

LIBRARY CASE STUDY: BENEFITS OF PASSIVE SOLAR VERSUS TRADITIONAL DESIGN

John F. Hedge, AIA
DesignGroup
515 East Main Street
Columbus, OH 43215
jhedge@dgcolumbus.com

ABSTRACT

This paper is a case study that analyzes whether passive solar design features are responsible for the significant difference in energy use in two public library buildings of similar size, plan and program use. Energy 10 software is used to analyze energy savings that can be attributed to different features. The study concludes that orientation; sun shading and day lighting are responsible for a 13.8% savings in energy use. It also concludes that increasing the effectiveness of the envelope could save another 46.8% in energy use.

1. INTRODUCTION

In 1983, the Columbus Metropolitan Library (CML) commissioned the Whetstone Branch Library and asked that the architect employ passive solar techniques to reduce the energy consumption. During the last 18 years, the Whetstone Branch has consistently used less energy than any of the 15 branch libraries. Whetstone uses 37% less energy than the Karl Road Branch (Fig. 1, 2 and 3), which was designed four years later, utilizing the same program and a similar plan, but without effort to incorporate passive solar features. This difference between buildings in energy cost prompted the library system to set energy cost requirements for all future branches. While this has helped lower energy use in subsequent branch libraries, none have come close to level established by the Whetstone Branch. Some have even contended that the different mechanical systems account for the difference in energy use. This study seeks to prove that the passive solar design is the reason for the difference.

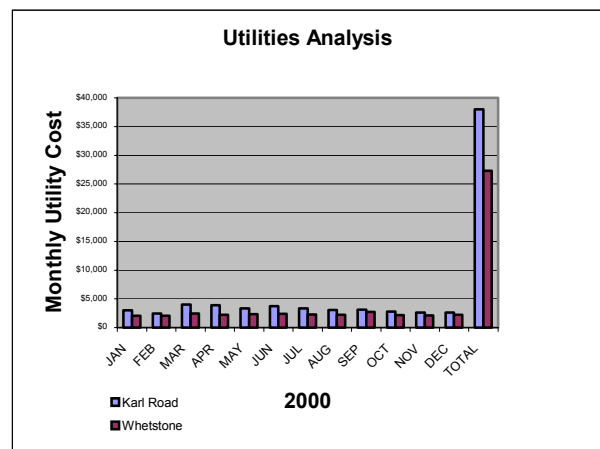


Fig. 1: Actual Monthly Utilities Analysis

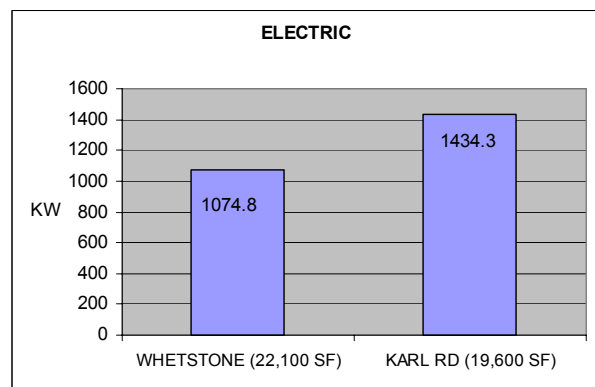


Fig. 2: Actual Annual Electric Usage

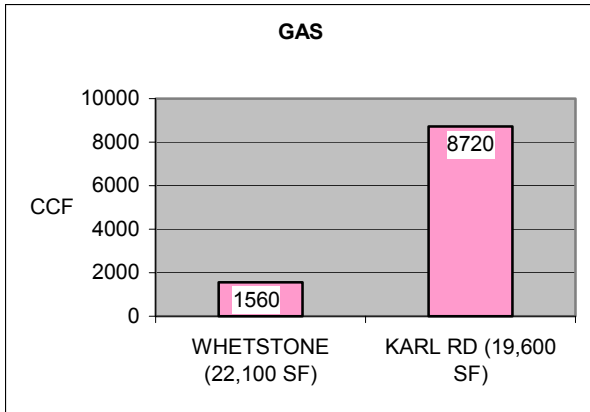


Fig. 3: Actual Annual Gas Usage



Fig. 4: Whetstone Photo

2. BUILDING DESCRIPTIONS

The two libraries were constructed within four years of each other on flat sites in Columbus, Ohio (40° north latitude) (Fig. 4 and 5). Whetstone is 22,100 S.F. (2053.09 m²), while Karl Road is 19,600 S.F. (1820.84 m²). The plans are very similar with a central east west spine that has natural lighting from top lighting (Fig. 6 and 7). Both buildings are one story slab on grade; face brick with concrete block back up, bearing wall structure with low sloping metal roof with the same amount of batt insulation. The structural steel bays are 24' (7.32 meters) wide at Karl Road and 20' (6.1 meters) wide at Whetstone. The ceiling height is 10'-0" (3.05 meters) in both with a higher area above the roof monitor spine that extends the length of the building from the west to the east. While this raised area provides natural light in both cases, Whetstone utilizes a 4' (1.22 meters) high "Kalwall" clerestory with 40° latitude sun shading overhangs. Karl Road has a 5' (1.53 meters) "Kalwall" barrel vault skylight that extends the length of the building. Both provide central day lighting. Karl Road does not gain any energy savings from the daylight because

no dimming is incorporated, while Whetstone does because of light sensors that turn lights off at adequate light levels.

While the ratio of exterior wall surface to floor area is almost identical, the vertical glass area at Karl Road is slightly higher. Karl Road also has 840 S.F. (78.04 m²) of unshaded skylight.



Fig. 5: Karl Road Photo

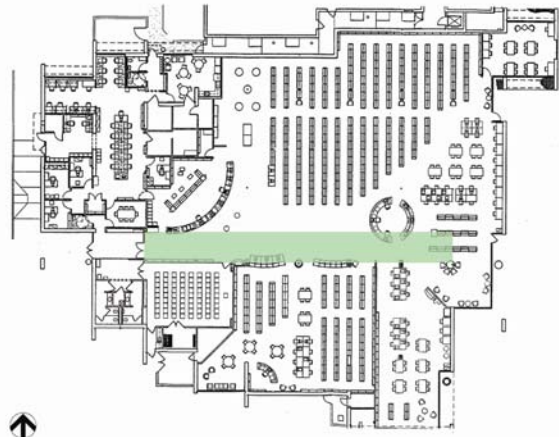


Fig. 6: Whetstone Floor Plan

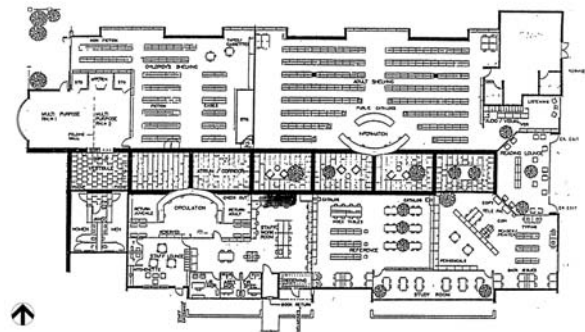


Fig. 7: Karl Road Floor Plan

3. ENERGY ANALYSIS

Energy use data was calculated on Energy 10 software utilizing the data in Table 1. Because the mechanical systems are different the comparisons were done using the most efficient system, DX cooling with gas furnace. The calculations indicate that Whetstone uses less energy/square meter than Karl Road (Table 2).

TABLE 1: BUILDING DATA

	Whetstone	Karl Road
Floor Area	22,100 sf (2053.09 m ²)	19,600 sf (1820.84 m ²)
Exterior Wall Surface Area	9,360 sf (869.54 m ²)	8,300 sf (771.07 m ²)
Exterior Wall Surface/Floor Area	.4235	.4235
GLASS AREA		
North/South Façade	200 lf (61 meters)	184 lf (56.12 meters)
East/West Façade	152 lf (46.36 meters)	116 lf (35.38 meters)
North	290 sf (26.94 m ²)	706 sf (65.59 m ²)
East	700 sf (65.03 m ²)	440 sf (40.88 m ²)
South	1,230 sf (114.27 m ²)	805 sf (74.78 m ²)
West	90 sf (8.36 m ²)	370 sf (34.37 m ²)
Skylight	0	840
Walls	R20	R20
Roof	R19	R19
Glass	U=49	U=49
Total Utility Cost 2000	\$27,281.00	\$37,984.00
Utility Cost (\$/sf) 2000	\$1.23/sf (\$.11/m ²)	\$1.94/sf (\$.18/m ²)

3.1 Orientation, Glazing and Sun Screening

The Whetstone branch was designed featuring the passive solar elements of a longer north/south than east/west façade, large areas of south facing glass, smaller areas of north facing glass, minimal east and west facing glass and sun shading on glass areas. It also utilizes a masonry structure that provides thermal mass. The Karl Road Branch was not designed with passive solar in mind but it

does share some of those features with Whetstone. The construction of the two facilities is almost identical and the ratio of exterior surface area to floor area is the same. The differences are in the fact that Karl Road has less south glazing and more north/east/west glazing than optimal and there is no sun shading on the south glass. Except for the fact that Whetstone has a much larger area of east glass, the actual and optimal areas are fairly close (Table 3). The glazing areas at Karl Road are not very close to optimum. While the east glazing at Whetstone is much larger than optimum, it does not produce unwanted heat gain from direct east sun because it is screened by a heavily wooded area. When the analysis is run without daylight simulation the difference is a 7.9% energy savings (Whetstone over Karl Road).

TABLE 2: ENERGY 10 CALCULATION

	Whetstone		Karl Road	
	Actual	Low Energy Case	Actual	Low Energy Case
Total KBTU/sf (m ²)	69.4 (6.45)	36.9 (3.43)	80.1 (7.44)	38.5 (3.58)
Heating KBTU/sf (m ²)	18.1 (1.68)	10.5 (.98)	30.5 (2.83)	9.8 (.91)
Cooling KBTU/sf (m ²)	8.5 (.79)	4.6 (.43)	13.4 (1.24)	5.1 (.47)

Examination of the actual energy use charts (Fig. 1, 2 and 3) show that energy use for heating is much lower for Whetstone. With the higher amount of south glazing and the fact that the differences in heating cost occurs in the winter months when the sun is low in the sky, allowing it to enter more directly the building, the advantage of Whetstone's passive solar design shows up most dramatically. The skylight at Karl Road works at cross purposes with respect to heating because it allows a great deal of heat loss while not gaining heat in the winter when the sun is low in the sky.

3.2 Daylighting

With a minimum north/south dimension of at least 116' (35.38 meters), both libraries benefit from the day lit roof monitor that extends the full length of the building from east to west down the center of the plan. The Karl Road branch has slightly more glass area but the window heads extend up to 8' (2.44 meters) off of the floor while at Whetstone the window heads extend up to 10' (3.05 meters) above the floor. This allows daylight to extend deeper into the space, making the day lighting more effective. While

the daylight along the central spine enhances the experience in both facilities, the Whetstone branch is the only one with light sensors to turn off unnecessary lights during daylight hours, thus saving energy on both lighting and cooling load. Energy 10 analysis was run on Whetstone including day lighting and the Karl Road analysis was run without. When Whetstone is analyzed without the benefit of day lighting, the energy use increases by 6.9%.

TABLE 3: GLAZING CHART

	WHETSTONE				
	North	East	South	West	Roof
Energy 10 Optimum	408 sf (37.90 m ²)	192 sf (17.84 m ²)	1,344 sf (124.86 m ²)	144 sf (13.38 m ²)	672 sf (62.43 m ²)
Actual	290 sf (26.94 m ²)	700 sf (65.03 m ²)	1,230 sf (114.27 m ²)	90 sf (8.36 m ²)	0 sf (0 m ²)
	KARL ROAD				
	North	East	South	West	Roof
Energy 10 Optimum	360 sf (3.34 m ²)	144 sf (13.38 m ²)	1,248 sf (115.94 m ²)	120 sf (11.24 m ²)	672 sf (62.43 m ²)
Actual	706 sf (65.59 m ²)	440 sf (40.88 m ²)	805 sf (7.90 m ²)	370 sf (34.37 m ²)	840 sf (78.06 m ²)

3.3 Skylight vs Shaded Clerestory

Top lighting of the central spine greatly enhances the experience in both facilities. Because of the library administration's concern of direct sunlight hitting the books, the glazing is a translucent panel instead of clear glazing. This also provides the benefit of a better U-value. At Karl Road the top lighting is provided by a 5' (1.53 meters) diameter barrel vault skylight with no sun screening, while at Whetstone, the top light is a 4' (1.22 meters) high clerestory that is screened by an overhang that provides 40° latitude sun shading. To determine how much advantage the sun shading provides, a 4' (1.22 meters) high sun shaded clerestory was substituted into the Karl Road analysis. The results indicate a 3.8% energy savings with the clerestory over the skylight.

3.4 Mechanical Systems

To determine if the choice of HVAC systems really contributes to the difference in energy use in the two facilities, an Energy 10 comparison for Karl Road was made using the DX cooling with gas furnace system used as the base system and the PTAC with gas boiler and HW coil system which is the actual system in use at Karl Road as the alternate system. The analysis indicates that the actual system uses 10.3% more energy than the systems used at Whetstone.

4. CONCLUSIONS

Although the Energy 10 analysis does not account for all of the 38% difference in energy use of the two facilities, it does show that the better passive solar design at the Whetstone Branch library does account for a significant portion of the energy savings. From the low energy case calculation of the Energy 10 software, it also was determined that a 46.8% additional energy savings could be achieved at Whetstone if greater attention was paid to glazing amount and orientation, infiltration U-value of the envelope, and efficiency of HVAC system.