Bioclimatic and Vernacular Design in Urban Settlements of Brazil

LUCILA C. LABAKI*
DORIS C. C. K. KOWALTOWSKI*

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Brazilian regional traditional architectural features are analyzed, especially with regard to the new emerging vernacular of self-built urban settlements. Bioclimatic design is discussed as to its scientific and technical features with respect to the subtropical climate of the city of Campinas in the State of São Paulo, Brazil. The main goal of this work is to analyze a specific self-building house phenomenon and its response to climate. From this analysis thermal comfort should be addressed in terms of correct architectural elements. An appropriate new architecture for the urban poor should be based on bioclimatic design principles and the positive elements of the new urban vernacular. © 1997 Published by Elsevier Science Ltd.

INTRODUCTION

In the study areas of housing and thermal comfort, a vast literature exists. When the two areas are connected, they are mainly referenced under bioclimatic design or the vernacular, with the emphasis on basic, good design principles. Bioclimatic design literature is on the whole more technical and scientific in nature [1], while works on vernacular architecture address issues of culture, tradition and aesthetics as well as comfort [2].

In this paper, both bioclimatic and vernacular design are discussed for the specific setting of the region of the city of Campinas, Brazil and its subtropical climate. The discussion is seen as urgent due to the proliferation of what is often termed the new vernacular or the self-built housing phenomenon. Urban settlements around growing cities are adopting a specific style of building which can be found to have aspects of vernacular architecture. These settlements and their individual houses, however, have various negative aspects which should be analyzed and corrected. Linking bioclimatic design with features of the local vernacular, it is hoped to create a design method for an appropriate domestic architecture for the popular suburban settlements of growing cities in Brazil.

VERNACULAR ARCHITECTURE

Vernacular architecture can be described as building new structures with old techniques, repeating dwelling types based on an old model with few technological changes. The vernacular includes attributes of tradition which are process and product distinct. A culture and place specific model is repeated, gaining variety and complexity over time. The model similarity consists of specific elements of massing and volume, fenestration and use of building materials. The vernacular is also said to show efficient use of resources with distinct preoccupation as to climate responsive design [3].

Predominant vernacular architecture in Brazil is linked to colonization. Imported models of urban 16th century Portuguese houses were built over the settled territory, European culture being transported to new lands. The new colonial cities adopted a narrow and long lot shape for its early subdivisions, as was customary in Portugal. Houses were built without setbacks as well. Both one- and two-storey row-houses were used. Since lots were very narrow, only the front and back spaces had natural light and ventilation and the house included unlit and unventilated internal rooms which served as private sleeping quarters as seen in Fig. 1 [4]. The plan configuration of these houses is rectangular in shape, with an internal predominantly central corridor. Room sizes are generous, due to sparse furnishing. Internal alcoves, however, have an area sufficient only for the placement of a bed. Service spaces such as kitchens and bathrooms are not part of the main house, but located in the back of the lot [5]. Windows and doors use a symmetrical arrangement of arched openings of almost standardized 1 m width. The triple arch arrangement is favored. Since ceilings are high, openings are long and narrow. Double hung window types are used which permit control of half the opening area for ventilation purposes. Both one- and two-storey houses are based on similar plan and detailing configurations (Fig. 2). On corner sites a variation of the urban colonial house permitted light and ventilation from three sides. With time, variations of the simple compact urban house evolved, with few changes to the plan. Houses were elevated for privacy in relation to the street with growing cities, gaining a ventilated cellar. The urban lot was widened to permit ventilation and light from three sides and the inclusion of a lateral narrow verandah. The urban colonial settlement is compact and lacks vegetation as a design complement. Streets and public squares have
few trees and private gardens are small, serving as vegetable gardens [4].

The first colonial settlements were urban in nature and determined the principal vernacular of Brazil. With time, the continuous permanence of the settler in the new territory and problems with supplies made rural activities necessary [4]. On the rural front, houses were of two distinct types: the large country mansions of the wealthy and the small huts of the agricultural workers. The large country houses are compact in plan, but with openings to all four sides. The central corridor plan is preserved but in larger scale. The one distinct addition to the house is the verandah, on the back of the house for service activities and on the front for social life. The small rural hut is a simple construction for shelter, with a space for cooking and eating activities and a room for sleeping, without divisions for different family members.

The indiscriminate import of a vernacular architecture over a vast territory ignored new local conditions and necessities. On the other hand, since climate across the territory is on the whole mild, the local vernacular did not ask for rigorous thermal comfort requirements. This vernacular has several bioclimatic elements, however. Building materials of clay were used and thick walls were predominantly white-washed. Opening sizes were generous in relation to room area and permitted hot air to escape from high windows. On the negative side, the vernacular is not specifically conscious of climate. Orientation is random, cross-ventilation is not a specific design element. Shading is largely ignored and in the urban scene landscaping is not used to its full comfort potential. The local vernacular thus did not opt for strong climate conscious design as is common in other cultures with appropriate rooms for specific seasons such as the summer and winter rooms of Oman for instance [6]. Occupancy patterns of hot and cold season were few, although summer houses in mountain areas were part of a pattern of living for the wealthy in Rio de Janeiro. These arrangements fell into disuse with declining wealth and social and cultural changes.
SELF-BUILT URBAN SETTLEMENTS

Self-built houses are presently the predominant mode of urban and suburban habitation production of low income populations in Brazil and of much of Latin America [7]. Considering that 70% of Brazil's population* is urban today, and around 65% of urban housing is self-built,† one can estimate that 12 million families are living in spontaneous settlements today in the country. Remembering the Latin meaning of vernacular as home-made or home-grown, this phenomenon can thus also be termed a new vernacular. The production of these self-built houses is considerably larger than the traditional vernacular which, according to some estimates, houses between 8 and 9 million families in the world [2].

There is a distinct self-built housing manifestation in the region of Campinas in the state of São Paulo.‡ Campinas is a city with approximately 1 million inhabitants, 100 km from the largest city in Brazil, São Paulo. The city is influenced by the strong industrialization trends of the region. Most self-built settlements are located on land considered unfavorable for large-scale urban development. This unsuitability influences land valuation and ironically creates conditions for large-scale, low-income developments. The typical outer suburbs use traditional grid-iron street patterns with lots of rectangular narrow street front shapes. These settlements lack adequate service infrastructure, giving rise to haphazard commercial enterprises amongst small houses. Lack of diversity, grid-iron streets, poor landscaping and infrastructure create a visual poverty of setting in the new developments. With time these outskirts gain in urbanization and tend toward fairly comfortable suburbs. This is true for smaller and medium-sized cities of Brazil, like Campinas, but not equally true for the larger metropolitan areas. There the self-built outskirts have a lower quality of life, houses are smaller, multi-storey on a narrow lot, predominantly unfinished and without a protecting roof, details which affect directly thermal comfort.

A survey of the self-building phenomenon was undertaken in several suburbs of the city of Campinas. This survey was dimensioned according to the population of the city and the total number of suburbs with self-building characteristics. The survey comprised a total of 524 questionnaires which raised questions on house construction, satisfaction, preferences and habits; 64 houses were analyzed in detail with measured drawings, observations as to opening location, room and window sizes, furniture, finishing and comfort conditions as well as owner-builder know-how.

Analysis of self-built houses shows predominant occurrence (58%) and preference (28%) of a specific house plan, as seen in Fig. 3, with congruence of area, volume, roof type, traditional building materials, siting on lot and wall conditions. The typical house plan gives the house a cubic volume. The roof is predominantly in a simple gable form. Room type distribution is fixed in relation to the front of the lot, which determines orientation towards sun and wind. The house no longer has the central corridor of the traditional plan. A side setback is included for outside access to the backyard, which enables the front door to be placed to the side of the house. The modern compact plan shows primary preoccupation for construction economy, and a change of cultural feelings is expressed through a reduced emphasis on privacy and increased emphasis on security. The typical four room plan of Fig. 5 is sometimes modified by a garage or

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*The total population of Brazil is estimated at 150 million people with an average of 4.8 persons per family.
†Based on reports of cement consumption in Brazilian urban areas [8].
‡The findings described here are the result of a study which had the support of the Fundação de Amparo à Pesquisa do Estado de São Paulo, FAPESP, Processo No. 92/4525-2.
Traditional building materials of ceramic brick and tiles are used. These materials are economic in the region and are still considered as "solid and good" materials for house building. These traditions and beliefs are, however, tied primarily to economic conditions and rapidly abandoned when poverty gets worse. This can be seen when self-built houses of Campinas and São Paulo are compared. Houses in São Paulo are gray in color due to the predominant use of concrete blocks and asbestos cement roof tiles. In Campinas, outer and room division walls are built with equal thickness (15 cm). Most houses are without wall finishing, but strive towards a stuccoed and painted or brick-veneered finish. Ceilings are constructed with prefabricated concrete beam and ceramic block with a thin concrete cover forming a ceiling slab. The roof structure uses wood and roofs are covered with traditional red ceramic tiles. Roof overhangs are sparing, of 50 to 60 cm width. Later additions and modifications are frequent, especially in the form of extending the roof over the side setback and at the back for service porches and rain protection to entrances.

The second most often found dwelling type is the house built at the back of a suburban lot, using three limits as outer walls as seen in Fig. 5. This type of house is an evolution of the service building of the colonial vernacular. It is smaller in area and volume and represents 33% of the total house production. Orientation of these houses is limited entirely by the lot orientation itself. The lean-to roof is the simple solution for shelter (Fig. 6). As an economic measure, some of these houses are covered by asbestos-cement sheet roofing, gray in color. Since these houses are inadequate in size, over time many additions occur with difficulties due to the roof shape. These additions interfere with functionality and comfort of the spaces of the first stage of building, by obscuring light and blocking out ventilation. An example of such modifications to the house can be seen in Fig. 7, where the hatched part of the plans are the original houses.

The self-building manifestations have been called the nascent or urban new vernacular due to their use of a place- and culture-specific model [9]. Complexity and variety are increased over time as in true vernacular architecture. Thus local building practices are perpetuated and regionality is valued. However, the house model of this urban vernacular lacks an authentic development, originating from middle class models which are poorly understood or misinterpreted [10].

Local building codes have a transforming influence on traditional ways of building. These codes are, however, often not correctly interpreted by the self-builder as to the intentions and therefore not always adequately applied. Codes are respected only to a certain degree to conform to public rules. Public health codes, as for instance the 1.5 m lateral setback for bathroom windows, which should ensure minimum ventilation and sunlight, are frequently ignored since the lateral setback is not very apparent on the settlement scale.
When comparing traditional vernacular architecture with new urban dwellings, one can notice the loss of several important elements. The self-built dwellings lack the ingredients of efficient use of resources and good relation to natural elements such as vegetation [3]. Effectiveness of response to climate, which in the local vernacular was not a main feature, is only sustained by the use of adequate building materials in the region of Campinas. To correspond to the definition of vernacular, self-built houses need adjustments of design, especially concerning environmental comfort, such as light, air, sunshine and indoor temperature. A regard for thermal com-
Thermal comfort should include concerns for ventilation, insulation, insolation and thermal resistance of materials. Adding climate response attributes to the small suburban houses in Campinas can be achieved through the principles of bioclimatic design, which takes into account socio-economic factors.

**BIOCLIMATIC DESIGN**

The term bioclimatic design appeared in the English speaking literature on thermal comfort in 1953 in the works of the brothers Olgyay [11]. Its meaning can be defined as follows: "Bioclimatic design in architecture is to ensure the existence and well-being of biological
organisms within the given climatic conditions (primarily of humans, but protecting bio-diversity). Bioclimatic architecture relies heavily on architectural science, especially architectural energetics, but goes well beyond that. It rejects energy-wasteful and inhuman environments, the ubiquitous glass boxes and skyscraper machines. It rejects fashion-dominated architecture, it returns to basic human needs and values, it encourages regionalism. Bioclimatic design employs appropriate technologies, as dictated by the particular task, by given socio-economic conditions, but it avoids the trap of romantic neo-primitivism. It does not reject high technology, but it is based on an ecological moral imperative: take least from and dump least into the environment” [1].

Strategies of bioclimatic design depend on an accurate climate definition. Monthly data which must be analyzed for this definition are: maximum and minimum average temperatures, temperature range, solar radiation, wind direction and speed, precipitation conditions and relative humidity. Specific climate definitions will then ask for a number of design strategies: orientation of building in relation to sun and wind, exterior ground treatment and landscaping, wall thickness, choice of construction materials and color, shading conditions, roof construction detailing and permanent ventilation of the space between ceiling and roof, often termed attic ventilation, location and size of openings and presence of cross-ventilation. Evaporative cooling and solar heating are often considered part of bioclimatic design, since passive conditioning is energy efficient and non-wasteful.

Examples of the vernacular are often used in the bioclimatic literature as climate appropriate designs. Specific strategies are related to specific vernacular design. Arab-
ian desert thick-walled dwellings or the lightweight open oceanic constructions are typical examples of good bioclimatic design [12]. Building in the traditional way, and therefore encouraging the repetition of good custom versus innovation, is repeatedly presented in the literature, but often without checking the full range of necessities of design, conveniences of sanitation, lighting, heating, as well as separate areas for distinct functions [13]. References must be closely analyzed to avoid the common bioclimatic trap of romantic neo-primitivism. Vernacular details, such as for instance wind towers, seen in Fig. 8, are given as good bioclimatic examples [14]. References lacking technical specifications, however, may lead to improper design. Example (a) in this figure showing the stack effect is only marginally successful and a wind tower, example (b), is effective when proper adjustments are made to height and area of air intake and exit, flue dimensions, location of tower in relation to building volume, reduction of solar radiation on tower walls, and the introduction of cooling elements, such as water pools, on incoming air.

**THERMAL COMFORT ANALYSIS OF THE NEW URBAN VERNACULAR**

Analysis of self-built settlements in the region of Campinas detects a number of design elements and details which affect thermal comfort conditions. As stated above, street orientation is at random but house plans are fixed in relation to the lot front. Survey data on eight room orientations are distributed: 25% of houses have their living and one sleeping room towards the north-west and an equal number of houses are sited with opposite orientation. The other 50% of houses are well dispersed as to the orientation of habitable rooms such as bedrooms and living rooms, as seen in Fig. 9. Insolation and ventilation conditions are therefore without control in houses surveyed. This dispersion of orientation shows a disregard for minimum and excessive insolation and for prevailing wind orientation. Siting conditions of houses are divided into six categories, as indicated in Fig. 10, with respective percentages of occurrence in the sample. Lot perimeters are walled, creating wind barriers. Most houses respect the street front setback of 4 m stipulated by local building codes, when sited on the lot. Side setbacks are, however, even if present in the first stage of building, often incorporated into the house for increased indoor space. This condition adversely affects ventilation around the house, therefore reducing the effect of structural cooling. One of the functions of ventilation is to cool the structure of a building when the indoor temperature is above that outdoors [15]. Figure 10 shows the sitting conditions of surveyed houses. It can be seen that 35% of houses have adequate structural cooling ventilation on the front and back, with marginal ventilation on one side. 24% of houses have single-sided ventilation only, whereas 10% of houses are adequately placed on the lot.

When analyzing house plans, two specific types were predominant, as previously described. Although the two plans are quite distinct in type, room area according to space function and opening size is almost standardized. Function determines room sizes: living room 14 m², bedrooms 12 m², kitchens 13 m² and bathroom 4 m². The total house area averages 65 m². The congruence of space and opening standards can be said to show that there is a cultural understanding as to specific functional needs. In relation to window and door detailing and dimensioning, a strong market influence can be felt, although survey results are not clear as to the origin of these standardized patterns. Most houses use three types of window designs in accordance to location. Living rooms are adorned with decorative windows predominantly in the triple arch form with small narrow openings, as shown in Fig. 2. These narrow arches create the colonial image of the house, but of diminished size, of 60 cm width strip louvered windows. This pattern of windows reduces the opening size by 50% when compared to the traditional triple arch arrangement of the colonial house. All windows are of very elementary construction without insulation or double glazing and gaps are present even when windows are closed. Bedrooms have small shuttered win-
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Fig. 9. Solar orientation distribution of self-built houses.

dows, 1.20 x 1.00 m in size, with only half the glazed opening available for ventilation. Kitchens and bathrooms are poorly lit and ventilated by small utilitarian louvered windows. The openings of most windows are below code requirements of one fifth of the floor area, due to the fact that the most economic standardized market available components are used. All houses have at least two doors, the front and kitchen door. The kitchen door is placed predominantly at the back of the house for privacy, or to the side for both privacy and rain protection, since the high lot enclosure wall acts as a shield. When adding the size of doors to window openings, code requirements for minimum illumination and ventilation are met for kitchens and living rooms.

Verandahs as protective elements of walls and openings are present in only 14% of self-built houses in Campinas. However, 70% of houses have specific spaces attached to the house for laundry activities which are mostly in the form of a small back porch. 51% of houses are unfinished, waiting for stucco and paint on external walls. The unfinished houses are the color of their ceramic building materials or a gray tone from the rough first coat of cement finish. Finished houses are painted in light colors of green, blue and pink as well as pastel tones of beige. White-washing is no longer part of the local custom. Asphalitic paint is often applied on external walls to prevent moisture penetration where protective roof overhangs are impossible. This is particularly true for the back of the lot houses, where three external walls are painted black and lack any shading elements. Internally, 63% of dwellings are finished including paintwork.

The low frequency with which the verandah is present in the self-built house of today in the Campinas area is a sign of social and cultural pattern changes. A large percentage of the population of the self-builders came from other regions to Campinas. Most of this population has a rural background. Providing shelter in a new and unknown urban environment is very much influenced by economic pressures and the lack of physical space on small suburban lots, in contrast to rural building possibilities. Investment is primarily in terms of indoor space. This can be confirmed when analyzing changes in public housing estates where the new tenants quickly incorporate available verandahs into the house to gain functional area. Urban life habits also exert a strong pressure on house form. The outdoor activities of the rural verandah are no longer possible or necessary due to security problems and new life styles of working far from home, as well as predominant social activities around the television.

The climate in the region of Campinas is largely determined by its location, with a latitude of 22° 53' South, longitude of 47° 04' West, and altitude of 693 m above sea level. During the months of September until December, winds are predominantly from the south-south-east. The rest of the year has winds from the south-east. The average wind velocity is 5.6 m/s with a maximum occurring in September (7.2 m/s). The average yearly temperature
is 21.3°C and the annual temperature range is 11.8°C. The average maximum temperature is 33.5°C and the average minimum temperature is 9.4°C. The highest absolute temperatures fall in the months of September to November, and the lowest absolute temperatures from June to August. The hot season starts in September and ends in March. The climate is, however, divided into two periods due to differences in relative humidity. From November until June the average relative humidity is over 70%, while during the rest of the year it falls between 70 and 50%. Precipitation is strongest in the months of December until March, when humidity and temperatures are high. There is no large body of water in the region, which might affect the climate. The climate can thus be divided into three types: hot and humid, hot and without precipitation, and cool and relatively dry. During the cool months solar radiation can elevate daytime temperatures to 30°C with cold nights, which can reach temperatures down to 3°C. This climate has no strong features, like a specifically directed and timed sea breeze, which may induce design with climate response.

The previous descriptions of houses reflect directly on thermal comfort conditions, especially considering the problems of hot seasons. Since adequate ventilation is the main element of comfort in hot and humid climates, the majority of houses show poor conditions due to the minimum openings used. Cross-ventilation is not consciously designed into the house. The positive value of night ventilation cannot be fully explored due to security fears, privacy habits and insect disturbances. Shutters on bedroom windows help privacy conditions but diminish air flow. Solar radiation is also not controlled through orientation or shading devices. Depending on the lot situation, the house will be more or less comfortable. A quarter of the houses with their living and bedroom directed towards the north and without a shading veranda or large tree will therefore have large heat gains during the day (Fig. 9). Heat gained on unshaded east, north and west walls will radiate in unventilated rooms during the night. This heat gain in walls is further increased since 50% of houses are unfinished and of a dark gray color. The use of traditional ceramic building materials is, on the other hand, positive, since these materials have low thermal conductivity. Tendencies towards the increased use of cement products, such as hollow-core concrete blocks, as seen in the city of São Paulo, will, however, deteriorate thermal conditions further. For wall materials, the thermal conductivity of ceramic material such as common brick is 0.72 W/m°C, and for concrete block is 0.91 W/m°C [16]. There is therefore a considerable difference. A change of roof materials from ceramic tiles to asbestos cement will also adversely
affect thermal conditions. The second material is very thin, therefore emitting long-wave radiation to internal spaces. Roof construction detailing in the new vernacular does not include ventilation elements between ceiling and roof cover, an important heat reduction detail. The use of ceramic tiles, however, creates minimum conditions of attic ventilation, not present with the use of large sheet roofing materials such as the popular asbestos cement sheets, a material most used in the squatter settlements or *favelas* of Brazil.

Comfort conditions can be measured by evaluations of house owners. When specifically asked to rate thermal summer conditions, 48% of owners complained of discomfort. In winter, a 30% discomfort was indicated. This data must, however, be assessed in contrast to the 70% satisfaction data in relation to the house as a whole. The same houses are evaluated by independent observers with only a 36% positive rating. Self-builders, having spent time and resources on their own house, are shown therefore not to be accurate evaluators. The high rate of house reforms, 100% in the back of the lot houses (Fig. 7) and 40% in the front of the lot houses, must be used as an important indicator of dissatisfaction and discomfort.

House owner knowledge of thermal comfort detailing is limited to simplistic and some erroneous construction elements. 18% of self-builders claim not to know of any means of improving comfort in summer, and 32% are ignorant of winter comfort detailing. The elements cited to aid against excessive heat are large openings, by 30% of the population, and a high ceiling, by 10%. The new vernacular, however, does not adopt these beliefs, using small windows and low ceilings for economic reasons. In the literature, high ceilings are not found to be an important cooling element in house construction, when roof conditions are ideal [15]. Older, colonial houses have, however, better comfort ratings in summer, which must be attributed mainly to the possibility of high level air vents with high ceilings and elongated large windows, thick white-washed walls and attic ventilation. Winter conditions are said to be improved by the simple closing of windows by 23% of the population, and the use of heaters by 29%. Heaters are, however, not part of local practice, nor is air-conditioning for cooling due to energy costs.

Expectations, by the local population, concerning thermal comfort are still not high, since experiences of working in totally air-conditioned buildings are rare and there is a cultural distrust towards mechanized cooling, which may adversely affect health. Expectations and knowledge therefore do not exert strong needs for improving house design for thermal comfort. Social and economic conditions also restrict access to better ways of building. Simple design strategies, however, are available to improve the new vernacular.

Climate responsive attributes can be incorporated in the house design through simple modifications of wall and roof color, introduction of ceilings or shading devices and change of roof material. To show the comfort gain of combinations of such modifications, a simulation is included here using as an example the house design shown in Fig. 11 [17]. This house is used by local authorities in low-income housing projects as minimum shelter. The house consists of a single kitchen/living space and a bathroom. The house is provided as a first stage of building.
which through additional building stages would be amplified to create a typical four-room preferred house. Although in its primary stage this design does not represent the preferred house of the new vernacular as described previously, it can be used to exemplify the importance of simple design features to improve comfort.

The program used to simulate simple design changes shown in Table 1 is ARQUITROP [16]. This program includes a good databank of local building materials, techniques and climate conditions. The program was developed as a first-step analysis tool for designs in Brazilian climate conditions. Simulations of various elements in this basic house design can show marked improvements in summer comfort. Ten different conditions were simulated. Variations of orientation are indicated by the angle formed clockwise between the true north and a line perpendicular to the front of the house. Colors are graded 1 to 5, from white to black, with intermediate shades of gray. Two external wall and roof colors, white (1) and gray (3), were used. Houses with or without ceilings were simulated. Wooden and prefabricated beam and ceramic block+concrete slab ceiling materials were distinguished. Shading of window glass was simulated through a white external awning. Nonshaded windows were also included. Evaluation was based on maximum internal temperature and the hour this occurs, solar and internal heat gain and monthly degree hours.

Results showed that the best condition (3) is achieved when the orientation angle measures 158° from north, with the front of the house facing south-east; external walls and roof surfaces are white and no ceiling and shading is included. Although the example lacks shading and a protective ceiling, therefore unfavorable roof detailing, it shows the importance of roof color and orientation to improve thermal conditions. The positive impact of a white roof surface is the most important feature in this example, which in normal conditions is, however, not maintained, due to dust. Another example (8)* with good results is a house facing north-east, with white walls, gray roof material but including a slab ceiling and window shading. The second example is therefore a recommended design strategy. The simple simulation shown here thus stresses the importance of design elements, such as wall color, ceilings and window shading, to improve summer thermal comfort.

**DESIGN IMPROVEMENTS FOR THE NEW VERNACULAR**

Increased awareness of improvement possibilities must be the first step to create a climate for changes in design and construction. This awareness must not cause distrust of unknown technology. New strategies should be restricted to local ways of building to avoid cost problems, cultural rejection and therefore quick abandonment of new positive elements. This is especially true with regard to basic construction techniques, wall thickness, plan configuration and aesthetic elements.

The local construction techniques are positive in relation to summer comfort, since they are based on the use of materials with adequate thermal resistance. This adequacy is, however, not consciously applied and precariously dependent on cost factors. Awareness of technical comfort data must therefore be increased. Color as a simple means of improving summer comfort is an important factor to be taught. Self-builders should be encouraged to stucco their houses in due course, and white-washing must be shown to its full advantage.

The basic preferred house plan must be preserved. Examples of housing projects, based on new and unfamiliar plan configurations, have shown high transformation rates, where house owners attempt to incorporate preferred space arrangements into their house modifications. Transformations are always wasteful and should be avoided in housing aid and design systems.

The house in the back of the lot must be avoided. This type of house has no possibility for cross-ventilation even with open room doors and no control of orientation for window placement. Three outer walls also have no roof overhang, and are usually painted black for moisture penetration control. Due to these conditions, this type of construction has few possibilities for improvement and is not preferred. The vast majority of these back-of-lot houses are changed over time since they are too small. These additions create particularly unfavorable conditions with regard to thermal comfort. Openings of first

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<td>15</td>
<td>0.89</td>
<td>875</td>
<td></td>
</tr>
</tbody>
</table>

*Example 7 is not recommended since this orientation in a final house configuration would include rooms entirely facing south, thus without minimum insolation.

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**Table 1.** Table showing thermal comfort results of simulation of varying construction conditions of a simple one-room and bathroom house.
stage rooms are obstructed, blocking out ventilation and light. Self-builders must therefore have access to this knowledge and must be encouraged to start their house in the center of the lot, where conditions for the building of an adequately sized and comfortable home are favorable. This home can be achieved through design and building recommendations in the form of a design support system [18]. In Fig. 12 a preferred house plan is shown with possible construction stages, which are both functionally and technically adequate. In Campinas a technical support system for self-builders can be based on house plan drawings, since a good plan reading capacity was detected in the population. The support system, based on preferences, must include information on window location with respect to individual lot conditions, opening sizes, verandah location and possible construction evolution as shown in Figs 12 and 13.

Since the preferred house plan is sited in relation to the street front, self-builders must be made aware of shading necessities to avoid excessive insolation. Positive design elements such as verandahs and large overhangs should be favored. The role of vegetation in the form of large trees must be stressed. Opening sizes must also be consciously related to room sizes for adequate ventilation. This can be achieved through the aid system introduced previously, furnishing the self-builder with properly sited and shaded floor plan arrangements for his specific suburban lot. Such systems can be computerized for quick
Fig. 13. Result of computerized design method (three-bedroom house) for eight orientations of one lot type.

individualization and result in outputs as seen in Fig. 13, where eight sun orientations are adequately incorporated, for a specific lot condition. For minimum insolation of all three bedrooms,* lots facing north and south need new plan configurations. For the preferred plan on most suburban lots, window placement is restricted towards the front and back of the lot, due to lack of proper side setback conditions. Shading, however, is necessary for the worst window orientation conditions of north and north-west facing walls. Here verandahs should be encouraged. Verandahs, as positive shading elements, are only useful when added to house designs of adequate size, to avoid the incorporation of the outdoor space into the interior functional area.

Increased awareness of the importance of vegetation in relation to thermal comfort should be part of the design recommendation as a whole. The positive influence of landscaping must be stressed in the self-building environment. Grasped areas promote evaporation and absorption of solar radiation. Since most house builders spend their efforts primarily on the interior of the house, the rewards of landscaping must be culturally taught. Shade from trees is a major positive feature. Shade trees are a problem on small lots, however, causing insufficient sun penetration in humid climates and cold winter days,1 as well as constant maintenance needs with falling leaves and branches. Large trees are therefore rarely planted in self-built settlements. The subdivision arrangement of street detailing should, however, include a public nature strip for shade tree placement. This comfort improvement is seen as belonging to the local building authorities, introducing adequate by-laws in subdivision regulations for this purpose.

Construction detailing of the houses must concentrate on the conscious introduction of cross-ventilation into the design. Large, but shaded, openings on two sides of a room should be used when possible, with good control over the opening mechanisms. The narrow lot often forbids the placement of openings to the side of the house, although for cross-ventilation, controllable openings could be introduced which are not in the form of traditional windows. The location of windows in small

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*A three-bedroom house is not the most preferred design, since self-builders are conscious of their economic limits. However, a substantial percentage (38%) of the population indicates a need for such larger houses.

†Most trees in Brazil are not deciduous.
homes must take into account furniture placement, to have lasting effects on comfort. Since windows are expensive items in the construction of houses, real awareness of the importance of size and cross-ventilation must be taught and evolutionary construction encouraged* as shown in Fig. 12, where small resources are adequately and properly applied over a time span. Ventilation openings that cannot be closed should not be introduced in habitable rooms. The lack of control will interfere with privacy and cause discomfort on infrequent cold occasions. Openings for permanent ventilation must be a feature of roof design, however, greatly enhancing summer comfort. Construction detailing of this feature must include security needs and avoid animal access to the space between roof and ceiling. The influence of lot conditions on the comfort of the house must also be made clear. Setbacks from lot walls are positive for ventilation, although not always possible on small narrow lots. The habitual subdivision arrangements, with monotonous rows of narrow lots, should suffer some changes, through regulations and professional training.

**CONCLUSION**

It can be shown that a specific vernacular architecture exists in Campinas, Brazil. This style is an evolution of the traditional Brazilian house. Climate appropriateness is not a strong feature of the local vernacular, although the traditional house has a number of positive elements. The new vernacular is proliferating around growing cities with varying degrees of satisfaction due to thermal comfort conditions. Simple design strategies can, however, improve the houses of the urban poor. Design elements and methods are shown which respect local habits and preferences.

**REFERENCES**