert,
- dry grassland,
- subtropical, and
- tropical

as presented schematically in Fig. 1.

Typically, the most vulnerable areas affected by extreme weather events (including wind) are within the coastal countries i.e., Namibia, South Africa and Mozambique (Goliger, 2001). For inland countries (e.g., Botswana and Zimbabwe), the most critical climatically induced adverse conditions involve drought and bushfires. It should be noted, however, that wind is a factor affecting the consequences of drought (e.g. Stigter et al., 2002) and the major factor promoting the spread of bushfires.

3. Origin and character of severe wind storms

A schematic map of the occurrence of strong wind events over southern Africa, based on Griffith (1972), Lundholm (1979), Goliger and Milford (1998), is presented in Fig. 2. It can be seen that the region is dominated by coastal winds (including sandstorms in Namibia) and thunderstorms (which can generate tornadoes). Madagascar (in particular the eastern portion) and, to a much lesser extent, the Mozambican coastline are also subject to cyclonic activity.

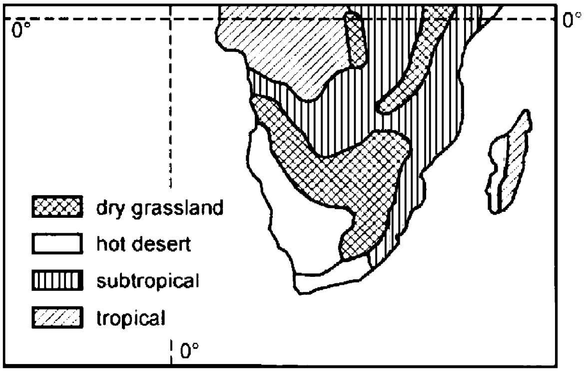

Fig. 1. Four basic climatic zones.

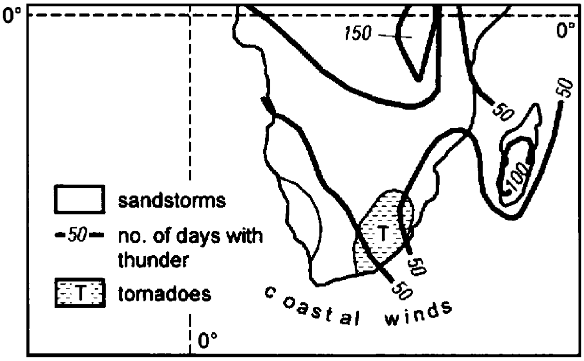

Fig. 2. Distribution of strong winds.

3.1. Coastal winds

An investigation into the geographical distribution of zones of strong coastal winds in South Africa has been undertaken by Goliger and Retief (2001) and Goliger (2002). Four prevailing types of coastal wind have been identified:

1. Coastal low buster, which occurs along the Mozambican channel and south towards the Algoa Bay.
2. Cut-off lows, westerly and easterly, which occur over the southern tip of the sub-continent and originate in extra-tropical cyclones.
3. Shallow south-easters, which develop as a result of localised coastal lows. Their influence extends along the western and southern coast of South Africa, from Luderitz (Namibia) to Mossel Bay (south-western Cape).
4. Mid-latitude lows, which are due to large-scale circulation systems that develop over the southern oceans dominated by the Antarctic circumpolar current. Mid-latitude low systems have a significant inland penetration of about 1000 km, and can envelop a large portion of South Africa.

The latter two types of wind event (i.e., 3 and 4) are of particular interest in terms of the occurrence and magnitude of devastation. The spatial extent of the occurrence of such events is presented schematically in Figs. 3a and b.

Typical south-easterly winds are ‘shallow’ as they extend up to about 1 km in the vertical direction. They generate winds between 20 and 30 m/s close to ground level (say 2 m above the ground). However, several cases of extreme wind force have been reported, including severe damage to houses and buildings, road accidents (trucks and buses being blown over) and maritime accidents (the beaching of ships or ripping off mooring). The typical range of wind speeds generated by mid-latitude lows is between 20 and 35 m/s.

Fig. 4 presents the approach of a winter storm, originating in a mid-latitude low, off the western coast of the sub-continent.

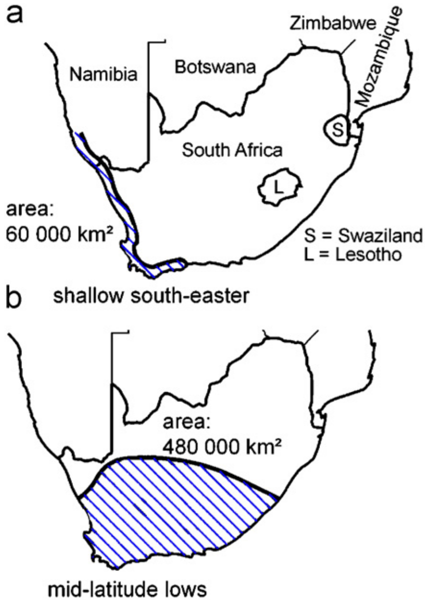

Fig. 3. (a) Occurrence zone of shallow south-easters. (b) Extent of mid-latitude lows.

Fig. 4. The approach of a coastal front.

3.2. Tropical cyclones

Tropical cyclones are generated in areas where the ocean surface temperature is greater than 27°, between latitudes 5° and 30°. On average, about 10 cyclonic events a year develop over the southern Indian Ocean, and they are regarded as less severe than tropical cyclones elsewhere in the world.

They usually travel in a westerly direction and get redirected south, to merge with westerly winds. Upon reaching Madagascar, most of the events dissipate and less than 40% of the events have sufficient strength to re-generate over the Mozambican Channel (Olivier, 1991).

In tropical cyclones developing over the southern Indian Ocean, the highest wind speeds generate over the south-eastern quadrant of the 'eye', due to the proximity of a high-pressure gradient. Research by Meteo France (2001), based on measurements at Réunion, suggest that most of the cyclones develop wind speeds of between 30 and 50 knots (up to 25 m/s, 10 min mean) although in three recent events wind speeds of more than 100 knots (more than 50 m/s, 10 min mean) were measured.

Fig. 5 maps the occurrence of cyclonic events over Madagascar and the coast of Mozambique (JTWC, 2004). This map considers only events with wind speeds higher than 25 knots, in terms of 1° on the geographical grid. It can be seen that the rate of occurrence along the Mozambican coast is between 0.02 and 0.05 per year. The inland penetration of cyclonic winds is fairly limited—typically within few kilometres of the coastline.

3.3. Intense thunderstorms

Most convective activity in southern Africa takes place in a geographic region that overlaps South Africa, Lesotho and Swaziland. Three zones of thunderstorm activity have been identified in Goliger and Retief (2001), namely weak, strong and intense thunderstorms. The outflow due to intense thunderstorms can develop wind speeds of between 20 and 30 m/s, and the spatial extent of that zone is presented in Fig. 6.

The occurrence of extreme wind conditions is associated with the intense thunderstorms that develop in the form of super cells or squall lines. These events are also known to produce localised extreme wind phenomena: tornadoes and downbursts.

Tornadoes and downbursts develop when intense thunderstorms transform to an organised structure of sufficient strength (Goliger et al., 1997). Although the geographical extent of downbursts and tornadoes is very small (typically less than a few kilometres

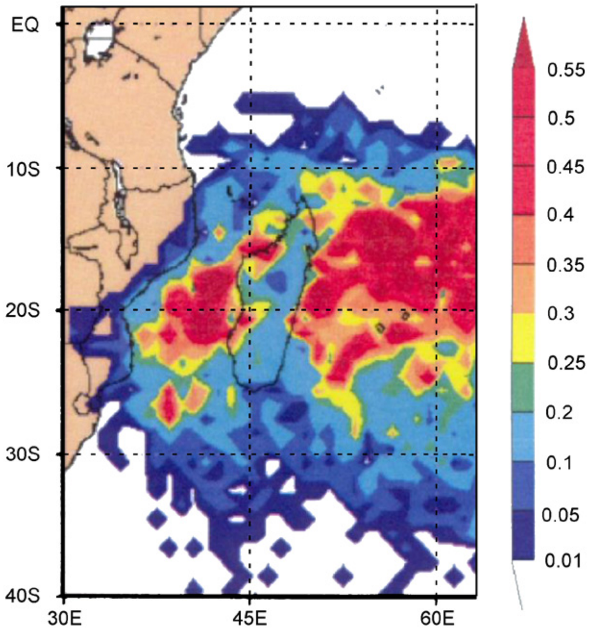

Fig. 5. Annual rate of occurrence of cyclonic events.

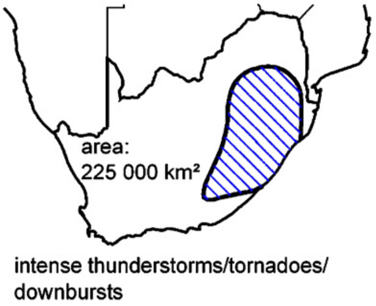

Fig. 6. Zone of intense thunderstorms.

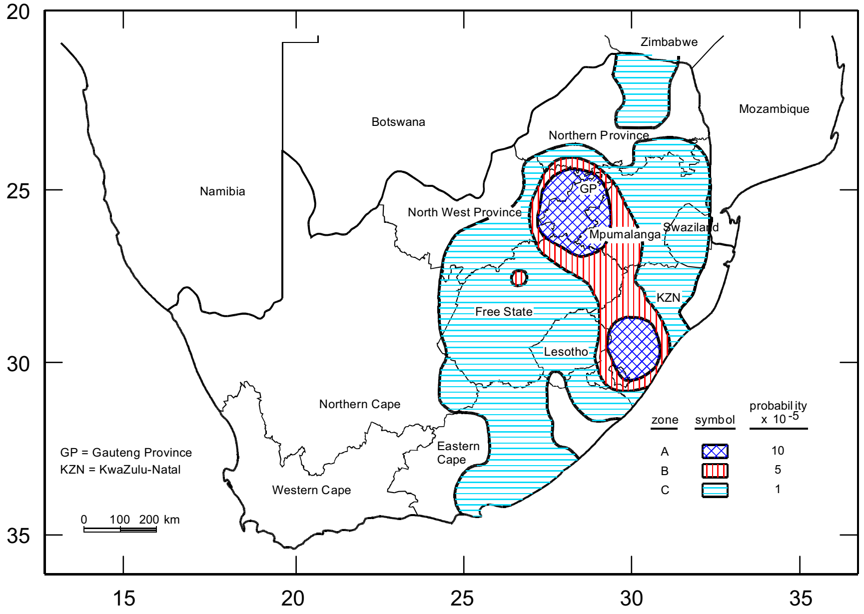

Fig. 7. Mean annual rate of occurrence of tornadoes (excluding events with an intensity of F0 on Fujita scale).

square) in relation to intense thunderstorms (with an area in the order of 2000 km^2), they can generate extreme winds in excess of 50 m/s.

Fig. 7 presents a map of the mean rate of occurrence of tornadic events in South Africa (excluding F0 events on the Fujita scale), and Fig. 8 shows a tornado funnel which developed outside Bronkhorstspruit in the north-eastern part of the country (December 1999).

4. Resistance of structures

4.1. Vulnerability: formal and informal developments

The damage to structures caused by windstorm events depends on wind hazard (i.e., risk) and the resistance (i.e., vulnerability) of structures. Broadly speaking, the damage potential is the product of risk and vulnerability (Davenport, 1997). The

Fig. 8. Bronkhorstspruit tornado (December 1999).

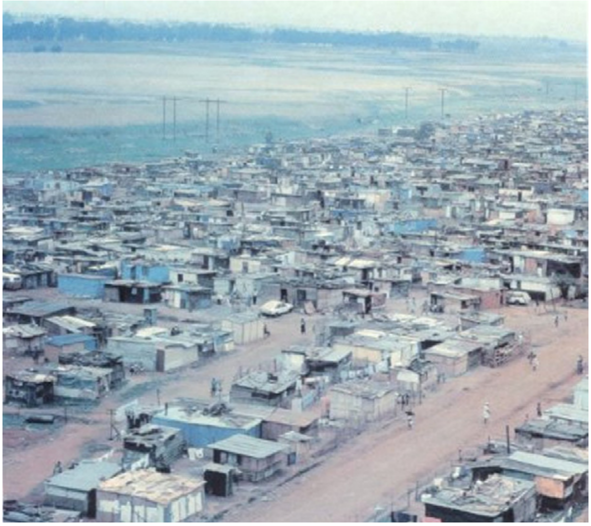

Fig. 9. An informal housing development.

vulnerability function describes the relationship between the wind speed and the consequent damage.

In developing countries (including South Africa), a large proportion of structures have little or no modern engineering input. Fig. 9 presents a typical township, which consists of informal housing units only.

In Fig. 10, the authors postulate a generic relationship between the magnitude of wind speed and the degree of damage for both types of structure (i.e., engineered and non-engineered). An assumption is made that non-engineered structures will fail at lower wind speeds than engineered structures. Furthermore, at low magnitudes of wind speed initial insignificant damage occurs, and the subsequent increase in damage with increase in wind speed is relatively small (i.e., low gradient of the curves). It can also be noted that a smaller increase in the wind speed (i.e., steeper curve) characterises the progressive damage to non-engineered structures.

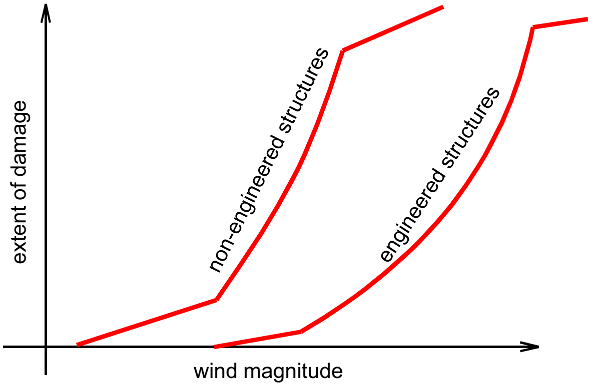

Fig. 10. Wind vulnerability: engineered vs. non-engineered structures.

4.2. Design and construction

In developed countries most, if not all, new structures have to comply with a minimum set of design specifications and/or regulations. In many cases, the regulatory requirements are also applied retrospectively, in that existing structures have to be modernised or upgraded in order to comply with current safety and structural requirements. The enforcement of these principles in developing countries is much more difficult, if not impossible. As a result, in many 'countries of the south' two mainstream types of construction markets and sectors coexist (i.e., the formal and informal).

In South Africa, the best example of this situation is the rural housing sector, in which, for various reasons, no standard requirements have historically been enforced. Furthermore, even within urban areas, a sharp contrast between the relatively high standards of formal housing and dismally low standards of informal (often squatter) areas is apparent.

Formal structures usually include some form of engineering and architectural input, and their final strength is determined by several contributing factors, which can be broadly grouped as

- design,
- approval, and
- construction stages/activities.

The informal construction sector typically refers to the erection of human shelter and other types of outbuildings. For these structures, only the third contributing factor bulleted above is applicable.

5. Damage

5.1. Examples of damage

It is useful and symbolic to initiate the discussion on wind damage by presenting the most spectacular example of wind-induced collapse of a nature-made structure. Fig. 11

Fig. 11. The ‘Finger of God’.

Fig. 12. Winter storm along the coast of Cape of Good Hope.

presents a famous landmark and tourist attraction in Namibia known as the ‘Finger of God’. This sandstone rock formation, about 35 m high and 500 million years old, maintained equilibrium in its pinnacle form for about 65 million years, until blown over during a sandstorm in December 1988.

Fig. 12 shows the beach front area of Cape Town subjected to a surge of wind and waves under the north-westerly wind, and Fig. 13 the remains of a container crane which overturned and collapsed in the Port Elizabeth harbour under shallow south-easterly winds.

The most significant damage to human development over the inland areas of the southern African region is caused by tornadoes and downbursts. A comprehensive analysis of these events has been included in Goliger et al. (1997). The two largest tornadoes which occurred recently were

- the 1988 Edenburg–Senekal event, with a path length of over 140 km, and which crossed over mostly unpopulated areas and introduced relatively little damage, and

Fig. 13. Collapse of container crane.

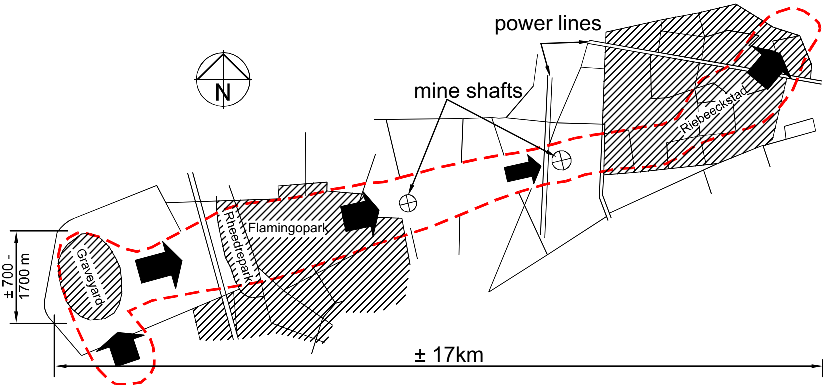

Fig. 14. Path of Welkom tornado (March 1990).

Fig. 15. Devastation of Albertynsville (November 1952).

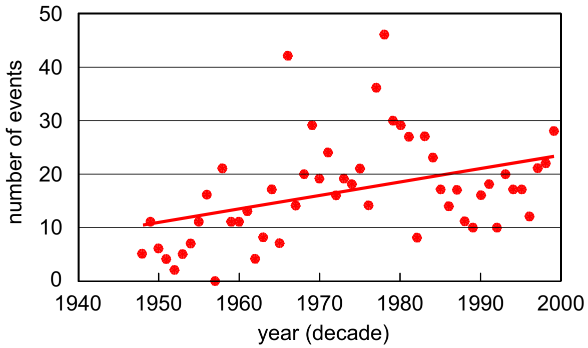

Fig. 16. Annual numbers of wind damage events.

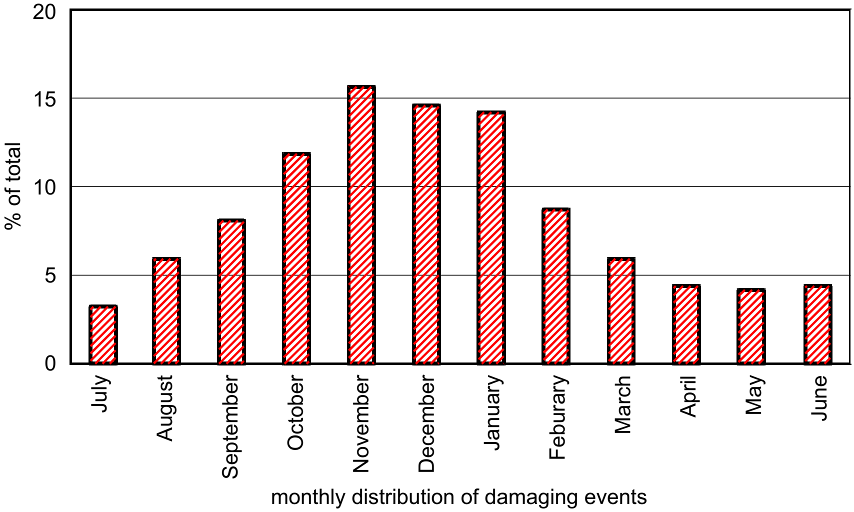

Fig. 17. Monthly distribution of damaging events.

- the 1990 Welkom tornado, which originated in a 240 km long severe storm front, had a width of up to 1.7 km, and proved to be the most devastating (in monetary terms) in South Africa's history—affecting, amongst other things, 4000 houses and 17 power lines. A schematic diagram of this tornado's footprint is presented in Fig. 14.

One of the most tragic events was the 1952 tornado, which crossed over the southern suburbs of Johannesburg, killing 24 people and injuring more than 600. An aerial view of the damage to the Albertynsville township is presented in Fig. 15.

5.2. Statistics

There are no statistics on windstorm damage and disaster on the African continent. In South Africa a wind-damage database has been set up, based on the surveys of the archives of the Weather Service, the State Library and the CSIR (Goliger, 1999). The database includes records of about 1000 events, about 30% of them classified as tornadoes.

The initial statistics of the database are presented in Figs. 16–20. In Fig. 16 a trend, in which the number of wind-damage reports has increased since 1948, is evident. This could be attributed to the increase in population density (i.e., the density of human development), better administrative and reporting procedures, and possible climatic change.

The monthly distribution (Fig. 17) indicates that, contrary to common belief, most wind-damage events occur in and around the summer months (September–February).

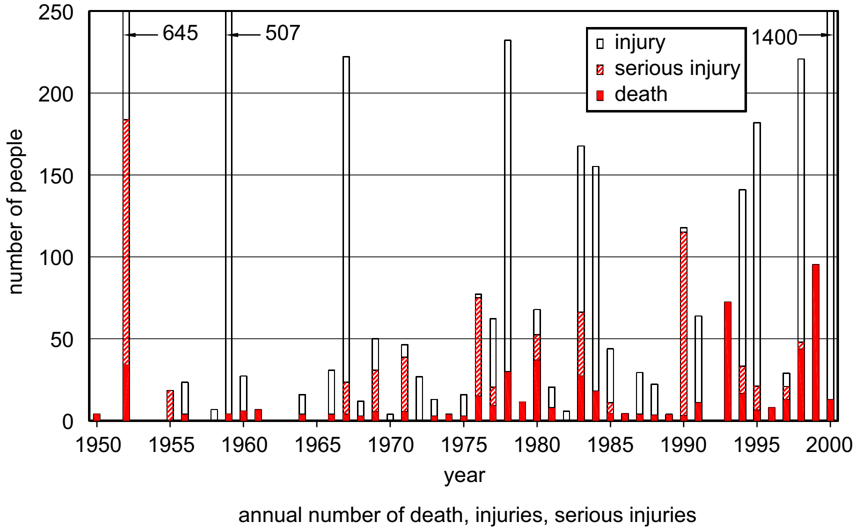

Fig. 18. Life and limb loss in strong wind events.

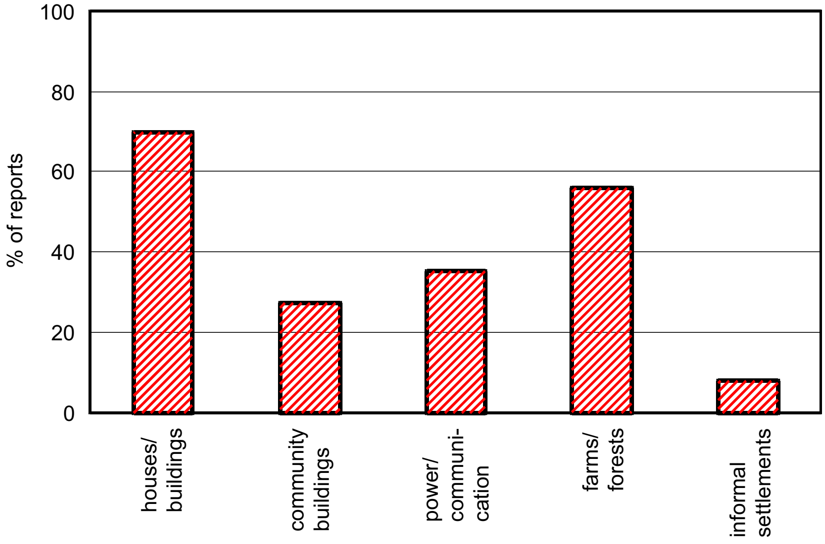

Fig. 19. Damage to various types of structure.

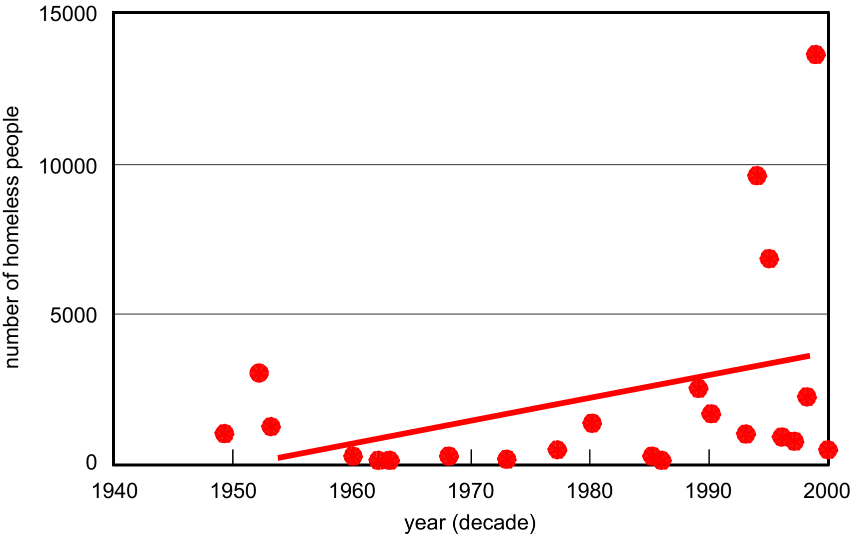

Fig. 20. Annual number of homeless people.

These are mainly to the result of thunderstorms, downbursts, tornadoes and south-easterly coastal winds.

Fig. 18 presents the information on loss of life and limb due to windstorms, with 1400 people affected in the year 2000. The large number of injuries and deaths in the 1950–1960 decade were due to two large tornadoes. Descriptions of these events suggest that most loss of human life resulted from the direct failures of shelters (i.e., structures) and airborne debris originating from such structures.

Fig. 19 analyses the nature of damage in respect to various types of structure. It can be seen that about 70% of the reports included damage to houses and buildings, 25% to community structures and 35% damage to power and communication systems. The close to 60% damage shown to farms and forests confirms the analysis recently made by Stigter et al. (2005) on wind and agriculture in Africa.

The information on damage to informal settlements and possibly also the rural areas, is grossly underestimated, owing to poor communication and reporting systems, and further compounded by the historically inadequate coverage by the media.

This statement is supported by the analysis of the number of people rendered homeless as a result of wind events shown in Fig. 20. In recent years, with more attention being paid to underdeveloped communities, a significant increase in the number of homeless people has become evident. This is largely owing to better reporting on damage in areas of mass housing and informal developments.

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