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ENERGY ANALYSIS OF OFFICE BUILDING DESIGN FOR THE HOT ARID CLIMATE OF EGYPT

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ABSTRACT. This article reports the impact of passive solar design techniques for an office building on heating and cooling conditionning demands. Analysis and discussions are applied on the Egyptian Building Research Center in Cairo, which is a typical governmental office building. Thermal analysis for the existing conditions are determined using a computer energy simulation program, then, energy savings opportunities are assessed through optimization analysis for fenestration, shading, reducing infiltration, walls and ceilings insulation and finishing. A set of inexpensive design enhancements succeeded in achieving a total reduction in the annual mechanical loads of about 36% compared to the initial existing conditions.

INTRODUCTION. Rapid increases in energy prices aroused strong interest in improving energy efficiency in all energy- consuming sectors. The annual electrical demand in Egypt reaches $45x\ 10^9$ Kwh against an annual production of about $60x10^9$ Kwh. Industry consumes 55% of the annual consumption, agriculture uses only 5%, Public & commercial buildings are second largest consumer of energy , 35% of the total consumption . Finally , the governmental buildings account for a share of 5%.

It is urgent to cut energy consumption through the implementation of technologies and policies for energy efficient buildings. For air conditionning, electric bills can be reduced through simple systems of thermal storage , insulation and shading which make it possible to move about 40 percent of electrical demand. In fact, it costs no more to constuct an energy-efficient office building than it does to construct an inefficient one.

Efficiently designed buildings will slash energy bills, liberate the capital investment and avoid the expense of constructing new power plants.

S. Alvarez et al. (eds.), Architecture and Urban Space, 843–848.

1. DESCRIPTION OF BASE CASE

The main office building is rectangular (fig. 1), elongated on a North -South axis. It is six storeys high. The East facade which is entirely occupied by offices has 2/3 of its area glazed while the West facade which contains offices and services, has 1/3 of its area glazed. Windows occupy the entire width of the office rooms. They are single glazed and externally shaded by a 0.6 m horizontal overhang on the West facade. East facade windows are shaded by a series of vertical fins, 10 cm away of the glass surface and having 0.6 m depth and a 0.9 m spacing in between.

External walls are made of red bricks , 0.25 m thick, plastered from inside and covered by 6 cm red brick tiles from outside, giving a thermal transmition of 1.7 W / m²°c . The roof of the last floor is a concrete slab , 0.16 m thick, covered by layers of water insulation, sand and cement tiles having an overall U-value of 1.12 W / m²°c.

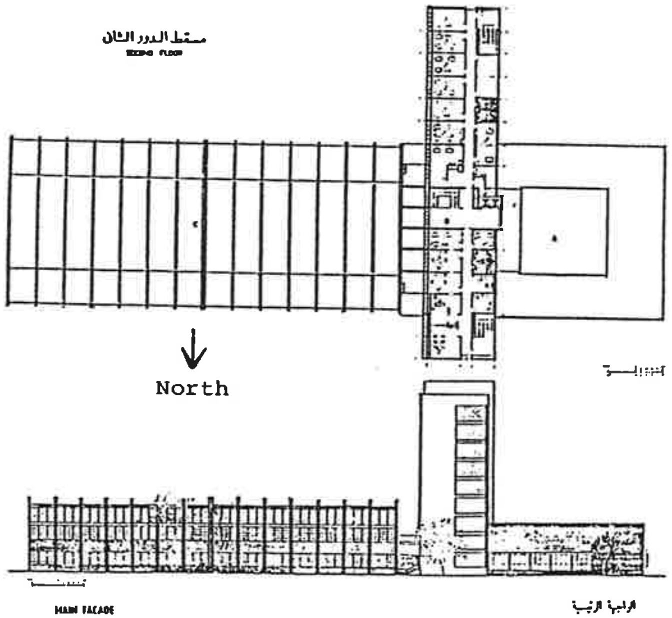

Fig. 1 : Typical floor and main facade of GOHBPR.

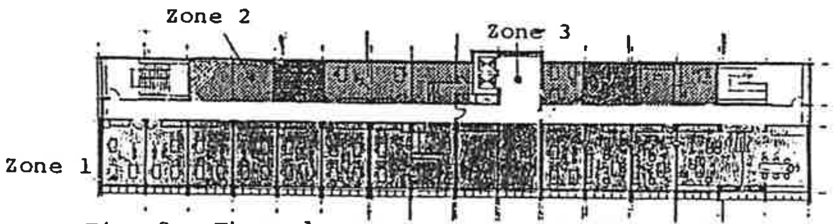

Fig. 2 : Thermal zones

2. THERMAL ANALYSIS FOR EXISTING CONDITIONS

The plan of the typical floor , Fig. 2, was devided in thermal zones for evaluations of thermal loads and compar
Zone 1: a series of offices on the East facade.
Zone 2: offices on the west facade.
Zone 3: circulation area.

Table 1 shows the floor area for each zone, the are external walls and glazed areas according to orie Calculations of heating and cooling loads were performed an energy simulation program CALPAS 3 (1), all year rou 7:00 AM to 3:00 PM in order to keep indoor temperatur minimum of 19.5 °C in winter and a maximum of 26.6 °C in s

Table 1. Characteristics of thermal zones(m²).

zones	floor area m²	walls N	E	S	W	win N	E
zone 1	384	21	120	21	--	--	104
zone 2	112	--	--	--	77	--	--
zone 3	273	--	--	--	56	20	--

Table 2 shows the results of computer runs. Zone 1 more energy for both cooling and heating per unit floor a zones 2 and 3. Figures 3 and 4 present a comparison of and cooling loads required per unit floor area for the zones in a typical winter day (January 21) and a typical day (July 22) .West zone needs heating from 8:00 AM to 1 with rates 25% lower than east zones. This may be due to glazed area as well as fixed external shading devices.

Table 2. Comparison of mechanical loads per uni area for the three zones (KBtu/Ft²)

zones	Cooling	Heating	Total	% of tc
Zone 1	35.97	6.31	42.28	57%
Zone 2	32.91	4.74	37.65	14.
Zone 3	25.7	3.8	29.5	28.

The cooling loads for East zone are much higher west zone untill noon. During afternoons, cooling loads east zone decreases while it gradually increases for the zone and reaches a maximum at 3:00 PM, the end of the wor

The difference in total annual loads between zones is emphasized due to the larger floor area of zone 1 about 3.5 times the floor area of zone 2. Zone 1 is res for 57 % of the annual loads required per floor against 1 zone 2.

3. IMPACT OF CHANGING ORIENTATION OF BUILDING

Calculations were done for heating and cooling loads in case of rotation of the existing design by 45°, 90°, and 135° to the East of South. The main office zone, (zone1), is then facing North-East, North and North-West instead of East. Table 3 shows the results and we can deduce that the rotation causes a decrease in total loads for zone 1 and an increase in total loads for zones 2 and 3.

Table 3. Comparison of thermal loads for different orientations (KBtu/ Ft^2)

Zones												
	C	H	T	C	H	T	C	H	T	C	H	T
Zone1	35.9	6.3	42.2	29.4	7.5	36.9	24.2	7.6	31.8	25.4	7.6	33.0
Zone2	32.9	4.7	37.6	37.0	2.9	39.9	39.5	1.9	41.4	46.7	2.5	49.2
Zone3	25.7	3.8	29.5	27.6	3.6	31.2	28.9	3.4	32.3	29.3	3.5	32.8
Total Kbtu	306844			292292			276255			292090		
Saving	---			4.7 %			10 %			4.8 %		

A 90° rotation decreases the total annual loads of the whole building by 10 %.

4. OPTIMIZATION ANALYSIS FOR EXISTING CONDITIONS

There are many opportunities to improve the thermal performance of the existing building. The impact of the following design enhancements is considered:

1- External shading:
 * The horizontal overhang of the West facade windows is increased from 0.6 to 0.9 m.
 * The spacing of the vertical fins on the East facade is narrowed from 0.9 to 0.4 m by adding a new fin between each two.

2- Applying insulation of external envelope:
 * Wall insulation by using foam concrete spray (Celton), 1.5 cm thick (K=0.04 W/ m.°C) that will reduce the overall transmition factor from 1.7 W/m²°C to 1 W/m²°C.
 * Roof insulation by adding a layer of expanded styrofoam 5 cm thick (K= 0.031 W/m.°C). This will decrease the U-value from 1.12 W/m²°C to 0.4 W/m²°C.

3- Reduction of infiltration from windows by changing steel frames by aluminium frames with rubber strips.

4- Light cream finishing colour for external walls surfaces.

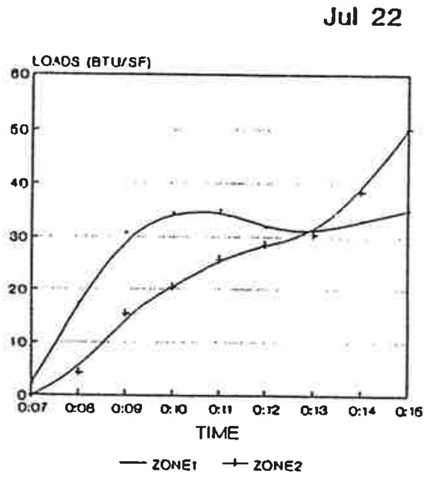

Fig. 3 : Cooling loads for office zones.

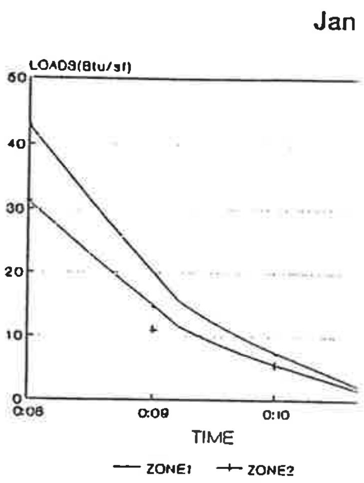

Fig. 4 : heating loads f office zones

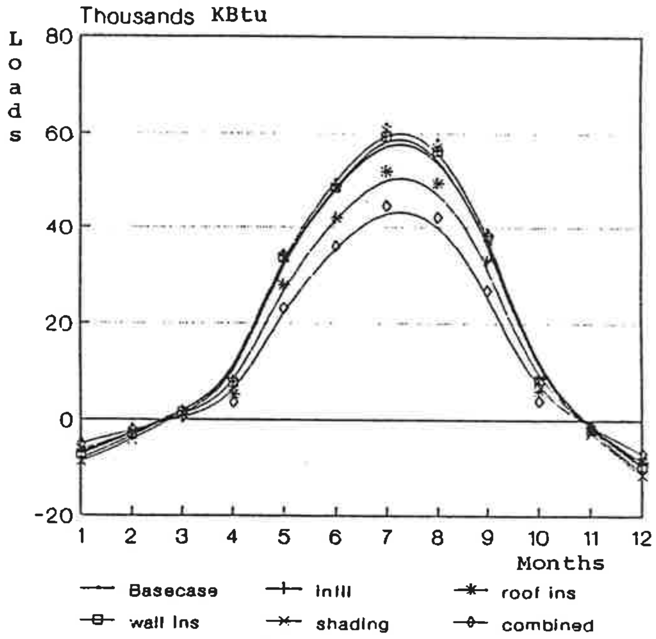

Fig. 5 : Thermal loads reduction by design enhancements for zone 1.

Table 4 shows the amount of savings achieved by each policy and the total saving that can be reached by combining them.

Table 4. Load reduction and saving opportunities of different design enhancement.

Policy	Loads in KBtu				Saving
	Zone 1	Zone 2	Zone 3	Total	%
Base case	[illegible]	[illegible]	[illegible]	[illegible]	—
* [illegible] shading.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %
* Wall insulation	166877	41894	84335	293106	4.5%
* Roof insulation	140833	35470	62624	238927	22.1%
*Reducing infiltra.	168094	43642	82449	294185	4.1%
*Light wall colour	172553	44269	96228	303050	1.5%
Combined	114549	28079	52292	194920	36.5 %

CONCLUSION

Most effective policies are roof insulation and optimizing the external shading of windows. A total saving of 36.5 % has been achieved in order to improve the existing conditions. On the other hand, thermal loads could have been minimized from the beginning by making the right design decisions as it has been proved by the analysis of the thermal impact of the orientation . Therefore, building energy analysis should be considered at the preliminary design phase, especially that with the advent of the personal computer energy analysis methods became accessible to a wider range of building professionals.

REFERENCES

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AUTHOR INDEX