An Approach to the Effects of Environmental Change on Building Design and Construction

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ABSTRACT: The environment, both the natural and the anthropogenic, is in a state of constant change. So, too, are the factors influencing the environmental behaviour of buildings. The construction or demolition of a building, for example, implies a change in a set of environmental parameters which may have influenced the design and construction of the buildings already present in the area and controlled their environmental performance. These changes depend upon the buildings' relative position, as well as their size and other characteristics of form and shell. This paper studies the changes in environmental parameters that may occur in an area and are related to the architectural design and the environmental and energy behaviour of buildings. It also evaluates and classifies the consequences of such changes and, wherever applicable, attempts to propose measures that could predict and control their results.

Keywords: building, design, construction, environment

1. INTRODUCTION

In order to realise its aims of creating comfortable, energy-efficient and environmentally wise buildings, environmental design uses and elaborates features that seek to exploit the beneficial effects of the elements of nature, such as the sun, the wind, earth and air temperature, moisture etc. These features, both qualitatively and quantitatively, are connected with the position of the building under study and the time at which the study is carried out. Although it is certain that future changes of one kind or another will have to be made to the features used in the study, generally it is not easy to predict what these will be and so take them into account. This fact, which justifiably causes embarrassment in all cases of environmental design, reflects a reality, which can be explained by the changes that are constantly taking place in both the natural and anthropogenic environments. Sometimes these changes are slow and in practice have no effect on the environmental behaviour of buildings. In other cases, however, they occur within the lifetime of a building and have a considerable impact on its environmental behaviour. It is the changes in this second category that constitute the subject of this study. To be precise, this study records and examines the changes occurring in the natural and anthropogenic environments that have a detrimental effect on the factors that determine the interaction between a building and its environment. This study pinpoints aspects of environmental design which could prove pointless in the future as a result of changes in the environment of the building concerned. The study also investigates the scope for predicting the changes that might occur in a building's environment and the effects they might have on it. Wherever applicable, it proposes ways of exploiting the possibilities of predicting these changes in the environmental design process.

2. ENVIRONMENTAL CHANGES AFFECTING THE INTERACTION BETWEEN A BUILDING AND ITS ENVIRONMENT

Environmental changes can, for methodological reasons, be divided into two categories: natural and anthropogenic.

2.1 Natural changes

Some natural changes occur on a geological time-scale and in this sense their effect on buildings is non-existent (e.g. continental drift or large-scale climatic changes). Others take place on a shorter time-scale and so have effects that are only visible many years later. This category includes, among other things, land subsidence and erosion, siltation and coastline changes. It also includes changes in the fauna of a particular area (e.g. desertification). Usually the effects of these changes on buildings and technical works in general are traced in archaeological surveys. There are other natural changes, however, that occur in a shorter timespan and with greater frequency, whose effects on the buildings lying within their range of impact can be clearly seen. The most typical example is that of earthquakes, whose effects on the buildings in the area in which they occur are often catastrophic. Equally important are the effects of so-called natural disasters (e.g. floods, landslides, landslips, windstorms, volcanic eruptions, large fires). Many of these disasters involve the buildings themselves. Could there be more blatant examples of the effects of the environment on buildings? Aside from this, the changes that are caused – apart from the damage

they cause to the landscape, which itself affects the living conditions of the local inhabitants – also have other, more conventional effects on the environmental behaviour of buildings. These are detrimental effects of a permanent or temporary nature on the microclimatic features of the area affected, which cover a wide range of environmental parameters (e.g. temperature, humidity, wind, air quality etc.). The destruction of a forest, for example, brings about considerable changes in almost all the microclimatic factors of the wider surrounding area, and a direct and serious impact on the environmental behaviour of the buildings situated in it. Likewise, the contraction of diseases by plants, which help to protect a particular building from the sun, noise, wind etc., represents a great blow to the environmental behaviour of the building concerned.

2.2 Anthropogenic changes

Anthropogenic changes generally occur more frequently and have more tangible effects on the environmental behaviour of buildings.

One category of such changes concerns natural changes which are caused, intensified or accelerated as a result of human intervention. In effect, all forms of natural disaster, even earthquakes, can fit into this category.

Apart from natural disasters, many of man's activities on the planet cause considerable changes in the environment, with consequent effects on buildings. Atmospheric pollution, for example, either on a local or a wider scale, is a factor which is directly connected to human activities and influences the environmental design of buildings [1]. The same is true of traffic, industrial and environmental noise. Building construction, in its broader sense, can produce numerous changes in the microclimate of a particular area. The urban climate, which encapsulates these changes, produces a different set of values for climatic parameters as a whole to those produced by the natural environment [2]. The heat island phenomenon, albedo change, and change in the roughness of the ground surface are some of the mechanisms responsible for this.

In the case of anthropogenic changes of a more localised nature, one may discern a large category of such changes that are produced when a technical work (e.g. a building) is built in such a position that it acts like a shield against the environmental influences on other buildings in the area. These influences include direct and indirect solar radiation, external sound and wind. While the presence of an obstacle in the path of solar radiation or airborne sound causes them to decrease in strength, this is not generally true in the case of wind. An obstacle in the path of the wind will certainly cause it to change direction yet, as far as the wind's strength is concerned, it is likely to make it increase or lose force in lower-lying areas. The effects of the construction of a new building in a particular area can also include restrictions on the views available from already existing buildings: views, as a quality factor in the internal environment, constitute a basic parameter in environmental design. The impact that the screening effect of neighbouring structures has on the environmental behaviour of a building can also be understood from the fact that such structures have always been desirable for the protection they provide against environmental influences (e.g. as solar, noise and wind barriers).

Generally, the closer an obstacle is to the building it obstructs, the more intense are the screening effects. Even so, their impact can be felt over long distances, depending on the conditions. For example, the shadow of a building lengthens as the sun draws closer to the horizon. A case worth special mention is that of the construction of a building very close to or even directly against another. In this case all of the environmental influences on the section of the shell covered by the adjacent building are eliminated. More specifically, in this section of the shell there is absolutely no incoming solar radiation or wind pressure and complete protection from environmental noise and driving rain. Also, in this section there is a reduction in the thermal transmittance coefficient.

The demolition of a neighbouring building (or any kind of technical work), on the other hand, can have the opposite effect on the interaction between a building and its environment. In this case the screening effect is lost completely and the exposed sides of the building are completely vulnerable to environmental influences. If the demolished building stood against another, then the exposed side of the remaining building acquires the properties characteristic of a shell, which it did not previously possess.

The proximity of two buildings can cause interactions that do not belong to the screening effect category. A typical example is the radiation exchanged between their opposing surfaces. This phenomenon, combined with a low air flow in the intermediate space, may cause the buildings to become overheated. A similar phenomenon is the reflection of sound waves, again on their opposing surfaces. The proximity of two buildings can cause channelling of the wind or create conditions leading to a reduction in air flow in the intermediate space, in which case there is a possibility of aerial pollutants accumulating there. All these phenomena represent changes in the environmental characteristics of a building arising from the construction of another building (or technical work) in its vicinity. Conversely, the demolition of a building standing close to another effectively eliminates the conditions that can cause these phenomena to appear.

This category – the consequent environmental effects of anthropogenic changes – may also include those effects created by the buildings themselves. Buildings house activities which usually produce some form of pollution. Air pollution is carried by the wind and affects the buildings in the local vicinity. The same is true of noise produced inside the building. The water pollution and production of solid waste that are connected with the functioning of a building have a degrading effect on its surroundings, which also affects the neighbouring buildings. To these factors can be added the loss of privacy that the close proximity of buildings entails, a fact which should concern architectural and environmental design.

Yet it is not only environmental changes that affect buildings in different ways. The buildings themselves,

in the changes they undergo chiefly in the area of wear and tear, receive and absorb environmental influences in a different way. These changes include wear and tear on the elements of the shell (e.g. door and window frames), decay in the structural and insulating materials, and wear and tear or failures in the systems for controlling environmental influences. Even a change in colour or pollution of the external surfaces of a building can induce changes in its environmental behaviour.

3. THE EFFECTS OF ENVIRONMENTAL CHANGES ON THE ENVIRONMENTAL DESIGN OF BUILDINGS

The possibilities of predicting the changes that might occur in a building's environment are limited, given the diversity and complexity of the factors that cause them. An extreme value analysis can calculate the statistical probability of a physical quantity exceeding a specific rate within a specific period of time. This method is applied in natural phenomena of graduated intensity, which usually take the form of natural disasters (earthquakes, floods etc.), so that the dimensions of technical works can be calculated to ensure they can cope with the loads involved [3]. Statistical methods are also applied for the assessment of the progression in the feature of some critical for the environmental design parameters, like weather data [4,5]. However, in the case of the anthropogenic changes that can affect the environmental behaviour of buildings, there are no reliable methods for predicting them. Some of these changes may be predicted on an empirical basis. For example, in an area with a high construction rate it is very likely that at some point a free plot of land will be built on. Other changes may already be at the design or planning stage so, their realisation can be regarded as imminent. Others can perhaps be excluded because present circumstances do not permit them. For example, it is unlikely that a building will be constructed on a site where building is legally prohibited (e.g. a road or a square). Generally, it could be accepted that in any area there are certain indications or suspicions that could serve as a guide to predicting future developments in its anthropogenic environment. Of course, the possibilities of these predictions coming true fade as time goes by.

However, apart from the difficulty of predicting changes in the environment, even when changes can be predicted or are thought likely to occur, it is not easy to assess exactly what changes they will bring about in the environmental behaviour of the buildings they affect. For example, when a new building is constructed it is generally possible to predict that it will affect direct solar radiation in the local area. However, it is extremely difficult to determine how it will affect the formation of the wind pressure field on the shell of an adjacent building and how this, in turn, will affect the natural ventilation conditions in the building's interior.

4. THE ENVIRONMENTAL DESIGN OF BUILDINGS IN THE LIGHT OF ENVIRONMENTAL CHANGES

The abundance and variety of ways in which the factors determining the interaction between a building and its environment can change in effect cast doubt on many aspects of environmental design, and certainly degrade it. A building designed to behave in a certain way towards its environment may soon end up behaving differently because the environment has changed. These changes do not have an equal effect on all aspects of the environmental design of a building. For example, it is possible that the building's exposure to external noise may be affected but not its exposure to solar radiation. What is more, neither do they have an equal effect on all the different sides and areas of the building.

Given this reality, it is interesting to investigate the possibilities of dealing with its consequences.

4.1 One set of choices involves the incorporation into environmental design of a number of parameters that will take account of future changes to the environment of the building under study.

- As a step in this direction, extreme value analysis can provide useful data on aspects of environmental design that concern statistically quantifiable effects (e.g. earthquake resistance, the pitch of a roof to prevent accumulation of snow etc.). Likewise, useful may be the results of the methods producing design weather data that accounts for future changes to climate.

- In the case of changes that may be predicted on an empirical basis, it would be useful if a systematic record and assessment could be made of these, alongside the record of environmental data for the site where the building under study is to be constructed. In the case of effects of directional nature, the record could include the sides or areas of the building that are likely to be affected. The findings of this record are likely to form a framework of interaction between the building and its environment, which differs from that presented by the usual picture of 'the existing situation'. Yet insofar as this provides a more realistic idea of the conditions in which the building will function, it will prove useful in many different ways in its environmental design. One obvious way in which it will be useful is to indicate environmental influences and probably also the sides or areas of the building where it would be advisable or not to install structures to deal with the effects of these influences, depending on the degree of the changes predicted. For example, it would be logical to avoid the use of Trombe walling in places which are likely to be covered by the shadow of a building that is due to be erected. Also, it is logical to make greater provision for soundproofing on sides where noisy activities are likely to occur.

- Apart from taking account of certain changes that are thought likely to occur in a building's environment, it is advisable, as part of the environmental design process, to provide for measures that will enable the behaviour of the building to adapt to a wide range of changes in its environment. Here we are principally concerned with

measures whose cost of implementation at the construction stage is relatively low and multiplies if the measures need to be carried out at a later stage. For example, increasing the thermal insulation of the shell in order to cover future increases in heat loss is a measure which it is clearly better to implement at the construction stage. Similarly, it is better to damp-proof a basement at the construction stage, regardless of whether underground water courses have been located, rather than having to do it at a later stage because of a rise in the local ground-water level.

4.2 An important role in dealing constructively with the problem of the effects of environmental changes on the environmental behaviour of buildings can be played by appropriate relevant legislation. The wider community normally finds it necessary to protect itself against unrestrained decision-making by individuals owning particular sites, and society lays down a set of legally binding constraints designed to regulate the impact of new buildings on the environments of their adjacent sites. Such regulations also attempt to prevent land uses arising which either are incompatible with the wider aims of society and/or which conflict with the zoning arrangements established on environmental planning grounds in the interest of the wider community. Such legal constraints on the range of socially acceptable decisions are necessary to ensure that client and architect do face up to their wider social responsibilities. Rights of light, for example, have existed since Roman times. Unfortunately, legal rules usually have to be relatively simple to be workable and for this reason they are often scientifically crude. There is always an important distinction between what is legally acceptable and what is environmentally desirable. The pressures on land often force the issue towards the minimum standards accepted by the law. However, these apparently simple rules are of fundamental significance because they determine the range of acceptable forms lying within the rules, and therefore influence the local climates likely to come about. Unfortunately, the legal rules governing urban form were often established when urban environmental problems were relatively poorly understood. Therefore they should be considered as a subject requiring critical re-examination from the environmental point of view. There are other sets of environmental rules fixed on considerations of health; the link between the drafted rules and health, however, is often obscure, some being based on ill-founded medical beliefs of the mid-nineteenth century. Such rules affect built form and therefore local urban climates.

4.3 Yet even apart from legislation, the design of a building (or, more generally, a technical work) often leaves further scope for dealing with the environmental changes caused by its construction and the effects these have on the buildings in its vicinity. Thus, in investigating alternative solutions, it is possible and advisable to pinpoint and favour those which are less detrimental to the environment and have less impact on the environmental behaviour of the buildings that are likely to be affected. Examples of these are solutions concerning the spatial form of the building under study, the orientation and formation of its external surfaces, the positioning of air ducts etc. Also, it is advisable for the construction of a technical work to be accompanied by supplementary works designed to protect the environment and reduce the disturbances caused by the work both at the construction stage and when it is actually functioning. This recommendation is of greater importance in the case of environmental factors that have been seriously degraded in contemporary urban environments. This category could include works and measures concerning sound protection, pollution restriction etc.

5. CONCLUSIONS

Although in all forms of design there are cases in which data changes in the course of time, in environmental design such symptoms are more frequent and more pronounced and concern more aspects of the subject. In other words, compared with other forms of design, it appears that the relationship between environmental design and time is more dynamic. A simple example to demonstrate this point is the provision of trees to provide protection against the sun, noise and wind etc. This measure requires a long time (often years) to take effect and produce the desired results. Another example is the uncertainty regarding the result that characterises many of the choices made in environmental design. Although mathematical simulation models are invaluable tools for predicting the environmental behaviour of a building under study, it often takes a long time after its construction before the choices made can be seen to have been right or wrong.

Another area in which the correlation between environmental design and time can be seen is that of the changes that occur in the interaction between buildings and their environments as a result of changes in the environment and in the buildings themselves.

This study methodically presents the changes that occur in the natural and anthropogenic environments and examines their effects on the parameters involved in the environmental design of buildings in a particular area.

With regard to the way in which these effects could be dealt with, it proposes that environmental design could be improved by combining a) the extreme value approach, in the case of effects caused by natural phenomena of graduated intensity, with b) the empirical prediction of the disjunctive or qualitative effects of such phenomena, thereby adapting the design data to a more realistic framework for the behaviour of the building under study. Environmental design could also be improved by c) broadening the resistance to environmental influences of the measures proposed within the framework of a study; d) supplementing the relevant legal framework, and e) incorporating into the environmental design of technical works measures limiting the effects of these works on their local environment and the buildings already existing within it.

REFERENCES

[1] N. Papamanolis, Air Pollution as a Parameter in Building Design and Construction, Proc. Fifth Int. Conference on Environmental Pollution, (2000), 80.
[2] H. E. Landsberg, The Urban Climate, Academic Press, London, 1981.
[3] Enrique Castillo, Ali S. Hadi, N. Balakrishnan and Jose M. Sarabia, Extreme Value and Related Models with Applications in Engineering and Science, John Wiley & Sons, New York, 2004.
[4] D.H.C. Chow, G. Levermore, P. Jones, D. Lister, P.J. Laycock and J. Page, Extreme and Near-Extreme Climate Change Data in Relation to Building and Plant Design, Building Services Engineering Research and Technology, Vol.23/4 (2002), 233.
[5] S.E. Belcher, J.N. Hacker and D.S. Powell, Constructing Design Weather Data for Future Climates, Building Services Engineering Research and Technology, Vol. 26/1 (2005), 49.