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NOT EVERY COURTYARD IS NECESSARILY A GOOD ONE CLIMATICALLY
Physical Characteristics
design of domestic courtyards in the hot-dry climates of the sub-tropics

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ABSTRACT

One of the aims of this paper is to identify the physical characteristics of the courtyard which have direct influence on its performance micro-climatically and thermal environmentally. Here, the objective is to take these into account at the conceptual design stage so that these physical characteristics of the three-dimensional form of the courtyard work in harmony with other aspects of it; the goal is to ameliorate the severe micro-climatic conditions prevailing in summer, and ultimately to produce acceptable, if not desirable, thermal environmental conditions within the courtyard and inside the habitable rooms and spaces grouped around it and looking inwards towards it; this is specially so in the regions of the hot-dry climates of the sub-tropics where buildings should be designed to be energy efficient structures by incorporating concepts and principles of passive solar design due to acute shortage of energy for continuous cooling in summer and intermittent heating in winter.

KEYWORDS

courtyard; physical characteristics; three-dimensional form; traditional courtyard houses; hot-dry climates; sub-tropics; thermal environment; vernacular architecture; developing countries.

1. INTRODUCTION

The incorporation of a courtyard in the design and execution of a house or a building does not necessarily mean that such a structure is specifically designed to control the severe micro-climatic conditions prevailing in summer in the regions of the hot-dry climates in the sub-tropics. This is because not every courtyard is necessarily a good one micro-climatically. In other words, the concept of incorporating a courtyard is right, but its detail design (in terms of size, shape, form, etc.) may not be correct thermal environmentally.

There are many factors which determine the quality of the performance standards and performance specifications of an internal courtyard in the hot-dry climates of the sub-tropics. A detailed discussion of them is outside the scope of the present paper; however, the identification, analysis and appraisal of the broad principles are not; some of these are presently discussed in detail.

Here, some of the factors which make a courtyard climatically desirable or otherwise are identified, explained and appraised, particularly those relating to its physical characteristics. Therefore, when designing new buildings incorporating one or more courtyards (whether within traditional houses, residential buildings, or any other type), these factors should be taken into account; hence, such courtyards are consciously designed to be climatically desirable in the hot-dry climates of the sub-tropics. Besides, their thermal environmental performance in winter should also be considered so that they do not become a source of discomfort even during this short and cool-to-cold

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season. These conditions directly influence those prevailing in the habitable rooms and spaces surrounding it and looking inwards towards it. Here, the courtyard also acts as an in-between place or a transitional space physically, visually and sensually between the external micro-climate and the internal thermal environment.

Internal courtyards are a characteristic design feature of vernacular domestic architecture as well as of indigenous non-domestic architecture in the hot-dry climates of the sub-tropics, particularly in the Developing Countries of the Third World; these have been developed through the ages by a process of trial and error; here, the accumulated design experience of the master-builders and the technical know-how of the craftsmen were passed on from one generation to another to be understood, assimilated and improved upon before they were in turn passed on to the succeeding generation. The proto-type of such indigenous courtyard houses date back to antiquity; in the case of Baghdad, for example, this is found in the milieu of the Sumerian, Akkadian, Babylonian and Assyrian civilisations. (1), (2) and (3).

As used in this paper, the term courtyard refers to an internal courtyard which is the focal space of the house and the hub of the family domain; it is surrounded by habitable rooms and spaces (as well as ancillary areas) along two, three or four sides of it; these look out onto it visually and communicate with it physically either directly or indirectly; additionally, they receive their daylight and natural ventilation through it; at the same time, the courtyard provides them with contact with the external environment and the weather outside as well as with a view of the sky above. (4), (5) and (6).

It should be pointed out that from the point of view of micro-climates and internal thermal environments, what is considered to be a disadvantage in summer may well be an advantage in winter in terms of sun penetration, duration of sunlight, solar heat gain, high surface temperature and high air temperature. It is a case of striking a balance between the requirements needed to deal with the duration and severity (or otherwise) of micro-climatic conditions prevailing in one season with those of another; here, a set of compromise design criteria related to micro-climates and internal thermal environments for all seasons are rationally arrived and deliberately carried out.

2. SHAPE OF COURTYARD IN PLAN

The plan of the courtyard is usually rectangular in shape, but it can be of a perfect square; there are also a few rare examples where it is of a trapezium shape (7). The influencing factors in all cases are the shape and size of the building plot and the size, number and use of the habitable rooms and spaces grouped around it and looking inwards towards it at each floor level. The function and use of the courtyard is also an important factor in determining its size. All these are naturally related to the financial means of the owner-occupier as well as to his social standing in the community. It would seem that for the same floor area, a rectangular-shaped courtyard in plan with its axes oriented in the correct directions vis-à-vis the sun, would perform better micro-climatically than a square one of the same orientation.

3. SIZE OF COURTYARD IN PLAN

The size of a courtyard in terms of its floor area and plan dimensions varies considerably. It can be very small (with a floor area of 12 to 15 sq m (8), (9) and (10), etc.) to small, medium, large and very large (with a floor area of 80 to 90 sq m (11), (12) and (13), etc.). (Fig. 2, 3, & 6-8). There are also exceptionally small courtyards (with a floor area of up to 10.0 sq m (14) and (15), etc.) and exceptionally large courtyards with a floor area of 140 sq m (16), of 220 sq m (17), and even 330 sq m (18), etc.); but, these are rare cases representing the exception rather than the rule. It should be emphasised that from a micro-climatic point of view, the smaller the courtyard, the better its performance is.

4. NUMBER OF FLOORS

The great majority of houses incorporate courtyards which are usually two storeys high, consisting of ground floor and first floor. However, there are also courtyards which are only one storey high. There are also a few rare cases where the height of the courtyard can be of partially single storey and partially two storeys; alternatively, it can be of partially two storeys and partially three storeys. From micro-climatic point of view, two-storey courtyards perform better than single-storey ones having the same orientation, and three-storey courtyards are more effective than two-storey ones. However, this is also related to the size of its floor area, and to its plan dimensions. Naturally, the number of floors is related to the number of habitable rooms and spaces (as well as ancillary areas) grouped around it and looking inwards towards it. These are also related to the size of the building plot, the financial means of the owner-occupier, as well as to his status and social standing in the community.

5. FLOOR-TO-CEILING HEIGHT

At ground floor, the floor-to-ceiling height is relatively low and varies between a low of 2.70m (19) and 2.80m (20) and (21), a medium of 3.10m (22), and a high of 3.50m (23), or occasionally exceptionally high of 4.00m (24), with the great majority of houses having a floor to ceiling height of about 3.0m; this limits the extent of sunlight penetration into the interior in summer, and therefore reduces heat gain from direct solar radiation which is undesirable during this season. (Fig. 10 & 11).

At first floor, the floor-to-ceiling height is comparatively high and varies between a low of 3.00m (25) and (26); a medium of 4.00m (27) and (28), and a high 4.40m (29), or occasionally exceptionally high of 5.00m (30), with the great majority of houses having a floor-to-ceiling height of about 4.00m; this increases the extent of sunlight penetration into the interior in winter, and hence increases heat gain from direct solar radiation which is desirable during this season. (Fig. 10 & 11).

It should be pointed out here that the ground floor is designated mainly for summer habitation (and therefore designed to limit the extent and duration of sunlight penetration into the interior) while the first floor is designated for winter habitation (and hence designed to increase the extent and duration of sunlight penetration into the interior). It is also important to emphasise that all habitable rooms and spaces at first floor are not used in summer; they are completely deserted. Therefore, this floor acts as a barrier against the sun in summer by shielding the ground floor from its scorching heat; in a way, the first floor functions like a well-ventilated attic of a pitched roof in protecting the space immediately underneath it from direct solar radiation as well as from high surface temperature and air temperature.

6. HEIGHT OF COURTYARD

The actual height of a two-storey courtyard varies between a low of 6.50m (31) and (32), a medium of 7.50m (33), and a high of 8.50m (34), or exceptionally high of 9.0m (35), depending on the size of the courtyard in terms of its floor area and its plan dimensions; in turn, these are related to the size and number of habitable rooms and spaces (as well as ancillary areas) grouped around it and looking inwards towards it at each floor level; they are also related to the size of the building plot, to the financial means of the owner-occupier, and his status and social standing in the community. From a micro-climatic point of view, the higher the courtyard, the better its performance in summer is. (Fig. 10 & 11).

7. PROPORTIONS OF COURTYARD DIMENSIONS

From a micro-climatic point of view, the performance of a courtyard depends on, inter alia, the orientation of its axes, its three dimensional form, and the optimum proportions between its physical dimensions of length, width and height. These help to keep part of the floor area of the courtyard as well as its walls in the shade even around mid-day when the sun is nearest to the zenith. The extent of the shaded area of the floor and walls of the courtyard depends on the cut-off angles to the rays of the sun provided by the walls surrounding it and defining its physical size, and on the orientation of its axes in plan. The cut-off angles are determined by the three-dimensional form of the courtyard (especially the proportions of its length, width and height or that of its length plus width to its height), and by the altitude of the sun above the horizon throughout the year, especially in summer in the case of the hot-dry climates. The combination of all these factors keeps part of the floor area of the courtyard and of its walls in the shade; they also help to avoid high surface temperatures which in turn alleviate high air temperatures in summer.

The proportions of plan dimensions of width:length in the courtyards of existing traditional courtyard houses tend to approximate towards 2:3. However, their height is related to the size and height of their habitable rooms and spaces. In general, those at ground floor level are about 2.70m in small courtyard houses, 3.00m in medium-size ones, and 3.50m (or exceptionally 4.00m) in larger ones. On the whole those at first floor level vary between 3.00m in small courtyard houses, 3.50m in medium-size ones and 4.00m (or even exceptionally 4.50m) in larger ones. (Fig. 10 & 11).

8. OPEN AREA OF COURTYARD AT ROOF LEVEL

The micro-climatic performance of the courtyard also depends on the projected or elevated area of the courtyard at roof level open to the sky, namely, the size of the opening (or hole) in the roof immediately above the courtyard.(Fig. 4 & 9). This area may be smaller or larger than the floor area of the courtyard itself depending on the latter projected at first floor level and at roof level; these in turn depend on the four profiles of the courtyard in section, on the projection (towards the centre of the courtyard) of the access gallery (**Mamsha**), and on the projection of the roof (towards the centre of courtyard) at eaves level (**Sachagh**). (Fig. 10 & 11).

The intensity of direct solar radiation and the duration of sunlight in the courtyard depends on the size of this opening at roof level as well as on the proportions of its three-dimensional form. Therefore, the

smaller this area, the less sunlight is admitted into the courtyard, and the less direct solar energy penetrates the interior; hence, the better thermal environmental conditions prevailing in the courtyard in summer as well as in the surrounding habitable rooms and spaces grouped around it and looking inwards towards it.

9. SECTIONAL PROFILES OF THE COURTYARD

The sectional profile of the side of the courtyard can take any of the following forms: first, a vertical shear profile characterised by the lack of sizeable protrusions or recesses; secondly, an articulated, recessed profile; and thirdly, an articulated protruding profile. All of these may or may not incorporate an inward projection (towards the centre of the courtyard) of the roof at eaves level (**Sachagh**) beyond the face of the walls overlooking the courtyard at first floor.

In theory, of course, each side of the courtyard could have a different profile; however, aesthetically and practically, the profile of all sides could be the same, every two opposite sides could be identical, the two main sides could be the same while the remaining two sides could be either similar or different. In other words, there could be one or two common profiles and three or four different profiles.

A shear vertical profile would not contain appreciable recesses or protrusions; it can be either of a blank wall or may contain windows in the same plane (36). An articulated recessed profile may contain a recessed access gallery (**Mamsha**) (Fig. 11) or a recessed colonnaded gallery (**Tarma**) (37). An articulated protruding profile may contain a protruding access gallery (**Mamsha**) (38), (Fig. 10), a protruding colonnaded gallery (**Tarma**) (39) or bay-windows (known as the **Shanasheel** in Baghdad, **Mashrabiya** in Cairo and **Rawshan** (40) in Jeddah).

An inward protruding eaves would not only reduce the projected area of the courtyard opening at roof level, but would also shade the walls underneath it at first floor from the sun in summer and the rain in winter. (Fig. 10 & 11). Similarly, an inward protruding access gallery would not only reduce the projected area of the courtyard opening at first floor, but would also shade the walls underneath it at ground floor from the sun in summer and the rain in winter. (Fig. 10). In both cases, there would be less sunlight and direct solar radiation reaching the floor of the courtyard; shade means reduced surface temperature and consequently reduced air temperature. The combination of all these factors result in better thermal environmental conditions prevailing in summer in the courtyard and its surrounding habitable rooms and spaces.

10. DESIGNATION, GROUPING AND ORIENTATION

It is possible to group habitable rooms and spaces in such a way so that: first, those designated for use in summer are oriented away from the sun to reduce direct solar radiation, but at the same time they are oriented towards the prevailing wind to encourage convective cooling, especially overnight when the air temperature outside is lower than that inside; and secondly, those designated for use in winter are oriented towards the sun to encourage direct solar radiation to warm up the interior, but at the same time, they are oriented away from the prevailing wind to avoid heat loss by convection. Such concepts have actually been used in the past by the master-builders of Baghdad.

It is equally possible to group all habitable rooms and spaces along two or three sides of the courtyard, leaving the remaining two sides or fourth side respectively facing any undesirable orientation and incorporating all the ancillary areas or leaving it blank. Even these can be shaded using an access balcony (**Mamsha**) at first floor and inward-projecting eaves (**Sachagh**) at roof terrace level (**Satih**). Again, such concepts have also been used in the past by the master builders of Baghdad.

11. NUMBER OF COURTYARDS

In the great majority of houses belonging to the low and average income groups, there is usually only one courtyard. However, in the houses of well-to-do families, there may be one, two, three or four courtyards. each with special designation and with its own habitable rooms and spaces as well as ancillary areas grouped around it and looking inwards towards it. The first may be the family courtyard (**Housh al-Haram** or simply the **Haram**), the second may be the business and guests' courtyard (**Housh al-Diwan-Khana** or just the **Diwan-Khana**), the third may be the kitchen complex courtyard (**Housh al-Matbakh** or simply the **Matbakh**), and the fourth may be the stable courtyard (**Housh al-Tola** or just the **Tola**) where animals are kept. The use of more than one courtyard was adopted for family, social, business, and hygienic reasons. However, their use has helped to reduce the size of the various courtyards considerably which led to better micro-climatic and thermal environmental conditions prevailing in them in summer.

12. INFLUENCING FACTORS

There are many factors which determine the physical form of the courtyard and which ultimately influence its micro-climatic and thermal environmental performance. These include the following:

- the use and function of the habitable rooms and spaces grouped around the courtyard and looking inwards towards it;
- their size and number at each floor level;
- their plan dimensions;
- their floor-to-ceiling height;
- the proportions of their three-dimensional form;
- the use and function of the courtyard itself (ground floor level to roof level;
- its size in plans, sections, elevations and three-dimensional form;
- the size of the house as a whole;
- the size of the building plot;
- the floor-to-ceiling height at each floor level;
- the total height of the courtyard itself;
- the number of floors the courtyard and the house are composed of;
- the financial means of the owner-occupier;
- the status and social standing of the family in the community;

All these factors are inter-related and have a direct influence on each other; hence, they should be considered in total and not in isolation.

There are other factors which affect the courtyard performance; these are related to prevailing micro-climatic conditions (and ways of ameliorating them), building materials, landscaping, and procedures followed by the inhabitants themselves. These are the subject of a separate paper by the author.

13. OTHER ASPECTS OF THE COURTYARD

There are other aspects of the domestic courtyard which are equally important and which have a direct influence on its performance; however, these are not discussed here because they are outside the scope of the present paper. They include the following topics:

- functional aspects;
- the courtyard as the hub of family life and of daily living activities;
- the courtyard as the gathering place for social festivities;
- the courtyard as the centre for religious ceremonies;
- the courtyard as a mitigator of micro-climates and attenuator of internal thermal environment;
- the courtyard in winter;
- what makes a courtyard climatically desirable;
- visual characteristics;
- non-functional aspects; and
- the courtyard in a historical and archaeological context;

Some of these aspects have already been discussed in separate publications while others will be dealt with in future papers.

It is not always possible to satisfy the requirements of all these aspects of the courtyard; a compromise solution would have to be adopted which would satisfy most of these requirements according to a weighting system of priorities adopted for each case. Therefore, this paper is only one in a series which the author has been writing; these deal in detail with the micro-climatic and thermal environmental performance of courtyards and of their houses in the hot-dry climates of the sub-tropics and cover wide-ranging topics.

14. CONCLUSION

The physical characteristics of the courtyard, especially of its three-dimensional form, affect the duration (and intensity) of sunlight in it throughout the year. This duration has a direct impact on its performance micro-climatically and thermal environmentally.

In summer, the design objective is to shorten this duration to a minimum in order to reduce heat gain from direct solar radiation to avoid overheating the interior because of the hot-dry micro-climatic conditions prevailing during this season.

In winter, the design aim is to lengthen this duration to a maximum in order to increase the heat gain from direct solar radiation to warm up the interior because of the cool-to-cold conditions prevailing during this season.

The designer's goal is to reach a compromise between the contradictory requirements of the design criteria for these two different seasons. The balance depends on the severity and duration of the particular season in question. Here, a weighting system may be used to tilt the balance between the requirements of the design objectives of the two seasons and to prioritise them. Therefore, the resulting design would produce environmental conditions which would not be too hot in summer nor too cold in winter.

It is perhaps pertinent and to the point to mention here an Arabic saying used by the people of Baghdad which states that "not every nut is rounded, and not every rounded object is a nut". Therefore, not every

courtyard is necessarily a good one micro-climatically and thermal environmentally; in other words, there are climatically good courtyards, but there are also climatically bad courtyards; that is, the performance of each courtyard depends on its own merits which are directly related to all the influencing factors discussed here. This is especially so when there may be contradictory requirements between the functional aspects of the courtyard (which may dictate its physical characteristics in terms of size in plans, sections, elevations and three dimensions) and its micro-climatic and thermal environmental performance.

Hence, a check list should be used to identify, analyse, and assess the performance of the courtyard from all aspects: functional, physical, social, religious, cultural, micro-climatic, thermal environmental, planning, architectural, visual, and psychological.

When these are arranged in a hierarchical order of priorities and a weighting system is applied, the resulting design of any particular courtyard would be rational, appropriate and fulfilling the necessary requirements in question. Because in most cases the priorities are different, the resulting courtyards would also be different, reflecting the priorities themselves; however, the concept, design and detailing of the courtyard itself would be correct for the circumstances under discussion.

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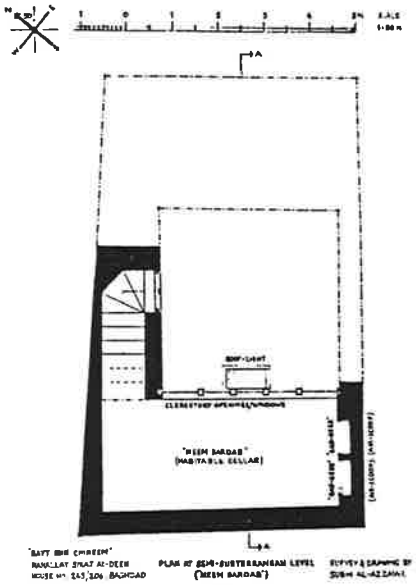
7. REUTHER, Oscar. (1910). Das Wohnhaus in Bagdad und Anderen Städten des Iraq. Verlag von Ernst Wasmuth, A.-G. Berlin. Fig. 73, p. 34 and fig. 74, p. 35, Bayt Sha'shoor, Baghdad.
8. And plan dimensions of 4.0m x 3.0m.
9. And plan dimensions Of 3.65m x 3.65m. Bayt Ibin Khadh-dhoori, house no. 249/206; Mahallat Siraj Al-Deen, Baghdad; measured drawing by the author (1971-72).

10. And plan dimensions Of 3.90m x 3.90m. Bayt Ibin Chireem; house no. 245/206; Mahallat Siraj Al-Deen, Baghdad; measured drawing by the author (1971-72).
11. And plan dimensions of 11.55m x 7.25m. Bayt Al-Haj Ali Al-Kaw-waz; house no. 259/206, Mahallat Siraj Al-Deen, Baghdad; measured by the author (1971-72).
12. And plan dimensions of 10.0m x 8.65m. Bayt Al-Haj Abdul-Ameer Al-Khateeb; house no. 112/14, Mahallat Al-Qattana, Bab Al-Murad, Kadhimiya, Baghdad; partial measured drawing by the author (1971-72).
13. And plan dimensions of 10.40m x 8.45m. Bayt Falih Al-Qassab; house no. 24/1/19, Mahallat Karradat Maryam, Baghdad; measured drawing by the author (1971-72).
14. And plan dimensions of about 4.0m x 2.5m. Bayt Usta Hasan Faraj (formerly, Bayt Abu Shawqi); house no. 275/206, Mahallat Siraj Al-Deen, Baghdad.
15. And plan dimensions of about 3.0m x 3.0m.
16. And plan dimensions of about 14.0m x 10.0m. The Haram courtyard of Bayt Hussein Pasha, Baghdad; measured drawing by Oscar Reuther (1908-10); op. cit.; fig. 63, p. 29.
17. And plan dimensions of about 14.5m x 14.5m. The Haram courtyard of Bayt Menaheem, Baghdad; measured drawing by Oscar Reuther (1908-10); op. cit.; fig. 48, p. 20.
18. And plan dimensions of about 22.0m x 15.0m. The Diwan-Khana courtyard of Bayt Hussein Pasha, Baghdad; measured drawing by Oscar Reuther (1908-10); op. cit.; fig. 63, p. 29.
19. In the Tarma of Diwan-Khanat Al-Estarabadi; op. cit.
20. In the Tarma of Bayt Ibin Khadh-dhoori; op. cit.
21. In the Tarma of Bayt Ibin Chireem; op. cit.
22. Measured by others, but not by the author.
23. In the Tarma of Bayt Falih Al-Qassab; op. cit.
24. In the Tarma and Talar of Bayt Al-Haj Ali Al-Kaw-waz; op. cit.
25. Bayt Ibin Khadh-dhoori; op. cit.
26. Bayt Ibin Chireem; op. cit.
27. Diwan-Khanat Al-Estarabadi; op. cit.
28. Bayt Al-Haj Ali Al-Kaw-waz; op. cit.
29. Bayt Sha'shoo'; house no. 3/8/1. Mahallat Al-Sinak, Baghdad; partial measured drawing by the author (1971-72).
30. Measured by others, but not by the author.
31. 6.575m in Bayt Ibin Khadh-dhoori; op. cit.
32. 6.50m-6.60m in Bayt Ibin Chireem; op. cit.
33. 7.38m in Diwan-Khanat Al-Estarabadi; op. cit.
34. Measured by others, but not by the author.
35. 9.05m in Bayt Al-Haj Ali Al-Kaw-waz; op. cit.
36. Menzil (Bayt) Ali Efendi Labib; house no. 4 Harat (alleyway) Al-Lebbana, Al-Qal'a, Cairo; occupied by the late Egyptian architect Hassan Fathy.
37. Diwan-Khanat Al-Estarabadi; op. cit.
38. Bayt Ibin Khadh-dhoori; op. cit.
    Bayt Ibin Chireem; op. cit.
    Bayt Falih Al-Qassab; op. cit.
39. Bayt Al-Haj Ali Al-Kaw-waz; op. cit.
40. Menzil (Bayt) Ali Efendi Lebibb; op. cit.
    Menzil (Bayt) Jamal Al-Deen Al-Dhahabi; Harat Hosh Qadam, Cairo.
    Menzil (Bayt) Al-Suhaymi, Harat (alleyway) Al-Darb Al-Asfar, Jammaliya, Cairo.



"BAYT IBN CHIREEM"
MAHALLAT SHAZ AL-DEEN
HOUSE NO. 243/206, BAGHDAD.
PLAN AT SEMI-SUBTERRANEAN LEVEL ("HEEM BARDAB")
SURVEY & DRAWING BY SUBHI AL-AZZAWI.

FIG. 1

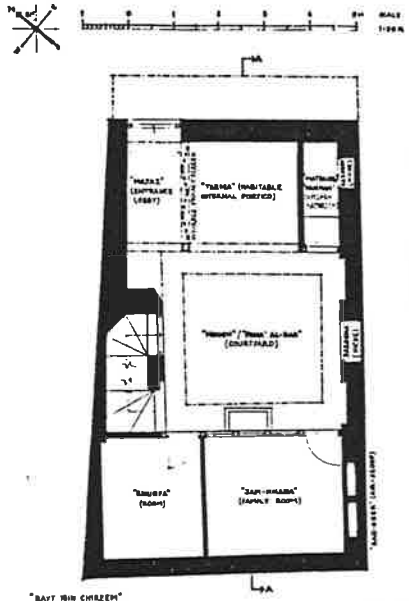


FIG. 2

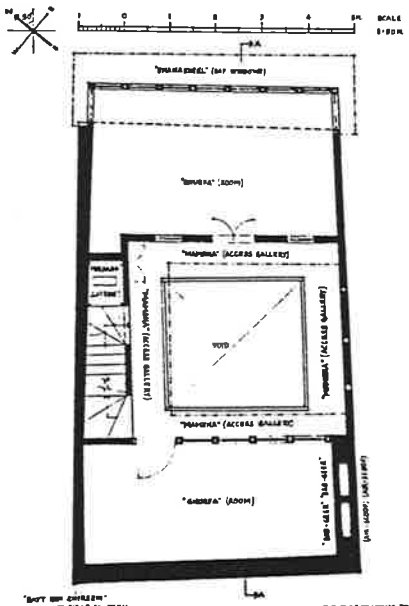


FIG. 3

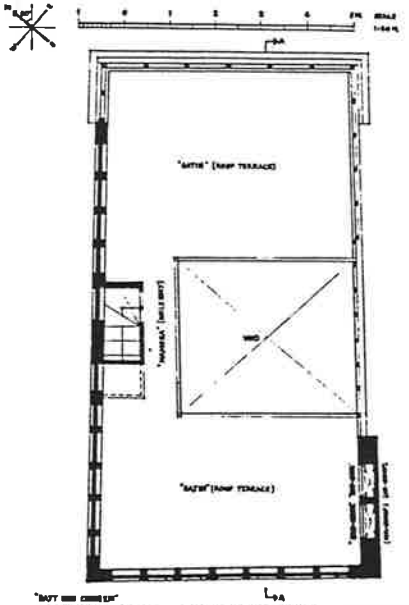


FIG. 4

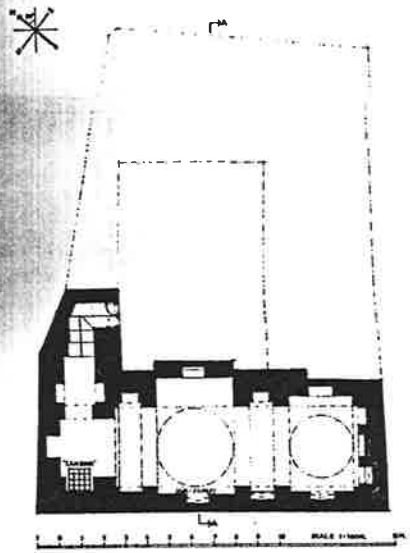


FIG. 5

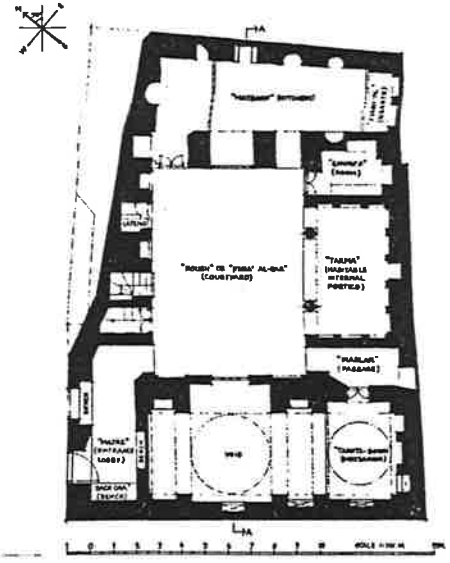


FIG 6

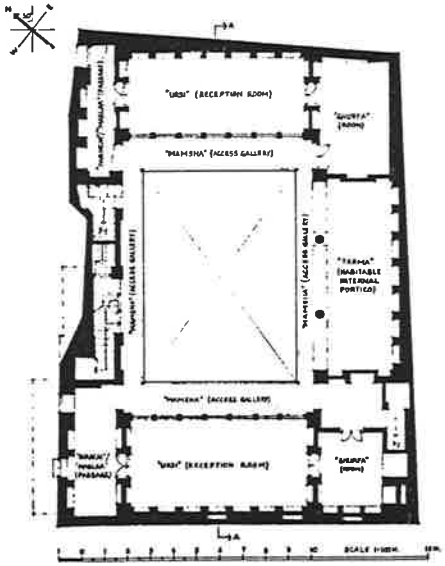


FIG. 7

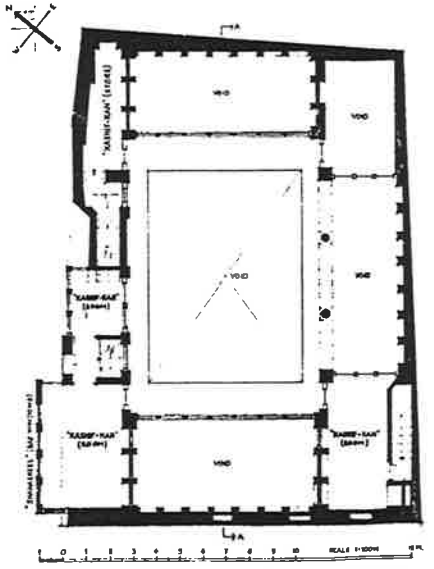
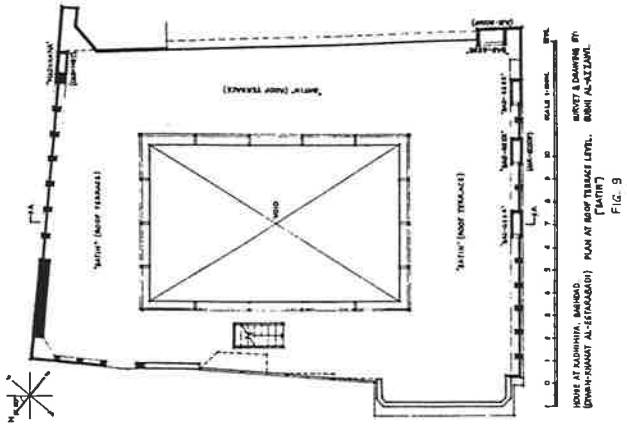


FIG. 8



HOUSE AT RADHIHIYA, BAGHDAD (DIWAN-KHANAT AL-ESTARABADI) PLAN AT ROOF TERRACE LEVEL. ("SATIH")

SURVEY & DRAWING BY: SUBHI AL-AZZAWI.

FIG. 9

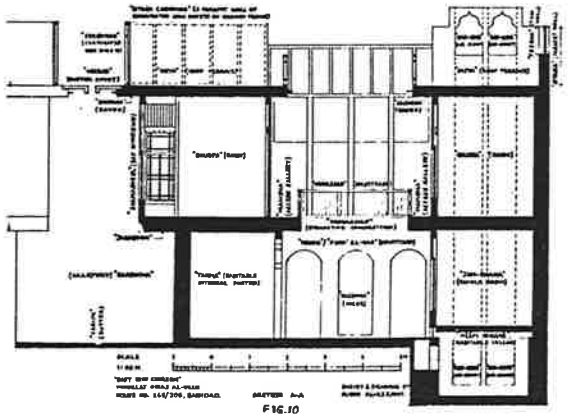
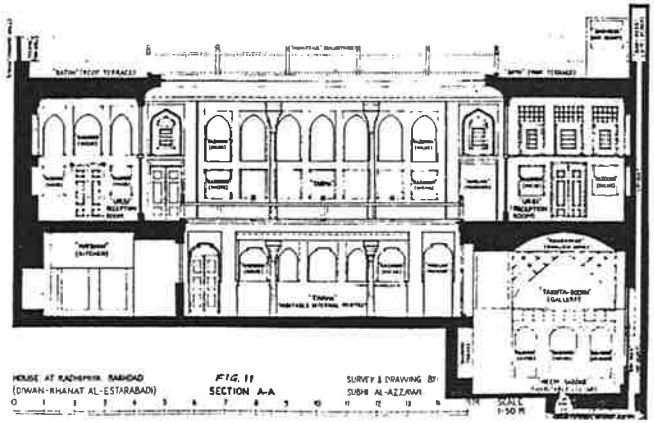


FIG.10



HOUSE AT RADHIHIYA, BAGHDAD (DIWAN-KHANAT AL-ESTARABADI)

FIG. 11 SECTION A-A

SURVEY & DRAWING BY: SUBHI AL-AZZAWI.