An Overview of the Balcony’s Contribution to the Environmental Behaviour of Buildings

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ABSTRACT: Balconies constitute an important element of the architecture of buildings in a broad spectrum of geographical areas. Especially in areas with a mild climate, they represent an inseparable and characteristic component of the local architecture. The main purpose of a balcony is to offer the inhabitants quick and easy access to the environment. Nevertheless, in parallel with their functional role, their presence on a building’s façade influences several mechanisms that determine the interaction between the building and its environment. Such mechanisms and the resulting influences concern numerous aspects of building physics, like sun-control, daylighting, heat transfer, damp protection, sound insulation, wind-loading, natural ventilation, etc. Accordingly, the building’s energy behaviour is also affected. This paper examines the role of balconies in the environmental and energy behaviour of the buildings to which they belong. In particular, it determines the environmental factors whose interaction with buildings in which balconies appear is altered by the presence of those balconies, it investigates the mechanisms which cause these changes and assesses their results.

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INTRODUCTION

Balconies are extensions of the roofed areas of apartments above ground level that are intended to offer the residents quick and easy access to the external environment. Although they may be found in buildings at all latitudes, their presence is more pronounced in buildings situated in areas where the environmental and particularly the climatic conditions are mild for long periods of the year. In conditions such as these, the role of balconies is enhanced to the extent that the external environment is attractive for long periods of time and they possess properties which are more conducive to a feeling of comfort than those which exist in the interior of buildings. In these areas balconies represent an important factor in the functional organisation of apartments situated above ground level, and a conspicuous morphological feature in the faces of the buildings to which they belong. They also play a decisive role in the environmental and, by extension, the energy behaviour of the buildings that have them inasmuch as they intervene in and influence almost all of the mechanisms which determine how buildings interact with the environment. Finally, in these areas balconies represent an important factor in building architecture, particularly the architecture of residential buildings.

This paper identifies and examines the mechanisms and processes that determine the environmental behaviour of buildings and are related to the presence of balconies on their façades. It also investigates the conditions which determine whether balconies play a positive or negative role in the environmental and energy behaviour of the buildings to which they belong, with a view to drawing conclusions about the usefulness of, and the preconditions for, including them in the design of buildings in areas in which such conditions prevail.

2. THE STRUCTURE AND ELEMENTS OF A BALCONY

As structural elements of buildings, balconies take the form of projections. Their structure varies in accordance with the supporting structure of the building to which they belong, but generally they are formed by constructing an extension of the slab between two successive levels (floors). A conventional concrete balcony consists of a slab approx. 15 cm thick whose reinforcement forms an extension of the reinforcement of the adjacent firmly fixed slab of the supporting structure. As for balconies constructed on a metal supporting structure, these consist of a series of horizontal metal girders approx. 10 to 15 cm wide which also form an extension of the horizontal girders in the adjacent floor-level, and the intervening gaps are filled with small slabs of ceramic material or concrete. Similarly, in the case of a wooden supporting structure, the balcony rests on wooden beams whose intervening gaps are covered...
by planks. The length of these projections is subject to considerable limitations due to the moments produced by the loads they bear and, in any case, is dependent on the nature of the supporting structure. In conventional buildings with a supporting structure of concrete or metal, which make up the majority of multi-storey buildings, balconies rarely exceed 2.5 metres in length, a semi-empirical limit which satisfies their simple and relatively low-cost construction, and also falls within the tolerable vibration level when variable loads are exerted. Wooden balconies are usually narrower due to the fact that wood is a weaker material [1].

Balcony floors are constructed on top of the final surface of the supporting structure with materials suitable for outdoor areas (e.g. ceramic tiles, marble, terrazzo). Their surfaces are slightly inclined for water drainage purposes. In addition, they are constructed at a lower level than that of the indoor floors in order to prevent water flowing into the interior of the building. A relatively rare type of balcony floor is that in which a section of the floor close to the façade of the building contains openings which are covered over with a grating to enable the air to flow vertically over the surface of the building.

Apart from its horizontal floor, every balcony has a parapet at least 1.10 m high along its outer edge which protects all those who use it from the danger of falling off. The parapet, which generally forms a supplementary feature of the main structure of the balcony, may be constructed from a variety of different materials and possess different forms. In cases where the construction material is wood or metal, they generally take the form of railings. On the other hand, in cases where they are built of concrete or brick, they are usually solid. A relatively recent version involves the use of a metal frame to support highly durable panes of glass, with varying degrees of transparency, as facing panels. Finally, not infrequently parapets may consist of a variety of different forms and materials, usually a mixture of solid and semi-permeable components, even on the same balcony.

One structural element of buildings which is directly connected with balconies is that of balcony doors. All balconies need at least one balcony door to provide residents with access to them. Moreover, the presence of balconies in front of openings in the shell of a building favours the construction of balcony doors instead of simple windows. The fact that the opening in a balcony door has roughly twice the surface area of a window of the same width is already an indication of the type of indirect influences that balconies exert on the environmental and energy behaviour of the buildings to which they belong.

3. INFLUENCES OF BALCONIES ON THE ENVIRONMENTAL BEHAVIOUR OF BUILDINGS

3.1 Influences on appearance

A building without balconies has flat, vertical faces. These may well consist of a number of flat vertical surfaces situated at different distances from each other and perhaps with different orientations, yet the overall impression that the building creates is of a prismatic structure. The presence of balconies on its façade certainly breaks up this prismatic appearance. It lightens it and adds variety. Indeed, as in most cases balconies do not consist merely of their structural elements but also a host of other objects and accessories (e.g. chairs, tables, cupboards, flowerpots, awnings), the effect they have on the overall appearance of the building to which they belong is even greater. These observations reveal the first and most obvious consequence of the presence of balconies on the façade of a building: the alteration of its geometrical features and, ultimately, its appearance. The extent to which these things are altered depends, of course, upon the number and size of the balconies in the building concerned, or alternatively the proportion of the overall surface area of its faces that the balconies occupy. However, even if this proportion is small, the impact of the balconies on the overall visual effect is catalytic. In areas where the climatic conditions favour their existence, balconies form a characteristic feature of the façades of buildings. In Greece, for example, which has a Mediterranean climate, balconies are an essential feature of all residential buildings. All apartments above ground-floor level will have at least one balcony in the form of a projection. Indeed, very frequently more than one balcony will exist, or even continuous balconies occupying most of the surface area of the building. The width of balconies in residential buildings in Greece ranges from a minimum of 0.5 m (in the case of secondary balconies) to a maximum of approx. 2.5 m. Sometimes the balcony width is further increased by incorporating a section of the roofed area of the apartment within it (Fig. 1).

Figure 1: Façades of typical multi-storey apartment buildings in Greece. The presence of balconies in them is very conspicuous.
3.2 Influences on shading and natural daylighting

An obvious influence of balconies on buildings is the way in which their presence produces a shading effect on the buildings’ façades. When solar radiation strikes the surface of the shell of a building, it influences its energy balance via the energy it transmits to the building materials and the way it increases the amount of natural day lighting in the building’s interior. While the existence of transparent openings is essential for the natural daylighting of a building’s interior, where energy transmission is concerned – although this is manifested mainly as solar heat gains on the materials of the shell – the existence of transparent openings in the shell means that the interior will also be heated through the greenhouse effect [2]. Balconies, as projecting structures, shade part of the surface area of a building’s faces, in accordance with their width and the position of the sun in the sky. This shading, in accordance with what has been set out above, is more substantial if it takes in openings or parts of openings in the shell. Given that the shading provided by a projection of a particular width is greater when the sun is higher above the horizon, balconies, as means of sun control, function more effectively on façades with a southern orientation in the northern hemisphere, and vice versa in the southern hemisphere. In these cases, of course, shading occurs in the parts of the shell that lie beneath the projection and any openings which exist there. In this respect, it is interesting to note that often in the static and architectural design of multi-storey buildings, for reasons of simplicity, the balconies and openings in the faces are arranged in series. As a result, each balcony provides shading for the opening directly beneath it. On the other hand, when the sun is low on the horizon (at dawn or dusk), the limited amount of shading provided by the horizontal section of the balcony is supplemented by the shading afforded by its vertical parapet, where this is opaque. Of course, when the sun is low on the horizon, solar radiation is considerably less intense and there is less of a need for any form of sun protection.

3.3 Influences on thermal transmission processes

Apart from the influences that balconies exert on the energy behaviour of buildings via their shading effect, they also have a more direct influence by playing a role in the thermal transmission processes that occur through a building’s shell. Balconies are by their very nature highly vulnerable to the mechanisms which form the ambient air temperature. However, owing to their construction as a projection of the plate that separates two floors in the same building, an element which generally has a relatively high thermal conductivity coefficient (e.g. concrete or metal), they essentially function as thermal bridges, permitting, via their mass, the transmission of heat on both sides of the shell [3]. It is characteristic that this particular problem cannot be tackled with conventional thermal insulation techniques.

If environmental influences cause the temperature of a balcony to increase, it then begins to radiate the heat stored in the form of infrared radiation. Some of this radiated energy strikes the openings and the structural elements of the shell, causing an increase in their temperature and, indirectly, a change in the internal climate. These mechanisms, inasmuch as they are due to direct exposure to solar radiation, partly reduce the effects the shading has on the energy balance of the building. Indeed, it is possible to observe that a balcony may reduce the effects of solar radiation on the lower surface of the shell while increasing them on its upper one. This problem – if it is a problem – can be tackled with measures that reduce the balcony’s capacity to absorb radiation, i.e. they should have a strongly reflecting surface. In addition, they should be thin, light in weight and consist of materials with good thermal conductivity which quickly give off to the passing air any heat which has nevertheless been absorbed. In the case of balconies which do not possess these attributes, such as balconies constructed of concrete, the problem can be reduced by applying layers of thermal insulation on their upper surface. One practice which can reduce this problem, and is therefore often applied by residents in areas with high levels of sunshine, is the hosing down of balconies during periods when they become very hot as a result of absorbing solar radiation. The evaporation of water which ensues releases some of the extra heat.

In cases where, either as a result of direct exposure to solar radiation or for other reasons, the temperature in parts of the external surface of a building’s shell exceeds that of its surroundings, some of the excess heat is released by the shell into the adjacent layer of air. In windless conditions, the air which is heated in this fashion begins to move upwards. If there are balconies (or projections in general) on the façade of the building, this movement is obstructed. The rising masses of hot air are partly trapped underneath the balconies, where they return some of the heat they bear to the structural materials at those points and, through these, to the interior of the building. This phenomenon, to the extent that it obstructs the release of heat from the shell, can be tackled by constructing balconies with openings along their inner edge, openings which are usually covered with metal gratings in order to ensure the floors are uniformly flat. It can also be tackled by keeping the balconies short in length and leaving open spaces between adjacent balconies.

3.4 Influences on wind loading

In windy conditions balconies have a drastic effect on the air flow around the building to which they belong and, by extension, the wind pressure distribution on its shell, mainly on its windward sides [4]. Although the effects of their presence are generally of a complex nature, in terms of their basic principles at least they can be broken down into those which relate to the parapet and those which relate to the rest of the structure. The air-impermeable parapets of balconies create their own local distribution in the wind flow pattern. Pressure is increased on their windward face and decreased on the leeward and these effects have an influence on the adjacent surfaces of the main structures. Furthermore, the flow in the wake is severely turbulent and may give rise to local suction which
cause disturbances in the area of the balcony and quite likely damage to structural elements (e.g. doors, windows and shutters) and objects on the balcony (e.g. flowerpots, chairs). The behaviour of balconies with parapets that can be permeated by the wind resembles that of simple projections in that, as vertical obstacles, they obstruct the motion of the air masses adjacent to the external surfaces of the building, and force them to whirl round and escape at the sides. The extent of the deviated flow will of course depend on the size of the balcony in relation to that of the façade. It is to be noted that pressures on the upper and lower surfaces of each balcony will be approximately the same as those exerted on the adjacent wall surfaces and that the overall wind load on the balcony may be downward or upward depending on whether the balcony is low down or high up on the façade. The eddy produced in the angle between the balcony and the façade will lead to the sideways flow that will escape over the end of the balcony and around the side of the building, and where this is channelled and results in accelerated flow there will be the consequential reduction in pressure on the surfaces affected. Sometimes severe suction can be generated locally in such regions.

In buildings with numerous balconies on their façade, which is typical of multi-storey apartment buildings in general, the effect of wind incidence is to produce series of pockets of pressure across the windward façades, with the result that the pressure tends to fall off rather less than it otherwise would towards the edges of the façade.

3.5 Influences on natural ventilation

The influences of balconies on the wind-building interaction primarily concern the field of wind-loading but also relate to other areas of building physics as well. An example of the latter is the serious impact they have on the natural ventilation processes that occur in the interiors of buildings, with similar effects on both the indoor air quality and the energy balance of those buildings. Their disturbance of the air pressure field, insomuch as it causes changes in the pressure residuals between different sides of the shell, affects both the preconditions and the actual conditions for cross-ventilation in the interior. Apart from that, in the context of the more general disturbance caused in the air pressure field, as a result of swirling masses of air, acute wind pressure gradients are formed in parts of the shell. The gradients in the external – internal pressure residuals cause the air to flow through the openings that exist in the relevant areas and consequently form a driving mechanism that induces side ventilation in the adjacent area [5]. This phenomenon occurs in both ventilation and infiltration openings. In all cases the phenomenon is intensified by the fact that balcony doors are higher than windows and are consequently subject to greater differences in air pressure.

3.6 Influences on damp protection

The presence of balconies on the façade of a building provides the underlying sections of its shell with significant protection against wind-driven rain (and precipitation in general), which, whether it falls upon the external surfaces of the shell or ends up at ground level a short distance away from the base of the building, constitutes – as a source of damp – a threat to the structure and the quality of the indoor environment. The level of protection provided by each balcony depends on its width and, of course, the strength and direction of the wind. In any event, as a result of the disturbance that balconies cause in the wind flow around the building to which they belong, there are likely to be cases of precipitation being swept into areas of the shell which would not be affected if the balconies were not present [6].

One influence in connection with wind might arise indirectly from the role balconies play in creating thermal bridges. These thermal bridges, to the extent that they are accompanied by steep temperature gradients, may cause water vapour condensation either in the mass or on the surface of the structural elements of the shell [3].

3.7 Influences on sound insulation

Balconies provide the faces of buildings and the openings within them with sound insulation from noise generated externally, whether by traffic, industrial or other sources. This sound insulation is created by the way in which both the horizontal section of the balcony and its parapet, provided this is solid, as well as the objects and accessories lying on the balcony, obstruct the propagation of sound. The proximity of a balcony to the receiver increases its effectiveness in reducing the level of sound acting upon the latter. In addition, however, the sound insulation depends upon the nature, position and distance away of the source, as well as the characteristics of the transmitted sound, particularly its frequency. In the case of sounds produced at ground level (e.g. in the neighbouring streets) the sound insulation provided by the balconies of a building affects those parts of the shell which lie above them and concerns both sounds arriving directly from their sources and also the reflections which they probably experience. In this case the role played by the solid parapet of a balcony in its overall effectiveness as an insulator of sound is significant. The screening effects of balconies due to sound diffraction are limited to the higher frequency range because of their smaller dimensions, but their effect is beneficial because of the higher aural sensitivity of these frequencies [7].

Some of the energy of the sound waves that strike the external surfaces of balconies is reflected, thus contributing to diffuse environmental noise. Some of the reflected energy – which comes mainly from reflections off the underside (ceiling) of the balcony – is directed towards and strikes parts of the shell lying underneath it, thus increasing the level of sound acting upon them. This problem can be tackled by applying sound absorbing layers to the underside of the balcony. In the same way, suitably designed supports for the balcony slab help to reduce the sound level by minimising reflections into the room.

3.8 Influences on pollution

In the curved dihedral angles that are formed between balconies and the façades of buildings the circulation of the air is slowed down. As a result, at
these points there are thicker deposits of the solid pollutants carried by the wind. At the same time, in these same areas the wind is less able to dislodge and carry away the dirt which has accumulated there. This phenomenon, which is worse in the case of dirt with a greater accretion to the structural elements of the external surface of the shell (e.g. soot), explains why the curved dihedral angles on the faces of a building are the areas where pollution first becomes visible.

3.9 Indirect influences

In addition to the influences presented above, it is worth adding that balconies are suitable places for installing permanent or temporary systems for protecting a building from environmental influences. Such systems, which relate mainly to the fields of sun control, wind protection and sound insulation, would be vulnerable and difficult to install if there were no balconies. The fact that balconies offer this possibility could be counted as yet another way in which they indirectly influence the environmental behaviour of the buildings to which they belong. A very interesting category of objects usually found on balconies is that of plants, either in pots or beds. Apart from generally improving the aesthetic of a building and creating a pleasant atmosphere on the balcony which contains them, plants play a role in the environmental behaviour of buildings, particularly in the areas, once again, of sun control, wind protection and sound insulation.

CONCLUSIONS

Apart from their functional role and their active contribution to the external appearance of the buildings to which they belong, balconies also play a dynamic role in shaping a series of environmental influences that are exerted on buildings. A close study of these influences shows that some of them are of constant benefit. These influences concern the protection provided against driving rain and externally generated sounds. On the other hand, the fact that balconies create thermal bridges in the shells of buildings must be regarded as a constantly negative influence, insomuch as they are generally connected with the transmission losses that occur through the shells. As far as the other influences are concerned, whether they are viewed positively or negatively depends on the conditions under which they are examined. These influences are essentially either directly or indirectly connected with the energy behaviour of the building to which the balcony belongs and their evaluation depends on the extent to which they make a positive or negative contribution to the energy balance of the building concerned. A typical example is that of the shading effect that balconies produce on the buildings to which they belong. Where there is a high environmental temperature, this influence is considered to be beneficial in that it reduces overheating in the structural elements of the shell, as well as the excessive contrasts in the lighting level and glare. However, this influence is regarded as undesirable in cases where a low environmental temperature prevails, for the energy transmitted by the sun’s rays is welcomed as a means of heating the structural elements and interior of a building.

A careful examination of the ‘dependent’ influences of balconies on the environmental behaviour of the buildings to which they belong leads to the conclusion that, under any conditions, the positive influences go hand in hand with the negative ones. Moreover, even in respect of the same environmental factor (e.g. solar radiation), this paper has shown that the presence of a balcony can have contrasting influences in different areas of the shell. Regardless of this fact, however, in any one area the conditions are likely to be such that, in terms of their overall effect, they will either favour or not favour the balcony’s contribution to the environmental behaviour of the building concerned. This observation highlights the important role that climate plays in determining under what conditions balconies should be included in the design of buildings in a particular area. It also indicates the need for these conditions to be assessed together with the functional criteria that exist for the construction of balconies in buildings in the same area. In this respect, we may say that the extensive use of balconies in areas with a mild climate – where their positive and negative influences on the environmental behaviour of buildings are more or less equal – reflects mainly the functional benefits of their presence; i.e. the way in which they enable residents to benefit from the relatively favourable conditions that prevail in the external environment for long periods of the year. In addition, building designs should consider and apply design and construction solutions that increase the benefits and reduce the disadvantages of the presence of balconies in buildings. Such solutions are described in this paper, while even more, of an assuredly more reliable character, can be drawn from the traditional architecture of individual regions.

REFERENCES