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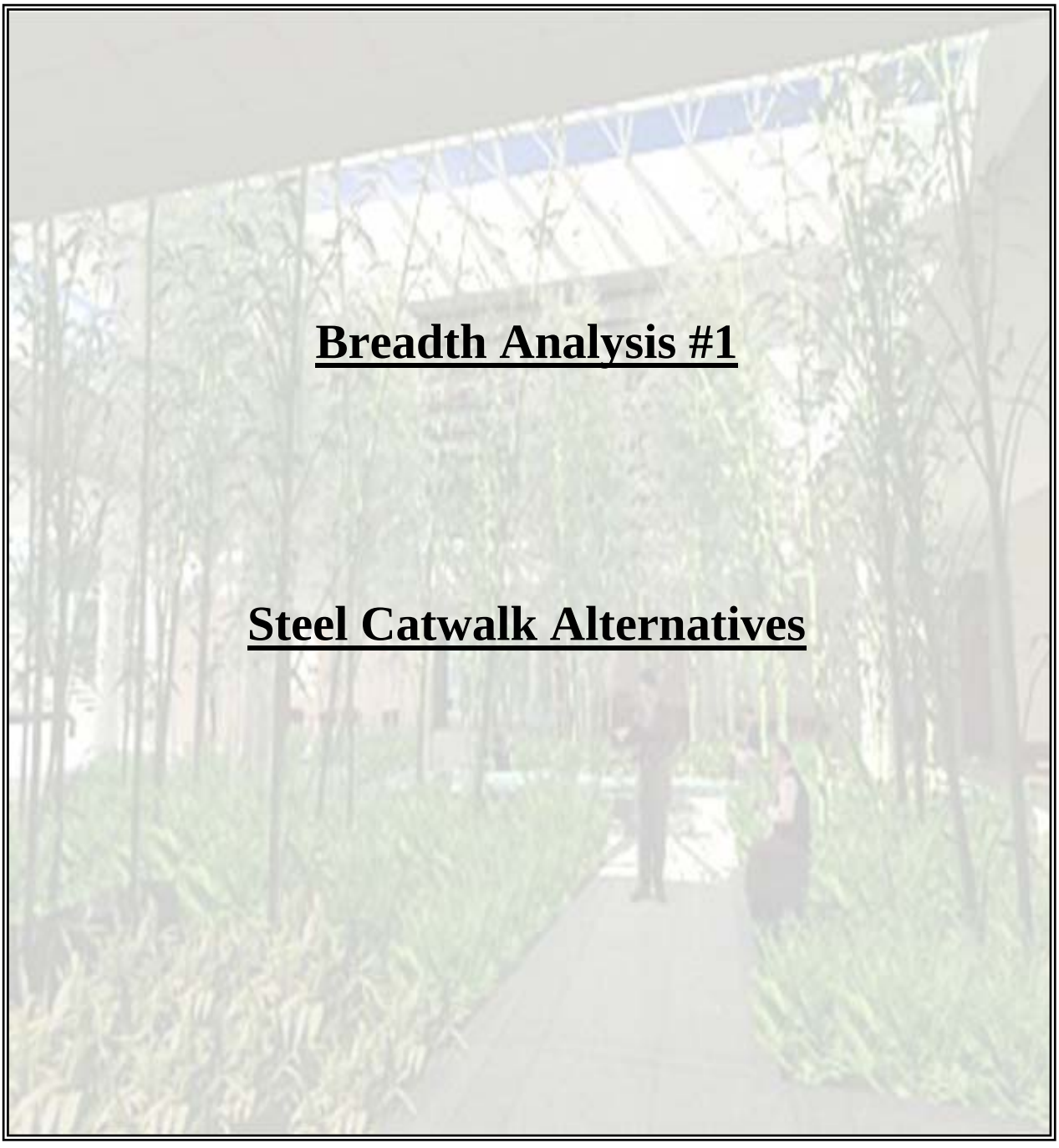
Construction Management Option



Breadth Analysis #1

Steel Catwalk Alternatives

Executive Summary

The Capital One Lecture Hall has been designed with a costly and heavy steel catwalk. With the project teams' inability to discuss appropriate design issues and value engineering options in a timely manner, the structural engineer, Rathgeber/Goss and Associates was responsible for producing a properly planned structure. Having little or no experience in such designs, they created a formation that would in no way feel unstable. As a result, large steel members were used for strength and constructability issues.

In order to devise an accurate schematic of which to compare alternative structural materials, three main construction management concerns were considered. Between the proposed steel; aluminum, fiberglass reinforced polymer (FRP), and wood members are analyzed for acceptable catwalk designs.

When looking at cost, lead time, and assembly duration, the FRP option is the most advantageous to the project. With an estimated savings of almost $14,000 and 3 weeks of assembly, FRP can add a significant amount of value to the Lecture Hall over steel.

The structural breadth evaluated in this analysis consists of load calculations for the critical steel hangers and girders. In turn, these results are used to analyze aluminum design adequacy for the specified dead and live loads.

Background

Like any hectic work week in the construction industry, the deadline for complete design documents creates a sense of urgency and long hours in the office. For Rathgeber/Goss and Associates, finishing the design of the Lecture Hall structural system was no exception. Within a few days of the design document due date, the architect requested that they design the auditorium catwalk. With no experience or prior knowledge of what catwalk design and serviceability requirements entail, RGA began their experimentation. To be 100% confident in their design, they made sure the catwalk did not vibrate, sway, or feel unstable in any way. As a result, the catwalk within the auditorium consists of large steel members that will support the 40 PSF live load and 20 PSF dead load requirements. This system is quite expensive due to the ever increasing market price of steel and contributes to a large portion of the subcontractor's scope of work.

As stated by the general contractor, the catwalk was always intended to be pre-engineered and prefabricated. A supplier of catwalks would have had a much better understanding of how much deflection, vibration, and sway is acceptable. In turn, this would result in a structure with more slim members of steel and a decreased cost in materials and labor. Due to time restraints and not considering this option at an earlier stage in design, the structural engineer was stuck with its creation.

In the 100% Construction Documents, the catwalk is in the shape representing an "H." The two main strips span a length of around 70', with a middle connection at 60'. There are also 3 small 15'segments branching off the side. No fireproofing is required for the catwalk since it is not considered structural steel. As shown in the accompanying picture, the catwalk will be fastened to the steel trusses being put in place.

Figure 10. Placement of Steel Trusses

Proposal

If the project teams in this venture would have been able to devote more time into choosing other valuable catwalk options, they might have been able discover the possibility of saving both time and money. Once a number of key construction concerns have been presented for the erection of the steel catwalk, alternate structural systems and materials will be taken into consideration. Topics such as cost, lead and construction times, system strength capabilities, and other miscellaneous specifications will be reviewed to better determine an appropriate catwalk structure.

System Comparisons

The following materials shall be investigated as a few of numerous possibilities that may satisfy the Lecture Hall catwalk structure. These results have been obtained through conversations with the general contractor, specialty subcontractors, and *RS Means 2006* analyses.

Steel

As previously stated, the 2 foot wide Lecture Hall catwalk is designed with structural steel members that are specified to support the 40 PSF live and 20 PSF dead loads. Before going into further research, it is important to first consider the load calculations for the steel. From this we will have a basis to which the alternate systems can be compared. For brevity purposes, only the critical members will be analyzed.

In order to hang the catwalk from the steel trusses, pairs of HSS 5x5x5/16 members have been utilized and are only subject to tensile forces. As long as the end stress result is below 50 ksi (1,000lbs/in^2), the design is adequate. After a tributary area of 25 was calculated, the total force per square foot was used with the live and dead load factors. The overall stress within the HSS hangers was calculated to be 0.27 ksi, much less than the maximum.

Likewise, it is imperative to check the W8x28 girders used to span lengths between 10-25 feet. First we must convert the already determined 88 pounds per square foot (PSF) into pounds per linear feet (PLF), and then use that to check the shear, moment, and deflection in the member. As a final check, look at the L/480 and L/360 deflection constraints. Respectively, if they are smaller than 0.625 inches and 0.833 inches, the members are good. For a more thorough numeric evaluation, please view **Appendix D**.

Now that there is an understanding of the structural aspects of the catwalk, we can dive into discussion of other criteria to assist our decision. Like many construction projects, steel is one of the most critical long lead items. For the Lecture Hall project, a lead time of around 8 weeks was expected for steel delivery. Once the steel arrived on site, pieces were individually lifted into the building by crane due to their heavy nature and bolted into place. Furthermore, in the Detailed Schedule included in **Appendix B**, an estimated construction time of 3 weeks was included for "A8000 Install Catwalk." In actuality, the assembly lasted 4 weeks. Since the installation of these steel members takes up a significant about of space on the scaffolding platform, this extension of time could end up setting predeceasing trades from starting their work on time. Lastly, concerning cost, a detailed estimate produced a cost around $75,850. The table below is a summary of the costs of each section. To view the detailed estimate, please turn to **Appendix E**.

Table 2. Steel Catwalk Cost Summary

	Total Weight (tons)	Material Cost	Labor Cost	Total Cost
Main Strip (2)	10.98	$21,951	$15,554	$37,505
Middle Wing (2)	1.85	$3,706	$2,627	$6,333
Middle Connection	5.21	$10,418	$6,903	$17,321
Top Tail	0.54	$1,074	$961	$2,036
Metal Grating	-	$4,800	$960	$5,760
			Total	$68,954
			Sub Profit	+10%
			Final Total	$75,850

Aluminum

For years, industry members have been arguing about the most advantageous material being either steel or aluminum. For argument sake, when looking at aluminum systems, the overall weight of aluminum structures can be roughly 30-40% less than that of steel. In this scenario, if it wasn't for the controlling 10" concrete slab poured above the steel trusses, a lighter designed catwalk may allow for a slimmer and less expensive truss system. Besides the inability of sizing down the steel trusses, a lighter aluminum system may permit larger pre-assembled sections to be inserted into the auditorium ceiling at a time. In turn, this will result in a shorter duration for construction and allow proceeding trades to begin their work earlier. With the ability to pre-assemble sections on site before installation, the previous 4 week allotment for steel could result in a shorter 3 week duration. Concerning aluminum lead times, a 6-7 week span for delivery after placement of the order can be expected. Corrosion concerns between steel and aluminum contact will be eliminated because of final cleaning and final painting of the members.

In order to obtain a comparable aluminum catwalk system to that of the steel, geometric properties were analyzed. Looking in "Stock Components for Architectural Metal Work," a Julius Blum & Co. text, similar sized aluminum shapes were found and substituted. Structurally, the same load analyses were considered. The different properties that need to be considered when analyzing aluminum are its yield strength of 35 ksi and modulus of elasticity of 10e3 ksi. Like the steel calculations, critical aluminum members used for this analysis include HSS 4x4x3/16 hangers and W10x10 girders. Stress in the hangers was calculated to be around 0.77 ksi, smaller than the 35 ksi limit. Deflection of the aluminum girder with the same dead and live load requirements end up being 0.5 inches, which is still less than the L/480 limits. These calculations can be found in **Appendix D**.

A detailed estimate for an aluminum system cost around $62,155. The table on the following page is a summary of the costs of each section. To view the detailed estimate, please turn to **Appendix E**.

Table 3. Aluminum Catwalk Cost Summary

	Material Cost	Labor Cost	Total Cost
Main Strip (2)	$17,440	$13,060	$30,500
Middle Wing (2)	$2,659	$1,991	$4,651
Middle Connection	$8,197	$6,138	$14,336
Top Tail	$720	$539	$1,259
Metal Grating	$4,800	$960	$5,760
		Total	$56,505
		Sub Profit	+10%
		Final Total	$62,155

Fiber Reinforced Polymer (FRP)

Fiber reinforced polymer composites are increasingly being used in civil infrastructure applications ranging from reinforcing rods and tendons, to all-composite bridge decks, and even hybrid and all-composite structural systems. Anecdotal evidence has provided substantial reason to believe that, if appropriately designed and fabricated, FRP composite materials can provide longer lifetimes and lower maintenance than equivalent structures fabricated from conventional materials. Further investigations and communication with FRP manufacturers will pose as an interesting venture in the determination to implement this system into the Lecture Hall.

Recommended by DAVIS' Project Manager; E.T. Techtonics is one of many reliable suppliers of engineered fiberglass bridges and building systems. Quoted by their website, "these high-strength FRP materials provide bridge systems with a strength-to-weight ratio greater than steel, offering design and erection advantages over traditional materials. E.T. Techtonics feature two basic design approaches referred to as truss spans and post-tensioned cable spans.

After brief discussions with G. Eric Johansen of E.T. Techtonics, Inc. the Lecture Hall catwalk was estimated to cost $62,000. All of the pieces are lightweight and can withstand a maximum weight of approximately 60 lbs. The 2' wide path consists of a solid FRP composite deck which can hinder objects from falling to the acoustic paneling below. Delivery of the catwalk would be no more than 6 weeks from the order placement date. According to the company's claims, 2 workers can construct a typical 25'x 2' section on the ground in 4 hours. Bringing these 25' pre-assembled sections could then be fastened to the steel trusses in 2 hours. Totaling about 6 hours per 25' section, a construction time of only 45 man-hours each for the nine segments is expected.

Table 4. FRP Cost Summary

Quantity	Span	Unit Weight (lbs)	Price($)/Unit	Total Cost
5	20'	750	6,000	30,000
4	25'	1,000	8000	32,000
			Total	$62,000

Wood

As a final alternative, pre-fabricated wood I-beams can be considered. The critical steel girders shall be substituted with acceptable Georgia-Pacific I-beams. To keep a consistent member depth throughout the system, 14" GPI 40 and GPI 65 elements will be used. Georgia-Pacific wood I-beams resist shrinking and twisting, and have consistent strength characteristics. Being composed of wood, members are much lighter than steel and can be cut easily on site if alterations need to be made. For durability and strength purposes, the steel HSS hangers in the initial design were kept and metal chairs will be used for the wood system to sit on.

40 PSF Live Load + 20 PSF Dead Load

Joist	Joist Depth	Spacing (Simple Span) 12" o.c.	16" o.c.	19.2" o.c.	24" o.c.
GPI 20	11⅞"	20'-05"	18'-08"	17'-08"	15'-11"
GPI 40	9½"	18'-00"	16'-06"	15'-07"	14'-02"
	11⅞"	21'-06"	19'-08"	18'-01"	16'-02"
	14"	24'-04"	21'-09"	19'-10"	17'-09"
GPI 65	11⅞"	23'-03"	21'-03"	20'-00"	18'-08"
	14"	26'-05"	24'-02"	22'-09"	21'-03"
	16"	29'-04"	26'-09"	25'-03"	22'-03"

Table 5. GPI Series Joists-Floor Spans

Like that of the FRP system, lead times for pre-fabricated wood I-beams can be around 6 weeks. Construction times will again be less than steel due to the ability to pre-assemble sections on site. In order to obtain a rough estimate, 50 PSF structural I-joists with wood flanges were considered from RS Means 2006 to substitute the GPI beams. Since the specified loadings are so small and the I-beam girders would be critical, equivalent wood members were also estimated to substitute steel railings and floor supports. On the down side, although steel was not required to be fireproofed, the flammability of wood is much greater than the previously mentioned material. For a detailed wood estimate for the catwalk, please view **Appendix E**.

	Material Cost	Labor Cost	Total Cost
Main Strip (2)	$1,554	$779	$2,333
Middle Wing (2)	$288	$116	$404
Middle Connection	$748	$350	$1,098
Top Tail	$62	$30	$92
Misc Steel	$9,250	$12,989	$22,239
Metal Grating	$4,800	$960	$5,760
		Total	$31,927
		Sub Profit	+10%
		Final Total	$35,119

Table 6. GP I-Beam Cost Summary

Recommendation

Now that all of the proposed structural systems and alternate materials have been considered, compiling the information into an easy to read chart is necessary before final suggestions can be made. The table below depicts three main construction management concerns of cost, lead and construction times, and an additional section for system downfalls.

Table 7. Catwalk Summary Table

System Material	Cost	Lead Time	Construction Time	Other
Steel	75,850	8-9 weeks	4 weeks	Heavy
Aluminum	62,155	6 weeks	2 weeks	Corrosion
FRP	**62,000**	**6 weeks**	**6 days**	**-**
Wood	35,119	5-6 weeks	2 weeks	Flammability

Not surprising, the wood structure costs the least amount compared to the other three. Although cost is a big motivator to an owner and general contractor, other characteristics need to be looked into. Being a much more flammable material, wood can be a greater fire hazard liability than an owner would want to risk, despite cost. In addition to this, although the construction time for a wood system would be less than steel, it is still lengthier than FRP.

The currently installed steel system also does not seem to be a valuable option. Compared to the other three, steel is more costly and takes up a considerable amount of time.

Without much analysis, it is easy to see the aluminum and FRP systems are pretty similar. With comparable estimates and lead times, the main advantage of fiberglass reinforced members over aluminum is the 6 days of construction time.

In conclusion, switching from steel members to FRP would be in the best interest of every construction entity on the job, especially Capital One and DAVIS. An up front cost of almost $14,000 can be saved, not to mention 2 weeks lead time and roughly 3 weeks in construction time. The shorter FRP durations will allow more freedom for other trades to do work above the auditorium and also benefit delivery deadlines from the smaller lead time.