# DEVELOPMENT OF A METHOD FOR ASSESSING BUILDING PASSIVE THERMAL PERFORMANCE

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*Abstract : A method of assessing building passive thermal performance for houses in Europe is described. The method is intended to provide the user with a means of understanding the factors effecting the thermal characteristics of the building, while giving figures that will allow the best use to be made of available passive energy techniques. The development and use of this method is outlined, and a description is given of how Genetic Programming will be used in this process.*

## 1 Introduction

Each building makes an impact on the environment, both in its construction and operation. There is no single factor such as fuel use or embodied energy which on its own can fully describe whether the building has a low environmental impact. It is the combination of several different factors which determines this impact. Work on this idea has been done at UEL through the construction of an Indicator Assessment Method (Kibesi 1996, Thompson and Evegeniou 1998). The method is intended to provide the designer with a means of quickly assessing buildings for their overall environmental impact, throughout the design process, when time is usually limited and many options need to be examined. By contrast, computer methods are limited to specific areas and their operation is usually time consuming.

This paper describes the work being done on the development of a manual method of assessing the building passive thermal performance, as part of the wider work described above. Passive performance is seen as one part of environmental impact. Current work is directed toward calibrating and refining the method which is briefly illustrated below. Initially it will be constructed to apply to assessments of houses in Europe but could later be extended for other locations and building types. The method is highly transparent and informative, and is readily accessible to designers. It can be described as a type of expert system.

## 2 Methodology

A distinctive feature of this method is that the user is involved in a process of assessing the relative importance and scoring of a selection of indicators, given the particular climate and building characteristics. The indicators are intended to measure all those factors which contribute to the thermal characteristics of the building. A possible list of these indicators is shown in Fig.1.

Data gained from a large number of computer simulations is used both to develop the indicators and to provide the user with a means of checking assessments made of individual buildings. The raw data from the computer simulations is searched for combinations of building and climatic variables which describe the data accurately. This process reduces the raw data set into more concise and manageable information. The combinations of variables which describe the computer simulations will be measures of how well the building makes use of passive techniques. The search method used to achieve this is based in Genetic Programming, a computer technique which can generate, or evolve many combinations of the appropriate variables through a process of simulated evolution (Koza, 1992).

## 3 Indicator assessment method

This method is based on the idea that if each characteristic of a building which contributes to its passive operation is individually assessed, an indication will be obtained of the overall performance of the building. Fig.1 (see below) shows a list of indicators which address aspects of the thermal characteristics of the particular house under assessment. The first group (1 - 3) are concerned with heat loss, the second (4 - 6) with potential heat gains, and the third (7 - 9) with thermal comfort. The latter are included to assess overheating risk as a measure of habitability, and therefore the likelihood of the passive systems working as intended. For example, if no shading is provided then the inhabitants may over ventilate the house. Together these indicators are giving the user information about the environmental impact of the house.

This list is by no means complete, but the method lends itself to modification and expansion of indicators. For example, consideration of Indicator 1 (resistance of the fabric to heat loss) suggests that a further indicator may be needed which assesses 'resistance of fabric to heat gain', a factor which may be of importance in the summer. Likewise, Indicator 6 'Storage of gains' suggests the addition of an indicator to assess possible energy use penalties associated with thermal mass. Another indicator could compare embodied energy of materials used with conventional energy savings for specified time periods. In this way the method can be developed and so provide a wider picture of total environmental impact.

1 Resistance of building fabric to heat loss
2 Designed Infiltration and ventilation
3 Degree of shelter

4 Provision of glazing for solar gain
5 Orientation of inhabited spaces for solar gain
6 Storage of gains

7 Prevention of overheating - shading provided by the structure
8 Prevention of overheating - shading provided by the surroundings
9 Prevention of overheating - provision of mass

**Fig.1 A list of possible indicators of thermal performance**

Each of the indicators is assessed by the user, first by assigning a numerical weighting to each based on its importance given the particular site conditions and climate and then by giving a score based on how well each compares to its theoretical best. An example of an assessment is shown in Fig.2 below. The numerical constant converts the indicator into a number, and the ideal score is the product of the constant and the weighting.

1. Resistance of building fabric to heat loss

| season | constant | weighting | ideal score | actual score |
|---|---|---|---|---|
| winter | 5 | 5 | 25 | 18 |
| equinox | 5 | 3 | 15 | 4 |
| summer | 5 | 0 | 0 | .. |
| TOTAL | | | 40 | 22 |

**Fig.2 Example of an individual indicator assessment**

When each indicator has been assessed the total scores can be calculated, and the ratio of actual score divided by model score gives a number between 0 and 1 (Fig.3). This ratio (index score) is a measure of the building environmental performance, and a similar ratio can be calculated for each indicator, or part of an indicator, for purposes of comparison. To date this procedure has been carried out manually, through a knowledge of the factors which contribute to thermal performance, and informed guesswork used where there are gaps in this knowledge. Previous work has shown a high correlation between assessments and monitored energy use (correlation coefficient $r^2$=0.9), suggesting that an experienced user can intuitively apply reasonable weightings and scores to particular buildings.

| | Summary of scores -Dawbank | Ideal score | Actual score |
|---|---|---|---|
| 1 | Resistance of building fabric to heat loss | 40 | 22 |
| 2 | Designed Infiltration and ventilation | 25 | 20 |
| 3 | Degree of shelter | 10 | 3 |
| 4 | Provision of glazing for solar gain | 20 | 7 |
| 5 | Orientation of inhabited spaces for solar gain | 15 | 10 |
| 6 | Storage of gains | 10 | 2 |
| 7 | Prevention of overheating - shading provided by structure | 15 | 6 |
| 8 | Prevention of overheating - shading provided by surroundings | 10 | 3 |
| 9 | Prevention of overheating - provision of mass | 10 | 2 |
| | total | 155 | 75 |
| | actual score / ideal score = INDEX SCORE | **0.48** | |

**Fig.3 Total score sheet**

The values given to the weightings and scores, as well as the indicators themselves, determine the usefulness of the method in terms of numerical consistency.

The aim of the ongoing development is to discover through empirical studies a combination of indicators, weightings and scoring figures which can be used in the manner described above, to predict environmental impact. This system combines the transparency of a manual method, with the level of flexibility of a computer simulation.

## 4 Development of the method

### 4.1 Computer simulations

A large number of computer simulations are being made, of examples of houses in different parts of Europe, with a wide range of physical and operating parameters. The data collected from these simulations can be thought of as representing all possible buildings whose parameters fall within the range that has been simulated. The data consists of the building physical variables in addition to the simulation variables such as plant operation, and the thermal characteristics of the building such as heat loss, internal temperatures, solar gains and plant energy use. This database will be used to determine the rules and values for weighting and scoring, through the use of advanced search techniques which include the computer methods of genetic algorithms and genetic programming described below. The aim is to find combinations of quantities which describe passive characteristics (i.e. indicators) which are common to all or some of the buildings in the database, as well as any associated weights and scores. The information resulting from this process will form a model of building passive performance. Later it is hoped to use collected data from real buildings to carry out a similar analysis.

### 4.2 Search techniques

It would be useful to be able to search for the measurements of passive performance mentioned above, which are both understandable to the user and which can be used for different houses in different locations. These promise to be available through the use of Genetic Programming, a computer technique which copies mechanisms observed in nature (reproduction, evolution) to grow new computer programs from a starting population of randomly generated programs (Koza 1992). More specifically in this case, regression is used to find programs which describe the data generated by the thermal simulations, for a variety of circumstances. These programs are simply lists of variables and operators structured in such a way that they have a high correlation with the given data (i.e. equations which describe the data).

For example, given data generated by the steady state equation, with terminals (analogous to genes) of A, U, N, V, To, Ti, E, and operators of +, -, *, / (also analogous to genes) the program generates a very large number of combinations of these terminals and operators, and tests each against the data. Those equations which give a good correlation between variables and heat load are said to be fitter than those which do not. These fitter equations are then given a better chance of creating the next population, through combining either parts or the whole of them with parts of other equations to form the next population. Therefore, there is a strong likelihood that the future populations (usually fixed in size) will gradually become fitter, until an optimum level of fitness is reached. Perfect fitness would be achieved if the correlation between heat load figures produced by the generated equation and those from the steady state equation = 1). Alternately only a limited level of fitness is reached, in which case the user can try different sets of terminals and operators. However, usually for simple problems such as finding the steady state heat equation it is easy to find the equation which perfectly fits the data (Koza 1992). The technique of genetic programming has many variations and is inherently flexible, so allowing the computer thermal simulation data to be examined against many different criteria.

Here the intention is to use genetic programming to find descriptions of the data set which satisfy three criteria :

- That the generated equations represent coherent and readily understandable indicators.
- There are not too many of them, such that the data set is not usefully reduced
- That they describe the data set to a useful level of accuracy

The process of finding these descriptions involves running the genetic programs with different terminals, operators, and rules for fitness, reproduction and so on, depending on what has been learnt from previous runs.

## 5 Summary

The outcome of the research is expected to be the following:

- Construction of a manual method of assessment of building passive performance which is part of a wider method for assessing environmental impact. It is highly transparent and therefore informative.
- Application of advanced search techniques (genetic programming) to the field of building thermal assessment.

Further work will be undertaken to expand the method for other building types and climates, and the construction of software is a possibility.

## 6 References

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