Analysis 2

Fabric Duct System Mechanical Breadth

Problem

The ductwork above the competition and leisure pools of the Warrenton Aquatic and Recreation Center consists of large exposed metal duct. From a cost and schedule perspective, this system is expensive and time consuming to install.

Goal

The goal of this analysis is to conclude whether or not a fabric duct system will save money and reduce installation time as well as supply the desired air to the space. In addition, by analyzing the duct support structure, determine if the members can be resized to reduce cost.

Methodology

1. Determine the sizes and quantities current ductwork
2. Verify accuracy of quantities with project personnel
3. Estimate the cost and duration of the metal duct system
4. Design the fabric duct system to maintain space requirements
5. Estimate the cost and duration of the fabric duct system
6. Do a comparative analysis between fabric duct vs. metal duct with regards to chemicals, humidity, temperature, etc.
7. Analyze the support structure for the duct to see if members can be resized
8. Compare cost savings and installation time of the respective systems and make the appropriate recommendation

Tools

1. Warrenton Aquatic and Recreation Center Construction Documents
2. R.S. Means 2006
3. UPS Cost and Time Estimator
4. Penn State Architectural Engineering Faculty

5. Forrester Construction Company
6. DuctSox Engineering and Design Manual
7. DuctSox Installation Estimator

Expectations

From the aforementioned methodology I expect to conclude that the fabric duct system will be cheaper for material, faster to install, and provide better air quality to the space.

Fabric Duct Advantages

The reason for the selection of the redesign is due to the many advantages of fabric duct over metal ductwork, especially considering the spaces being natatoriums. The first and foremost advantage of fabric duct is that it is not corrosive in the humid, chemical filled air that natatoriums contain from their pools. The fabric duct also can be cleaned easily by taking it down and washing it in the laundry. The specific type of fabric I have chosen also contains anti-microbial properties that kill bacteria and improve the air quality in the space. Metal ductwork is a hassle to clean and often goes overlooked through the operational period of a building. Furthermore there is no condensation on fabric duct because of the uniform air dispersion throughout the space and minimal dust collects on the ductwork as a result of the breatheability of the material.

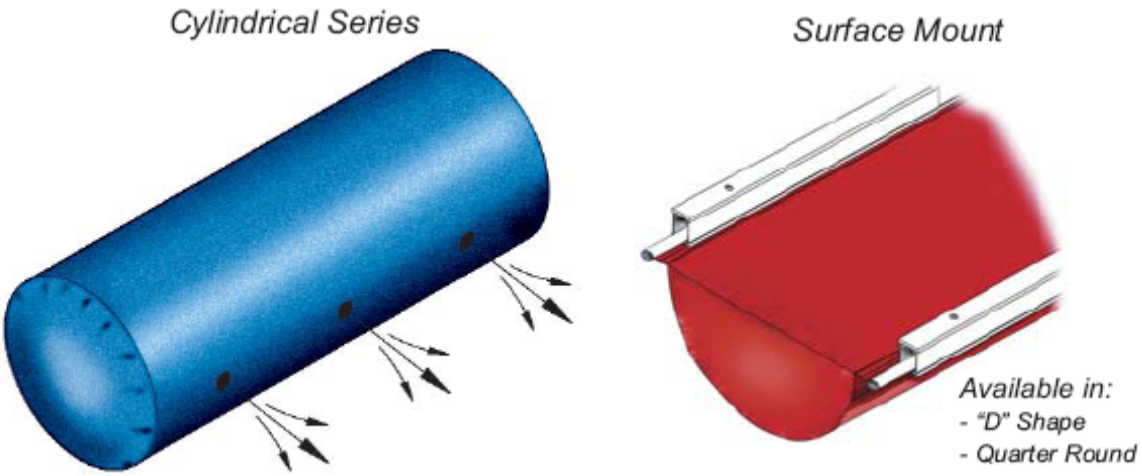
Fabric Duct System Design

The design of the fabric duct system is a simple, five step process. These steps are: selecting the shape for the space, determining the duct layout and size, selecting which type of fabric for the system, determine the type of dispersion system, and finally select the suspension for support. The following portion of this paper documents this design process for one of the duct runs.

Duct Run Design Example

Step 1: Duct Series/Shape Selection

The decision to be made in this portion of the design is the shape of the fabric duct. The options are either the cylindrical series or the surface mount series. This decision is easy because surface series are typically installed on a wall or against a ceiling. The ductwork for this space is running through the open trusses so the cylindrical series is the shape that is required.



Step 2: Design Layout

The first part of the design layout is to determine the duct diameter based on the amount of airflow required to the space and the inlet conditions. From the construction documents and the DuctSox design team, the numbers used to determine the diameter are an inlet velocity of 1600 fpm and a room capacity of 25,000 cfm. Using the manufacturers design tables, a diameter of 54" is sufficient to supply the required air to the space as seen below

50	13,635	16,362	19,090	21,817
52	14,748	17,698	20,647	23,597
54	15,904	19,085	22,266	25,447
56	17,104	20,525	23,946	27,367
58	18,348	22,017	25,687	29,356

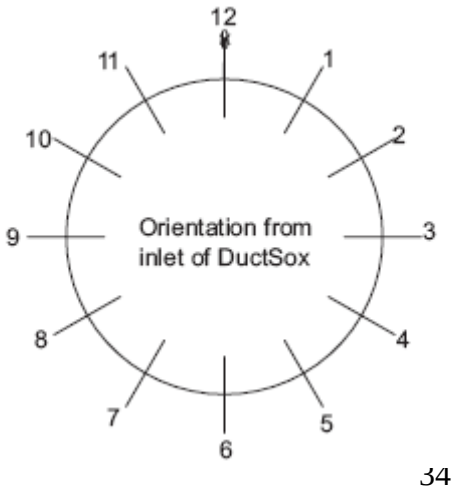
The next portion of the layout process is to determine the length of the run. From measurements around the pool, it was determined that 232' is the total length of fabric duct required. The length of allowable section of straight duct that corresponds to the 54" diameter is 25'. Therefore ten pieces of fabric duct are required. The layout for the space can be found in Appendix F. You will notice that the run of duct outlines the pool area. This is done so that when the system needs maintenance, easy access can be guaranteed and no special equipment is needed to service the duct

Step 3: Fabric Selection

To determine the type of fabric for the ductwork, the manufacturer offers many types. Each type has its own corresponding properties and usual types of spaces it is used for. For natatorium or pool areas however, either the Sedona-Xm or the Verona are generally preferred. Each type are sufficient for the space, but for this project I am selecting the Sedona-Xm because it has everything the Verona material offers, but comes with a 10 year warranty instead of a five and also is made of anti microbial material to improve air quality.

Step 4: Air Dispersion Design

The airflow through the duct will be what the manufacturer considers to be as "comfort flow." To design the air dispersion, you must first select the orientation of the vents along the diameter of the duct. Because the ceilings are high and we want to direct airflow downward, we will select the five and seven o'clock orientation of the vents.



The next steps are to calculate the airflow through the fabric, calculate the total vent size, select

the vent sizes, and finally specify the vent orientation. The equations used are as follows:

Pressure Review

$$AP = ISP_1 + 0.66x(VP-FL)$$

ISP_1 = Inlet Static Pressure
VP = Velocity Pressure = $(Velocity/4005)^2$
FL = Frictional Pressure Loss

AP= .1276 +.66((1600/4005)2 - .055)

AP= .1966 w.g.

Fabric Breathe-ability

$$Q_{fabric} = FP \times SA \times (AP/0.5) \quad (CFM)$$

FP = Fabric Porosity (rated) (CFM/ft^2)
SA = Surface Area (all fabric) (ft^2)
AP = Average Pressure (inch/w.g.)

Q_{fabric}= 1.5 x 3689.8 x (.1966/.5)

Q_{fabric}= 2176.2cfm

Using the table provided by the manufacturer, the

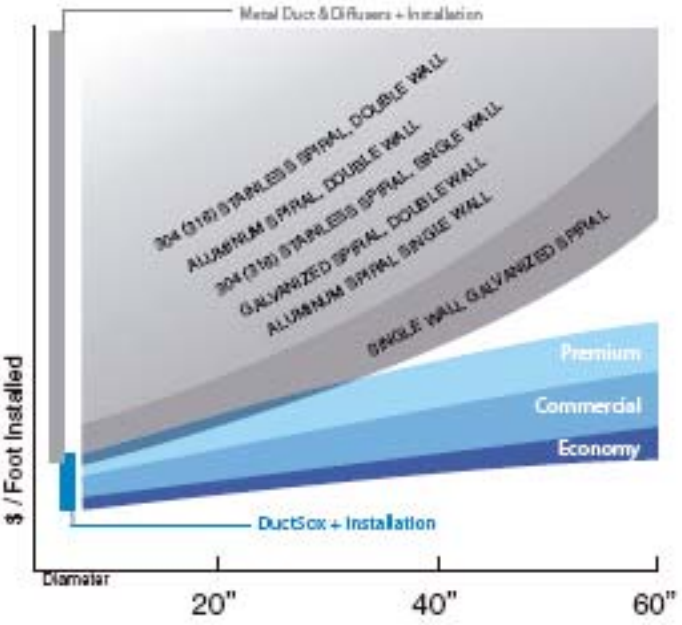
Step 5: Suspension System Design

The last portion of the design process for the duct system is to determine the suspension system that will support the duct. Three options are offered from the manufacturer: tension cable, suspended H-track, and flush mounted. The suspended H-track offers parts that are available in stainless steel, which is advantageous to combat the chemicals and humidity in the spaces. Because of this, the selection for the suspension system is the H-track.

The design of the duct system is now nearly complete, with one small item left, the filter. For fabric duct, the filter comes in three sizes, M, L, and X. Which on is chosen is based upon filtration quality desired and pressure loss. Because this run of duct is lengthy, the smaller filter is chosen, M. The filter is a cone shaped material that fits directly into the inner diameter of the fabric duct. The size is 4.5 x the diameter or 20.25' in length.

Cost Comparison

Typically, fabric ductwork costs on average 20-80% less than the average metal ductwork system. The adjacent graph depicts the typical costs based on diameter size for a total system comparing both fabric ductwork (blue) and metal ductwork (grey). The original design for the aquatic facility called for the second most expensive material, aluminum spiral, double walled duct. For an actual comparison within the aquatic facility, the following Table 2.1 is used for cost comparison.



Ductwork Pricing Comparison					
Area	Type of Duct	Quantity	Mat. Cost	Labor Cost	Total Cost
Competition Pool	Double Walled Aluminum	10876.78 lbs	$1.10	$5.05	$66,892.20
Competition Pool	Fabric Duct	307 ft	$52.12	$2.60	$16,799.04
Leisure Pool	Double Walled Aluminum	7896.52 lbs	$1.10	$5.05	$48,563.60
Leisure Pool	Fabric Duct	172 ft	$52.12	$2.60	$9,411.84

Table 2.1

Shipping cost

One further analysis with regards to cost that needs to be considered is how the change in weight will reduce shipping costs. With the original system, almost 19,000 lbs of ductwork were going to have to be shipped in. Using fabric duct, the shipment would weigh 600 lbs. To ship this ductwork you could use UPS freight service and receive the entire duct for the system in two days for only $1,900 by air. If you shipped ground, which is a distinct possibility with the time saved from installation, you could ship it for less than $500. The aforementioned spiral ductwork would take at least three truckload shipments and has an estimated cost of $2,900. Therefore, the savings in shipping can be a considerable $2,400, which could be the difference in being over budget.

Cost Summary

The total cost of the spiral metal duct system, including shipping, is $118,355.80 while the total cost for the fabric duct system including shipping is only $26,710.88. This shows that the total savings of the fabric system is $91,644.92. This amount saved corresponds to roughly a 2% savings in the mechanical contract.

Schedule Comparison

As you may have noticed from the cost comparison, the time and labor costs for standard metal ductwork is significantly higher than the fabric duct system. Furthermore research has shown that up to a 90% reduction in labor costs can be achieved. For this project, the following comparison was constructed using the actual data for the metal ductwork that was installed and data calculated using the DuctSox Installation Estimator. Results can be seen in Table 2.2. It is easy to see where the 90% savings can come into play as the reduction in installation time is almost 80% itself. A few reasons that the installation of the metal duct takes so long is because you have to lift every piece up in the lift which takes significantly longer than the duct, then after it is installed the crews have to provide a polished finish and install the vents and diffusers. With the fabric duct it is just attach the hanging track to the truss and clip the duct in, that simple. This reduces the installation time significantly as can be seen below.

Estimate of Duct Installation Time						
Type	Quantity	Daily Output/Quantity	Typical Crew Size	Number of Crews	Total Hours	Total Days
Spiral Aluminum Double Walled Duct	18773.3lbs	145 lbs	3	3	345.2	43.15
Sedona-XM Fabric Duct	479 ft	53.7'	3	1	63.2	7.9

Table 2.2

Schedule Summary

As you can see, the fabric duct system only takes 7.9 days to install compared to the 43.15 of the metal system. This is a savings of more than 35 days in the mechanical portion of the schedule.

Structural Analysis

The third portion of the breadth on the mechanical ductwork analyzes the effect of the lost weight of the double walled aluminum spiral duct after it is replaced with the fabric duct on the roof trusses. Quantity takeoffs were completed to determine the difference in the loading on the support structure (prefabricated roof truss.) The following Table 2.3 is a summary of the loads obtained:

Competition & Leisure Duct Totals			
Area	Length	Weight	Avg. lb/Lin. ft
Competition	1098.5	10876.78	9.90
Leisure	819	7896.52	9.64
Totals	1917.5	18773.30	9.79

Table 2.3

Fabric duct offers an average lb/Lin. ft of less than one. Therefore, to complete the analysis, each total would be divided by the area of the space it serves to determine the load/s.f. After doing this I obtained loads that were less than 1lb/s.f. in difference, which would obviously not be enough to influence a change in size of the roof truss members. Therefore, although the fabric duct weighs on average $1/10^{th}$ of the weight of spiral ductwork, I conclude that in a structure of this size that the ductwork redesign has no structural impact.

Breadth Conclusion

The fabric duct is a good product to be considered in open spaces, especially spaces with uncommon air properties such as a natatorium. It offers many benefits to the air quality of the space as well as to the O&M of the building as well. Through my analysis and comparison of the two systems, I have found that the fabric duct that I designed for these two spaces is superior in every aspect. It cuts a significant portion of the cost out, reduces the schedule drastically, and reduces the load on the roof truss members by nearly a factor of ten compared to the double walled aluminum duct. Therefore, it is my recommendation that the fabric duct system that I have designed be considered for installation in my building and in projects of similar scope.