Wind Resilience – What Do We Mean By It?

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Abstract

Resilience is a current buzz word that is receiving increasing use in respect of the built environment, particularly in regard to disaster risk management. Unfortunately it is often misused. The primary purpose of this paper is to educate wind engineering researchers on the correct use of the term, and provide information on sources of information which could be useful if addressing the issue in detail.

Introduction

Resilience is a current buzz word. Inserting "resilience" in Google produces approximately 40 million results covering a wide range of subject areas in which it is used. It is a far cry from its use 60 years ago. The 1946 edition of the Pocket Oxford Dictionary (Fowler & Fowler, 1946) defines resilience as 'the power of resuming the original form after compression' or 'elasticity both literally and figuratively'. At the time its primary use was probably literally as a mechanical property of materials but today the figurative use dominates. While the Oxford Dictionary (OUP, 2014) still lists the mechanical material property of the 'ability of a substance or object to spring back into shape' as one use of the word it also lists a second use as a generic term to describe 'the capacity to recover quickly from difficulties' which extends the meaning to include time dependency although still retaining conceptually something of the original Latin word 'resilio' which meant rebound. While the first use implies almost instantaneous rebound with the level of resilience being defined by the amount of rebound, the second use assumes a recovery time and implies that the level of resilience is a measure of the time taken to rebound. Inherent in both uses is that the level of resilience will be a function of the level of impact or difficulties.

A consequence of the generic character of the word is that in using the term resilience for it to have specific meaning it is necessary to specify resilience of what to what, with the latter also including the level of the impact or difficulties.

Areas of Application

The word has been adopted by a range of disciplines to describe this ability to recover from an abnormal impact in a timely manner. These uses can be divided into 3 groups as follows:

- Its traditional use as a mechanical property of material describing its ability to recover its original form if subjected to a transient abnormal load.
- Its use as a human behavioural characteristic describing the ability of individual human beings to recover from the psychological, physical and economic impacts of abnormal personal experiences. This is probably now the most common use of the word.
- Its use in a community sense when used to describe the capability of a community of interest to recover from a specified event. The community of interest may be a local community, a region, or a nation. Alternatively it may be used in respect of individual components of the community of interest such as:
    - Groups of people within a community – eg young. old, women, men, disabled, families etc

- The economy of the community – employment, wages, house prices, retail spending, construction activity, etc
- Organisations within a community – businesses, local, state and national governments, defence, emergency, medical, etc
- The natural environment – eco-systems, individual species, etc
- The built environment – buildings, water supply and sewerage facilities and networks, transportation networks, power generation facilities and transmission networks, communication networks, etc

There are interactions between these separate forms of resilience. The mechanical resilience of building components of buildings and other manufactured or constructed elements of infrastructure contribute to the resilience of the built environment. The resilience of the built environment contributes to the resilience of community groups, the economy, organisations and individuals, and together with the resilience of the natural environment they all contribute to the resilience of the whole community.

Forms of Impact

In relation to mechanical resilience it can refer to different levels of:

- Shock Loads – eg explosions, vehicle impact, hail, bullets, debris
- Extreme mechanical loadings – wind, earthquake, floods, snow
- Other loadings such as fire, extreme solar heat, extreme cold

In relation to individual resilience it can refer to different levels of:

- Medical disorders both psychological and physical
- Accidents causing bodily harm and/or financial loss
- Financial difficulties from loss of income, business failure, poor financial self-management,
- Impact of family disruption arising from death of loved ones, family break-up, etc
- Personal impact of catastrophic events such as severe storms, tropical cyclones, floods, droughts, earthquakes, etc.
- Social disruption due to war, terrorism, riots, etc.

In relation to community resilience it can refer to different levels of:

- Severe natural events such as severe storms, tropical cyclones, floods, earthquakes, droughts.
- Severe economic downturns.
- Major outbreaks of contagious diseases.
- Impact of war, terrorism or national or political decisions having severe negative consequences for community.

Wind Resilience

The term 'wind resilience' usually refers to the impact of severe winds on the built environment but it can include impact on natural environment – eg forests – and impact on individuals - eg pedestrian comfort in city centres.

In respect of the built environment it may refer to the impact of winds on an individual constructed asset, a group of similar constructed assets, or all constructed assets in a community. Constructed assets may be houses, commercial buildings, industrial facilities, government offices, schools, hospitals, bridges, transmission lines, water supply and sewerage pipelines and facilities, dams, port structures, etc etc

Use of the term 'wind resilience' may refer to:

- The mechanical resilience of a constructed asset to wind loads from any source.
- The resilience of a constructed asset in terms of its functionality to wind loads from any source.

- The resilience of a group of constructed assets in terms of functionality to particular events causing extreme winds – eg severe storms including tornadoes, tropical cyclones, blizzards, etc – where the mechanical resistance of constructed assets to wind loads will be a contributing factor but cannot be described as a measure of the resilience .
- The resilience of a community against major catastrophic events producing severe winds such as tropical cyclones and severe storms including tornadoes where the performance of all the constructed assets in a community when subjected to severe winds will be a contributing factor but cannot be described as a measure of the resilience.

A common fallacy in discussing wind resilience is to assume it can be measured by the wind code design criteria used. Only in respect of the first item – ie mechanical resilience – can the resilience of a building be directly related to the strength against wind loads, and then only for wind speeds up to the ultimate limit state design wind speed. Remembering that resilience is a measure of the ability to recover from an impact, not the ability to resist an impact, we can say that each constructed asset should be fully resilient to winds with wind speeds less than the serviceability limit state design wind speed. Above the serviceability limit state design load a building element may resist a load but suffer damage in the process. If damage occurs the level of resilience could be measured by the level of damage as a function of wind speed. If normal design objectives are met at least 95 per cent of constructed assets would be expected to be reasonably resilient to wind speeds less than their ultimate limit state design wind speed. How resilient they will be to wind speeds higher than the ultimate limit state design wind speed will depend on the nature of the design and the materials used. Brittle structures and constructed assets finely designed to satisfy code requirements but with few redundancies to provide any added factors of safety may have little or no resilience at this level of wind speeds, while others that possess larger coefficients of variation of strength due to inherent redundancies, material properties or more approximate and more conservative design may possess considerable resilience at this level on average. So even in the case of mechanical resilience it is not possible to fully describe the wind resilience of constructed assets just in terms of current code design criteria. Assuming it can be is one of the major common misconceptions regarding resilience of constructed assets. It depends on factors outside the scope of normal design criteria as earthquake engineers discovered when investigating the earthquake damage in Christchurch. Nor can it be described by a single value or index. Expressions such as 'this building is more resilient than this one' are meaningless unless the level of loading is also specified.

When resilience is expressed in terms of the functionality of constructed assets, although a function of design criteria inasmuch as for winds below their serviceability limit state design wind speed constructed assets should be fully resilient, above this limit the critical factor is not damage per se but whether any damage arising from overstress of individual elements is sufficient to render the constructed asset unusable for a period of time. If it does then the level of resilience will be a function of how long it takes to restore the building to a usable condition. The functionality will also be dependent on other factors such as water entry from wind driven rain which are separate issues from structural design. A building may suffer only minor structural damage but be rendered unusable due to water damage to internal linings and contents. The worst case scenario would be destruction of the building in which case the level of resilience would be a function of the time it takes to replace the building including the provision of temporary alternative accommodation. A Fijian bure at risk from destruction from a tropical cyclone may be more resilient than a normal building suffering significant damage because of the rapidity with which it can be rebuilt. Consequently if functionality is the critical issue for resilience it is only possible to talk about the contribution of the structural design for wind to resilience, not the resilience to wind per se. And again this contribution can only be described in terms of the level of winds relative to design levels.

When resilience is expressed in terms of disaster mitigation, which is the most common context in which the word is used in respect of the built environment, then the design wind speed is just one factor in many factors affecting the resilience. In this case it refers to the capacity of individuals, businesses, organisations and governments and the community as a whole to recover physically, economically and socially from an event having a major impact on them. In respect of normal wind design these events are usually natural events such as tropical cyclones, severe storms including tornadoes and extra-tropical intense low pressure systems and it is the full impact of the events that is important including the effects the associated heavy rain, coastal storm surge in respect of tropical cyclones, and hail in the case of severe storms. An important contribution to this will be the resilience of different types of constructed assets in terms of functionality, but an additional factor will be the cost of repair of physical damage and restoring functionality including the contingent costs of the disruption of goods and services arising from the damage and the cost of providing temporary alternative accommodation. Whether or not building damage is insured may be as important as structural adequacy as far as the community resilience is concerned. Because current design criteria is primarily focussed on life safety which is a function of mechanical resilience, design code criteria on its own cannot be used as a measure of disaster resilience, although it can make a significant contribution to it depending on the level of its implementation in the community.

Governments and Resilience of the Built Environment

A significant aspect of disaster resilience is macroeconomic resilience which is concerned with the recovery of national economies from disasters. Resilience in this respect will be a function of such things as the size of the economy, the degree of building stock in reserve and the level of financial protection from insurance, reinsurance and other forms of financial protection relative to the magnitude of the potential disaster loss. Macroeconomic resilience is becoming an increasing issue for governments worldwide. Driving it is the escalating economic and social costs of disasters arising from the impact of severe natural or man-made events in both the developing and developed world as a result of the increasing concentrations of population in large urban communities, and the increasing wealth per capita in these (Pielke et al, 2008). The added possibility of the magnitude of the weather related hazards associated with these events being amplified by climate change is an additional concern. For the major international agencies like the United Nations and the World Bank who are faced with trying to relieve the impact on developing countries, the OECD, and national governments of developed countries, increasing macroeconomic resilience to such events is increasingly being seen as a significant part of disaster risk reduction.

Examples of this are:

- The United Nations biennial global assessment reports on disaster risk reduction (UNDISR, 2013).
- The Global Facility for Disaster Reduction and Recovery which is hosted by the World Bank (GFDRR, 2014).
- An OECD Working Paper on risk and resilience (Mitchell, 2013).
- A report on increasing resilience to national disasters in the US (Tsai, P., 2013).
- The national strategy for disaster resilience produced collaboratively by the Australian Federal and State Governments (Australian Government, 2012) and an associated discussion paper on resilience of the built environment issued by the Australian Building Codes Board (ABCB, 2014).
- The New Zealand Government's vision of achieving a resilient national infrastructure by 2013 (New Zealand Government, 2011).

Associated Research and Implementation

A major consequence of the interest by governments and supranational organisations in community resilience has been significant funding of research and development and its implementation related to this resilience with the establishment of some major collaborative groups focussed on it.

Some examples of this are:

- The International Council for Research and Innovation in Building and Construction (CIB) has established a Task Group TG87 Urban Resilience: Benchmarking and Metrics and a Working Group WG120 Disasters and the Built Environment (http://www.cibworld.nl).
- The emBRACE project sponsored by the European Commission, which 'aims to improve the pan-European framing of the resilience concept using interdisciplinary, socially inclusive and collaborative methods.' (http://www.embrace-eu.org/home), a significant activity of which is the public DISASTER-RESILIENCE on-line discussion group which they sponsor. (http://www.jiscmail.ac.uk/disaster-resilience).
- The European Commission also sponsors RAMSES, which stands for Reconciling Adaptation, Mitigation and Sustainable Development for cities, and which is focused on adaptation of the built environment to climate change and addressing resilience as one of its parameters. (http://www.ramses-cities.eu/).

- The 100 Resilient Cities Project sponsored by Rockefeller Foundation is dedicated to helping cities around the world become more resilient to the physical, social and economic challenges that are a growing part of the 21st century. (http://www.100resilientcities.org/).
- The Community and Regional Resilience Institute (CARRI) which is largely funded by the US Government. (http://www.resilientus.org/).
- Closer to home Resilient Organisations (ResOrgs) is a collaboration between top New Zealand research universities, particularly the University of Canterbury and the University of Auckland which is funded by the Government's Natural Hazards Research Platform and supported by a diverse group of industry partners and advisors. (http://www.resorgs.org.nz/).

A key characteristic of all these groups is their multi-disciplinary nature, reflecting the multi-disciplinary nature of the term resilience when applied in the context of community recovery.

Concluding Remarks

Resilience is an excellent word to describe an important behavioural characteristic of people, organisations and physical objects like building, but as a generic word it is easily misused. The primary purpose of this paper is to clarify the meaning of the term resilience for those tempted to use the word in respect of their wind engineering research activities and to provide some sources of information which may be useful for those who wish to pursue the issue more seriously. The most common use of the word resilience in respect of the built environment is in the context of community disaster resilience. When used in this context it can only be effectively studied and used in a multi-disciplinary context. This can be a challenge for many researchers highly focussed on a single discipline.

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