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The solar envelope: its meaning for energy and buildings

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Abstract

The solar envelope, first conceived and tested by the author working with architecture faculty and students at the University of Southern California (USC), regulates development within imaginary boundaries derived from the sun's relative motion. Buildings within this container will not overshadow their surroundings during critical periods of solar access for passive and low-energy architecture. If generally applied as an instrument of zoning, the solar envelope will not only provide for sustainable growth but will open new aesthetic possibilities for architecture and urban design.

Keywords: Solar access; Solar energy; Solar envelope; Sustainable architecture; Interstitium

1. Introduction

We have worshipped at the altar of growth. Partly, this is the consequence of a need to house continuing migrations of people being drawn from traditional to cosmopolitan settings. Partly, it is the result of a swelling world economy that rewards ever-expanding markets over constancy, development over a steady state, novelty over tradition. Our predilection in favor of growth over maintenance has raised doubts about a sustainable future.

So far, there has been little incentive for developers to worry about the long-term energy costs of keeping our buildings comfortable and repaired. Pressures are so enormous to build fast and move on quickly to the next project that construction techniques emphasize rapid assembly over the effects of long-term wear and tear. Developers do not pay the bills for heating, cooling and lighting over time and seasons. Consequently they have demanded that architects specify energy-intensive systems rather than make the effort to design with nature. In the simplest ungrammatical terms, we "grow cheap" and "maintain expensive".

Spreading awareness of a global imperative is just now forcing attention toward a more sustainable architecture. Steele, in a recent book, defines sustainable architecture as "an architecture that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. He continues with this warning, "pushed not only by many pundits and the press, sustainable architecture will also be forced upon architects by an overwhelming confluence of ecological, social, and economic forces unless architects reach out to embrace and take control of it first".

Design research at the School of Architecture, University of Southern California (USC) has anticipated the concerns voiced by Steele and others about energy and buildings. The author began, in 1976, to develop and test the solar envelope, a zoning concept to provide urban solar access [2–4]. The underlying premise of this work has been that solar-envelope zoning would eventually result in a shift from fossil fuels to sustainable energy. Furthermore, it would evoke a profound change in the way we identify with our environments, a different way of judging the aesthetics of buildings.

2. Solar access

The sun is fundamental to all life. It is the source of our vision, warmth, energy, and the rhythm of our lives. Its movements inform our perception of time and space and our scale in the universe. Guaranteed access to the sun is, thus, essential to energy conservation and to the quality of our lives.

A thousand years ago in North America, settlements provided for solar access. Acoma Pueblo, located on a high-desert plateau about 50 miles west of modern Albuquerque, NM, exemplifies such early planning. Terraced houses face southward. Walls are of thick masonry. Roofs and terraces are of timber and reeds, overlaid with a mixture of clay and grass [5].

The Acomans built houses well-suited to a high-desert climate (Fig. 1, left). The sun's low-winter rays strike most

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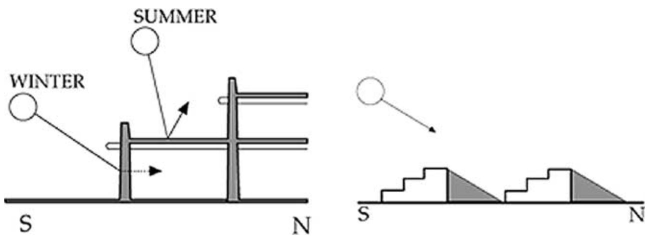

Fig. 1. Acoma Pueblo: thick masonry walls and timber roof-terraces respond well to seasonal migrations of the sun (left); the spacing between Acoma's rows of houses is strategic, just far enough to avoid winter shadows while conserving precious space on a high, small plateau (right).

directly south-facing walls where thick masonry stores heat during the day, then releases it to warm inside spaces throughout the cold nights. In contrast, the summer sun passes high overhead, striking most directly the roof-terraces that store heat less effectively. Finally, adjacent houses cover each other's side walls, thus, reducing the impact of summer rays directed from low in the east and west.

More important for this discussion, a study of Acoma shows that spacing between rows avoids winter shadowing of the terraces and heat-storing walls (Fig. 1, right). It was actually this critical relationship of building-height to shadow-area that originally gave rise to the solar-envelope concept.

2.1. Space–time construct

The solar envelope is a construct of space and time: the physical boundaries of surrounding properties and the period of their assured access to sunshine. These two measures, when combined, determine the envelope's final size and shape [6].

First, the solar envelope avoids unacceptable shadows above designated boundaries called "shadow fences". The height of shadow fences can intentionally respond to any number of different surrounding conditions, such as windows or party walls. Their height may also respond to adjacent land-uses, for example, with housing demanding lower shadow fences than commercial or industrial uses. Different heights of shadow fence result in contrasting shapes and sizes of the solar envelope (Fig. 2, left).

Second, the envelope provides the largest volume within time constraints, called "cut-off times". The envelope accomplishes this by defining the largest theoretical container of space that would not cast off-site shadows between specified times of the day. Greater periods of assured solar access will be more constraining on the solar envelope than shorter periods (Fig. 2, right).

2.2. Street patterns

Street patterns greatly influence the solar envelope's size and shape. In the US, regular subdivisions of the US Land Ordinance of 1785 have set street patterns between Ohio and the Pacific Ocean. Typically, throughout the mid-west and the west, streets run with the cardinal points so that rectangular blocks extend in the east–west and north–south directions. Los Angeles, the site of most solar-envelope research, additionally contains the much older diagonal grid of the original Spanish settlement (Fig. 3).

The size of the solar envelope and, hence, development potential, varies with street orientation. Generally, more envelope height is attainable at either of the two possible block orientations within the US grid while less volume is possible within the Spanish grid. This has made downtown Los Angeles a very challenging problem.

The shape of the solar envelope also varies with street orientation, thus, enhancing urban legibility. Lynch said, "to become completely lost is perhaps a rather rare experience . . .but let the mishap of disorientation once occur, and the sense of anxiety and even terror that accompanies it reveals to us how closely it is linked to our sense of balance and well-being" [7]. Pathways, districts, and directions take on clear perceptual meaning when the solar envelope becomes a framework for urban design.

3. Sustainable growth

As part of ongoing design research in the USC's School of Architecture's Solar Studio, a 10-year housing study has tested the possibilities for sustainable growth under the solar envelope. The study concludes that dwellings of 3–7 stories generally represent the best size range for passive and low-energy strategies in Los Angeles. These figures can vary among cities but the underlying suppositions of solar-access policy are broadly applicable to places of density everywhere.

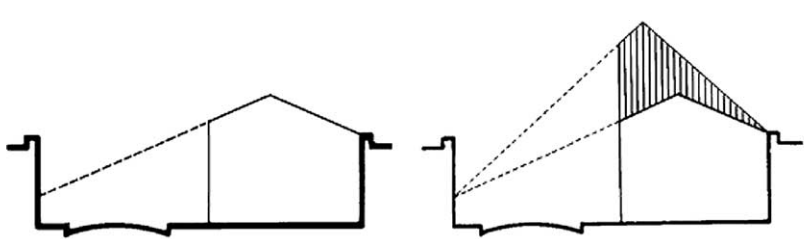

Fig. 2. Space–time constraints: shadow fences may have different heights on adjacent properties to avoid overshadowing such elements as windows or rooftops that could benefit from direct sunshine (left); specifying different cut-off times can increase or decrease volume under the solar envelope because of changed sun angles (right).