Evaluation of Basement's Thermal Performance in Iraq for Summer Use

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Abstract

The main environmental problem for people living in Iraq is the long hot dry summer. Basements were used in the past by the people to solve part of the problem. Recently older solutions have been bypassed in favor of air conditioning. The consequent electric loads are very high. In this paper the basement is evaluated thermally for summer use and tested for cooling loads. Climate factors were measured outside a building, inside it and in the basement. The measurements lasted from early spring to late autumn. The basement was by far the best of the measured spaces thermally. For most of the summer they were only slightly off reasonable thermal comfort readings for sedentary activities. However it did peak at around 35°C for two weeks. Calculations show that a relatively small cooling load would improve the interior to a comfortable temperature. By comparison a cooling load several times more would be required to reach similar conditions in an above ground space.

Keywords: Earth structure; basement; cooling load; green building; sustainability

1. Introduction

The capital of Iraq, Baghdad suffers from hot arid harsh weather conditions. This can be seen clearly from the data in Fig.1. The temperatures in summer soar to the upper 40's and sometimes pass 50ºC. The winter is cold especially in the north of the country often crossing bellow zero. Fortunately cheap fossil fuel heating is widely available during this period. But in summer the situation is much more difficult. It requires heavy cooling using air conditioners. This results in a huge increase of electricity loads.

Early Iraqi’s had found solutions to this problem. They developed a system that performed quite well and organized their daily routine of life to fit the climate. At nighttime the family would sleep on the roof where the cool dry night breeze was quite nice after ten in the evening. In the cool of the morning they rose early to avoid the morning sun and set to work. This stopped in the afternoon, when the weather gets hot. They would then return to their homes for lunch and sleep the hot afternoon away in the cool basement. In the evening they leave the seclusion of the basement to the breeze in the garden or the inner courtyard till nighttime sets again. This cycle allowed them to avoid the worst of the heat. It integrated the life cycle with building properties. A roof for sleeping and a basement was a prerequisite in every home.

With the advent of electricity and modern cooling methods the old ways were abandoned for the simplicity, comfort, and reliability of air conditioning. Especially since electricity is cheap here. Furthermore increasing water irrigation in gardens and poor drainage led to a rise in the underground water levels and many basements flooded. Building a basement became more expensive and risky. Modern Iraqi homes rarely contain any.

The issue of basement comfort and use has risen again recently. Rising land costs have driven many to build underground. This allows them to accommodate a garage and a few extra rooms. Furthermore the lack of a reliable electricity supply means that air conditioning
is now a poor option.

Another factor is safety. Basements are the safest place in a house with little or no outdoor windows to worry about and good protection from stray bullets or shrapnel.

The problems of basements in Iraq appear to be different from those discussed by published literature in the cold countries of Europe, Northern America and Japan. Here it is about the high water table and subsequent cost. Modern Iraqi basements use impervious reinforced concrete to line the basement. This protects and isolates it from underground water. Consequently most users don’t feel the humidity. Heating is not a problem either because of the high average daily and yearly temperatures. However a reinforced concrete structure is very expensive and sometimes still leaks water.

Current research worldwide concentrates on insulating the basement structure from moisture and on thermal transfer issues to help heating [2, 3]. Different materials and methods are tested and evaluated for effectiveness of heat containment in the space. Much work has also been done on the simulation of the thermal properties of underground spaces [4, 5]. Many of the popular simulation programs such as Energy plus, Ecotect, and Esp-r, include such a capability.

Possibly the closest work to this article is that which discusses earth shelters [6, 7]. Some of these relate to hot arid climates although not basements as such. Rather the use of the earth heat mass to help regulate temperatures inside a structure. Basements are different, especially deep ones. These are affected by underground water, as is often the case in Iraq. Rakesh et al. did some interesting work on earth contact buildings in the Indian climate [8] with the intent of studying reducing energy consumption. They found that the technology is viable in India.

The work done by Park et al. is an excellent example of the different values related to basement use in the cold developed countries compared to Iraq. The purpose of the paper is quite similar to that of this one which is the study of the environmental and thermal properties of earth structures. However Parks devotes considerably more time and effort to the study of moisture and condensation. He goes on to record in detail the year long performance of an experimental underground structure [9].

One Masters Thesis in the University of Technology discussed the use of earth mass and basements for Iraqi use [10]. However this study relied on theoretical calculations rather than measurements. The results from these were several degrees off from the measured ones. It did not take into consideration the effect of the high water table in most parts of Iraq or the ground cover. Research suggests that this can be significant and the reasons ....

were attributed to (1) the greater amplitude of the coupled soil surface temperature's amplitude, (2) the variation of the thermal conductivity with the moisture content, and (3) the advection of sensible heat by liquid moisture transfer. [11].

The procedure in this paper will include measurements inside and outside a basement to identify the basic issues. All temperature readings are in degrees Celsius. Calculations will later be run using this data through a thermal simulation program called "Ecotect" to compare cooling loads.

2. Indoor Environment above Ground

The indoor above ground environment during a summer day in Baghdad without any cooling is quite unacceptable. The average temperature is even higher than the outside. This is typical because the long daytime sunshine hours when the building absorbs heat is much longer than the short night when it radiates it. To describe this numerically, temperature readings were taken inside a small non-cooled single room building. Fig.2. shows the outside and inside readings during a July summer day in Baghdad. The average outside was 35.8°C and inside was indeed higher at 36.4.

The temperatures were measured using a four channel data logger with K type probes that have an accuracy of 0.1°C. The probes were calibrated with an alcohol thermometer beforehand. The measurements were taken on the 5\textsuperscript{th} of July 2006.

The room the measurements were taken in is a 4x3m room whose ceiling is 2.5m high. It is built of 24cm brick walls and reinforced concrete roof. This is typical Iraqi building material. The room has three exterior walls and one adjacent to another small un-cooled room facing west.

These measurements in Fig.2. show clearly why the Iraqi’s historically slept on the roof. The outside temperature during nighttime is three to five degrees lower than its equivalent inside. It also shows that at no time is the environment inside comfortable. However, during the day the inside is cooler than the outside between 11:00AM and 6:00PM but still far from acceptable at around 37°C. The maximum outside

![Fig.2. Daily Change of Temperature Inside and Outside a Ground Floor Room on 5\textsuperscript{th} June in Baghdad](image.png)
temperature was 41.6°C at 4:00PM and the minimum 30.7 at 5:00AM. The maximum inside was 38.5°C at 12:00AM and minimum 34.2°C at 9:00AM. These figures emphasize how big the problem is.

2.1 Basements

Typically present basements in Baghdad are built from reinforced concrete. This is for structural reasons and to keep out the underground water. In residential buildings the basement rooms are usually one to two meters below ground level as can be seen in Fig.3. This means that the ground floor is raised one to two meters to accommodate a basement with an acceptable roof height.

In non residential buildings the depth and ceiling height will vary according to design requirements. However they rarely go below four meters depth.

Measurements for this paper were taken in the basement of the Department of Architecture in the University of Technology in Baghdad. The floor is around 800m². It contains several rooms. The one where measurements were taken is shown in Figs.4 and 5. It is isolated and exposed to the outside from one side. It has a few small windows to the north. The inside is finished with cement plaster and the floor is made of mosaic concrete tiles. These finishes are typical for Iraqi basements. The basement floor is 2.5m below surface level. Its ceiling is 3.5m high.

Neither the basement nor the rooms above the space in which the readings were taken were cooled during the work.

2.2 Measurements

Temperature and humidity measurements were taken outside the building and inside. The interior readings were taken at ground level and in the basement. The measurements started in late winter and continued till late autumn. They were taken once a week at around noon.

In the basement itself, several temperature and wet bulb readings were taken as well as relevant surface temperatures. These were from a basement wall facing the outside, the floor and the ceiling. The readings from the wall were taken at 0.0, -1.0 and -2.0 meters from the ground level as can be seen in Fig.5. The floor of the basement was at minus 2.5m from ground level and the ceiling was 3.5m from the floor.

Above ground the outside dry bulb and wet bulb temperatures were taken. At the same level on the ground floor inside, similar measurements were taken of an exterior wall and the floor. These were for comparison with the basement readings.

3. Basement Temperatures

The air dry bulb temperature inside the basement rose steadily from spring and peaked in August. However this rise did not compare with that of the outside or ground floor interior temperatures which were higher.

As the graph in Fig.6. shows, while the outside air temperature rose from 20 to 43°C the inside temperature rose less to around 40 but the basement rose to no higher than 35°C. It must be remembered that these readings are not daily averages but were
taken at midday around noon. The outside and inside temperatures would fluctuate through the course of the day as shown in the graph in Fig.2. However the basement temperature hardly changes at all. The graph in Fig.7., which represents temperature readings for a 24 hour period in the same basement, shows that clearly. The maximum in this case was no more than 31.7 and the minimum 31.2. Consequently while the outside and inside temperatures would rise even higher than the measured data, the ones in the basement would not.

The graph in Fig.6. shows that in late winter, namely early March, the temperature in the basement is higher than that in the ground floor of the building as well as that of the outside air. Sometime during this month these cross over and while the first two begin to rise as the summer approaches, the temperature in the basement becomes relatively less. It stays that way till mid October where the temperatures again cross over and the basement once again becomes hotter than the other two spaces during winter.

The graph in Fig.8. shows the average temperature readings for the hottest of the summer months, July and August. It shows that the basement temperature is significantly lower than that of the outside and the ground floor. It also shows that the air temperature resembles the outcome of the surface temperatures. This is strongly affected by the high reading from the ceiling. Keeping in mind that the ground floor of the building is not cooled and quit hot as the data shows. In a fully occupied building it would be cooled and the floor temperature, and thus the ceiling of the basement would be cooler leading to an even cooler basement. Of course the surface data also shows that the lower the surface is from the ground level, the cooler the temperature, and thus a deeper basement can be expected to be cooler as well.

3.1 Comfort

Human comfort of course, does not depend on thermal temperature alone. It may be assumed that the activity being performed in the basement is relaxed, the clothes light such as shorts and T-shirt. These assumptions are based on traditional basement use in Iraq which is afternoon resting and napping. The remaining variables that need to be set are radiant temperature, air speed, and humidity.

3.2 Radiant Heat

Radiant heat depends on the radiation from the surrounding surfaces. The ones that were recorded in the basement were quite close to each other and to the air temperature. The surface readings were highest from the ceiling and then went down till ground level which was -2.5m, but the difference wasn't large as can be seen from Fig.9. The average difference for the month of July was 3.1°C.

As such it was no surprise when the MRT (Mean Radiant Temperature) was measured the result was an almost exact match with the dry bulb. The MRT measurement was done using a 13cm black copper sphere with a temperature probe inserted in the center. When the dry bulb temperature was 32.5, the MRT was 32.

4. Humidity

The graph in Fig.1. shows that the average relative humidity in Iraq changes from a maximum of 50% in winter to a minimum of around 13% in summer. The readings that were taken in the University of
Technology in Fig.10., showed that it is slightly higher inside and even higher in the basement but still averaging less than 36% for the summer months. This is reasonably dry but more humid than the ground floor of the same building which averaged 27%. At the same time the measured relative humidity outside was almost the same at 28% although higher than the national average in Fig.1. A dryer space increases comfort in the summer.

4.1 Comfort in the basement

The figures and assumptions discussed above, when converted to data to measure basement thermal comfort, translate as follows:
- Temperature 33.6°C average for the summer months of July and August
- Air speed from a ceiling fan of 0.8min/sec
- MRT equals 32°C
- Relative Humidity at 36%

The data was analyzed using a computer program called "Psycho tool" from Square One that calculates human comfort. The results show that for such conditions it would be on the hot edge of the zone with a dissatisfaction rate of 8-14%, which means it is only slightly uncomfortable. The result is shown graphically in the psychrometric chart in Fig.11. The activity would have to be typical napping in the afternoon.

A small rise in air temperature of only one degree, which some readings in the basement reached, would change the situation to uncomfortable and the dissatisfaction rate to over 40%. Such an environment is not suitable for normal residential use without cooling. To produce a comfortable interior for other residential activities the temperature would have to drop more than two degree to 31°C. This would produce an optimum dissatisfaction of 5%. For more strenuous business activity lower temperatures would be required.

Clearly without cooling the basement is only suitable for limited human utilization. Cooling is necessary for normal use.

4.2 Cooling Loads

Independent of the measured results, a few alternatives were studied to evaluate basement use by comparing cooling loads. The loads themselves were calculated using Ecotect version 5.2. The basement was modeled as a 7x4m room with a height of 3.5m immersed to a depth of 2.5m in the ground similar to that of the basement measured in this work. The weather data were downloaded for the Baghdad area. The conditions were assumed to be similar to that of the basement in the tests as follows:
- Interior finishing consists of cement plastering for walls and concrete tiles for floor.
- 20cm of reinforced concrete structure on all sides.
- 24cm clay brick wall with 3 cm cement plaster and 0.5cm bitumen water insulation below ground.
- Surrounding earth sandy with concrete pavement cover.
- Ground water 2m.

An above ground room was also modeled with similar physical properties except that the walls were assumed to be completely brick with cement plaster.
finishing.

Two activity and temperature scenarios were simulated for each case; one for sedentary residential activities and the other for office use. The following was assumed for the sedentary residential case:

- Clothes, trousers and shirt.
- MRT and dry bulb temperature 31°C.
- Air speed from a ceiling fan of 0.8min/sec
- Clothes, trousers and shirt.
- Relative Humidity 36%.

The psychrometric chart data was then updated to test a cooler space suitable for office working conditions. The new data was:

- Office activity.
- Clothes, trousers and shirt.
- MRT and dry bulb temperature 27°C.
- Air speed 0.5 which is less than the assumptions for the residential scenario. This is to allow for comfortable working conditions. Higher air speeds disturb paper on the desks.
- Relative Humidity 36%.

The simulation results can be seen in Fig.12. The two bars on the left are for the basement. The two on the right are for above ground simulations. The first bar to the left represents the case in hand of our test basement. Using the comfort assumptions that were outlined above, to maintain a basement temperature of 31°C would only require a cooling load of 5.4 kWh per meter square for the whole of the summer to cool a 28m$^2$ space. Furthermore the cooling would only be needed in July and August. For a similar residential activity and similar conditions above ground would require a cooling load of 29.3kWh/m$^2$. This represents a rise of 540%. Both cases were calculated assuming the room was isolated without any other spaces attached.

The simulation results for office work showed that the cooling load for the whole summer in the basement was an average of 24.75kWh/m$^2$. By comparison if the same space was above ground and the MRT assumed to be 27°C as well, the cooling load would rise to 97.5kWh/m$^2$. That is a rise of almost fourfold.

Further simulations revealed that even the small residential basement which is only lowered by 1 meter below ground level shows low cooling loads. The same 28m$^2$ model used above when changed to residential specifications for normal activity use at a low 26°C only required 11.9kWh/m$^2$ of cooling for the summer. The ceiling height was of course reduced to 2.8m which is typical for an Iraqi residential basement. A further drop of only 0.5m into the ground would lower consumption to 6.5kWh/m$^2$. The same space when pushed above ground required 34kWh/m$^2$ of cooling for similar surroundings and activity. This is higher than the earlier simulation because of the lower temperature.

5. Conclusions

The measurements show that the basement provides a much better thermal environment during summer than do above ground spaces. Without cooling the basement average temperature on a July summer day was 33.6°C compared to 38.1 for above ground. This is especially true of daytime hours when the average inside ground floor temperature goes above an unbearable 38°C.

Furthermore the basement, because it is not exposed to the outside sun and hot environment, requires much lower cooling loads to reach comfortable temperatures. Even if the basement is only one meter below ground it will still remain significantly better thermally than its above ground equivalent.

It must be mentioned that in an occupied residential building where most of the spaces are cooled the temperature results would be better than for the test basement measured in this paper. In this paper’s case the rooms above the basement where the readings were taken were not cooled resulting in higher basement ceiling temperatures which also result in higher basement readings.

The actual feasibility and use of a basement must be determined on a case by case basis taking into consideration the technical, financial and psychological problems of working in a basement or below ground space and not only its thermal performance. In this respect the Iraqi example is no different from anywhere else in the world.

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Fig.12. Summary of Cooling Loads and Respective Conditions in Basement and Above Ground

- Air speed 0.5 which is less than the assumptions for the residential scenario. This is to allow for comfortable working conditions. Higher air speeds disturb paper on the desks.
- Relative Humidity 36%.
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Footnote

Some parts of Iraq do not suffer from a high water table such as Najaf. These places use ordinary masonry to line the walls of the basement and they do suffer from high humidity.