Feasibility of Double-Skin Façades for Multi-storeys Office Buildings in Amman/Jordan:

An insight into Thermal performance for both summer and winter Peak Conditions

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Abstract: Amman, the capital city of Jordan, usually experiences a hot-dry summer with high solar radiations and a cold-wet winter. While the entire state of Jordan faces serious shortages in energy sources, significant growth in both industrial investment and constructions is noticed in the last few years particularly in Amman. This includes construction of both apartment and office buildings using a relatively new construction systems/elements. In Amman, for instance, Double-skin facades (DSF) have recently been introduced to a few buildings. However, there are no noticeable studies showing how it will work under the climate of Amman. Literature from similar climates indicates that while DSF is expected to perform well in winter, summer overheating is a major problem in hot regions due to large glazed surfaces facing excessive direct solar gains that coincide with high ambient temperatures. Thus, it is highly important to investigate the operational performance of this relatively new system in such a climate before it is widely applied due to its advantages as a promising passive technology. This study aims to investigate the thermal performance of DSF integrated into office buildings in Amman. Intended work was conducted using TAS tool and based on Amman's weather file. Results showed that integration of DSF into multi-storeys office buildings would generally increase indoor operative temperatures for both conditions. While this would lead to significant overheating in summer times, indoor thermal comfort would almost be achieved in winter with a slight possibility of overheating during peak hours. However, the reasonable operation of the system (i.e. openings control) would help to overcome potential overheating in winter, whereas applying passive cooling technologies is highly recommended for summer operation.

Keywords: Double Skin Façade, Thermal performance, Overheating, Hot regions, TAS software.

1. INTRODUCTION

Double Skin Facade "DSF" has many advantages including thermal, optical, ventilation, etc. thus consider as a promising passive solution for facades. Whereas it was basically introduced to buildings in cold climates, its applications are being transferred to hot climates in last years as well. Several studies have been conducted on DSF in hot conditions. To some extent, it showed an acceptable performance if it is designed and operated properly (Hamza 2004). However, there is still a wide debate regarding its thermal effectiveness in hot regions whether it works as a passive cooling strategy. The city of Amman usually experiences hot-dry summer with high solar radiations about 5kW.h/m² and cold-wet winter (Bani-Domi 2005, Al-Salaymeh, Al-Hamamre et al. 2010). Whereas Jordan faces serious shortages in energy, significant growth in constructional works in Amman is noticed in the last few years. This includes construction of both apartment and office buildings using a relatively new construction systems/elements, which might aim to work as passive techniques. Recently, DSF system has been introduced to a few buildings in Amman, Jordan. It was suggested for at least three new buildings there. Two of them are under-construction (Foster+Partners 2007, NES 2008).However, there is no noticeable studies on DSF in Jordan are found in literature whereas the system is already being transferred to the state! Thus, it is highly important to investigate the operation of this relatively new system there at this stage before it is being widely spread due to its numerous interesting advantages as a promising technology. Referring to literature from similar climates (Hamza 2004, Hamza 2008, Hashemi, Fayaz et al. 2010, Zhou and Chen 2010), both DSF and indoor space are highly likely to experience summer overheating due to large glazed areas with excessive direct solar gains coincide with high ambient temperatures. In hot regions, summer overheating is a common issue inherent with applying DSF in addition to the high possibility of glare in areas next to the façade. Enhancing DSF with cavity-integrated shading devices and proper ventilation seems a good idea to protect occupied spaces from direct gains and extract cavity-trapped heat to outside while shading devices are being protected within the system cavity. This work aims to investigate the thermal performance of office spaces attached to DSF under both summer and winter conditions. Work was conducted using Office-benchmark and DSF-benchmark cases.

2. METHOD:

2.1. Tools:

TAS (Version 9.2.1) software package was used to complete this work. A detailed model was constructed for benchmark and modified cases. Weather file with hourly data for Amman city (latitude: 31.98; longitude: 35.98) was used.

2.2. Benchmark Models:

Office-benchmark: office building consists of seven storeys and each storey has eight offices. Figure 1 shows the plan for entire office's block at 4th level, where the examined office is located. Figure 1 and Figure show a plan and section for the examined office; respectively. The main façade consists of three sub-parts; one vision and two non-visions; Table 1. Figure 2 presents a detail of the construction of vision part.

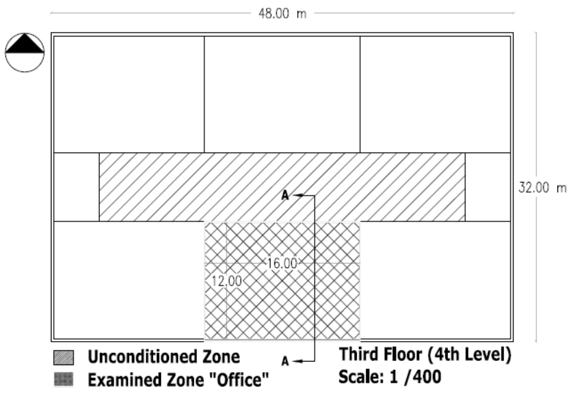

Figure1: Entire Office's Block Plan – Thirds Floor - 4th Level; (Source: Author).

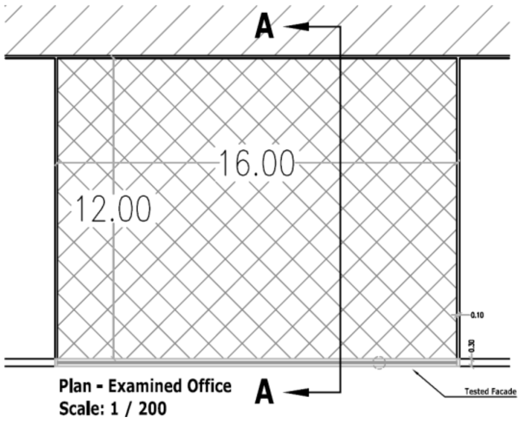

Figure 1: Examined Office Plan; (Source: Author).

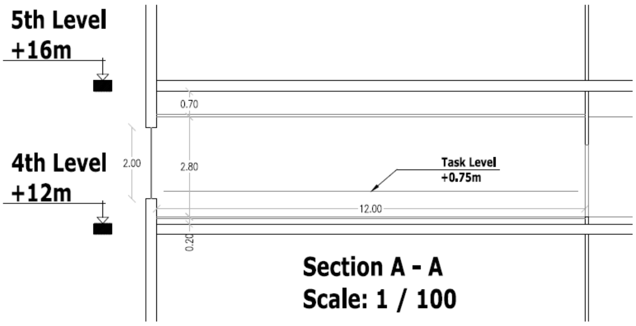

Figure 3: Office-Benchmark Section; (Source: Author).

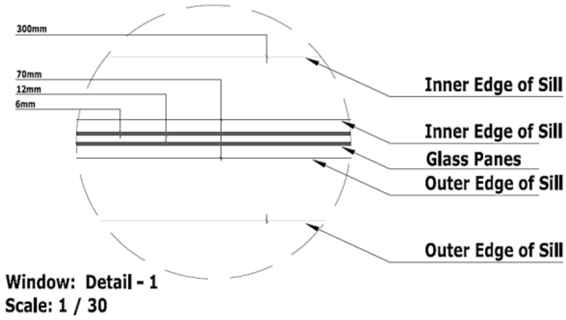

Figure 2: Details for construction of benchmark façade; (Source: Author).

Table 1: Construction of Office-Benchmark Facade. (Source: Author).

FAÇADE CONSTRUCTION		SPECIFICATIONS
ELEMENTS	NON-VISION PART (UPPER)	Spandrel Single Glass + Cavity + Insulation + Concrete + Gypsum Board
	VISION PART	Double Clear Glass Panes (6mm + 12mm + 6mm)
	NON-VISION PART (LOWER)	Spandrel Single Glass + Cavity + Insulation + Concrete + Gypsum Board
	WWR (%)	50%

Table 2: Specifications of the Vision Part of the Glazed Façade – Office-Benchmark. (Source: Author).

FAÇADE CONSTRUCT-ION	LAYER	SPECIFICATIONS			
		Width (mm)	Energy Transmittance-g (%)	Light Transmittance (%)	UV (W/m^2. C)
VISION PART	Pilkington K Glass	6	71	81	3.6
	Air	12	---	---	---
	Pilkington K Glass	6	71	81	3.6
ENTIRE CONSTRUCTION		24	68	73	1.9
NON-VISION PART	PILKINGTON ARCTIC BLUE GLASS	6	52	54	5.7

<u>*Double Skin Face (DSF) Benchmark:*</u>

Figure 3 illustrates a schematic section for the proposed DSF system attached to office-benchmark. DSF starts from 1st floor with cavity width of 1m. Results presented in this paper belong to the case with no additional chimney (H-ch=0m). The outer skin is fully glazed with single glass and would have two main openings located at the bottom (inlet) and top (outlet) of it. While inlet/outlet will be along the façade's depth itself, its height would be fixed to 0.5m. Inner skin (original office façade) is 50% glazed with double pane-glass. Each floor has two openings: inlet and outlet (each 0.5m-high). Figure 4 shows the examined office (4th floor) equipped with DSF system.

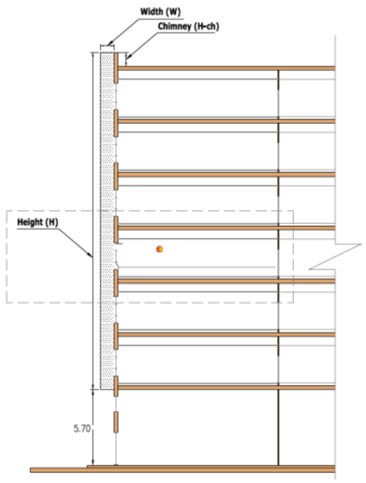

Figure 3: Double Skin Façade "DSF-Benchmark".

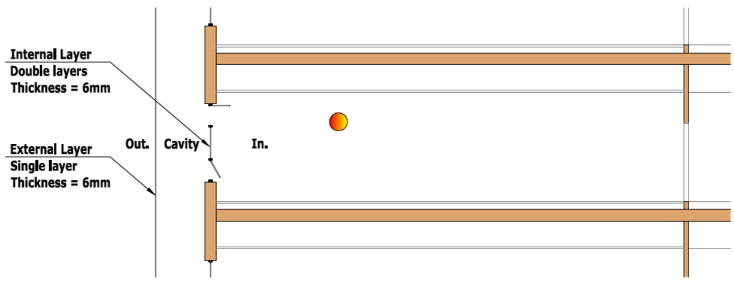

Figure 4: The Examined Office equipped with DSF system / Section.

DSF-Benchmark was initially investigated with natural ventilation through three scenarios (DSF-1, DSF-2 & DSF-3),

Table 3, and compared to Office-Benchmark. Those cases are different in the arrangement of both internal and external openings. The aim of this level of investigation was to determine the best natural ventilation scheme (arrangements and openness) with DSF based on summer/winter and day/night. Based on results for three cases, another three cases (DSF-4, DSF-5 & DSF-6) were set, which was basically derived from DSF-3.

Occupancy and Internal Heat Gains:

Regarding internal heat gains, Table 4 gives heat emission rates from human body within office environments. Table 5 shows values for the density of occupation and rates for both sensible and latent heat gains for occupants, equipment, and lighting. For the intended research, the office was considered with general use and occupation's density was set as 1 person per 12 m^2. Rates for heat gains were set as 6.7 and 5 W/m^2 for human's sensible and latent; respectively. Sensible heat gains for equipment and lighting were 15 and 12 W/m^2; respectively.

Table 3: Different investigated scenarios for Benchmark-DSF-Office and Benchmark-Office.

Scenario	ventilation	Summer		Winter	
		Internal	External	Internal	External
Non-DSF (NAT)	Natural	Open (full=50% of window)	null	Close (except 5% fresh air during daytime)	null
DSF-1	Natural	Open (full=50% of window)	Open (full inlet)	Close (except 5% fresh air during daytime)	Open (full inlet)
DSF-2	Natural	Open (full=50% of window)	Open (full inlet)	Close (except 5% fresh air during daytime)	Close (except 5% fresh air during daytime)
DSF-3	Natural	Close (except 5% fresh air)	Open (full inlet)	Open (full=50% of window)	Close (except 5% fresh air during daytime)
DSF-4	Natural	Same to DSF-3	Same to DSF-3	- Daytime: Open: (full=50% of window) - Night-time: Close	Close (except 5% fresh air during daytime)
DSF-5	Natural	Same to DSF-3	Same to DSF-3	- Daytime: Open: (full=50% of window) - Night-time: Close	Close (except 10% fresh air during daytime)
DSF-6	Natural	Same to DSF-3	Same to DSF-3	Open (full=50% of window)	Close (except 10% fresh air during daytime)

Table 4: Standards for Heat Emissions from Human Body at different state of activities - Offices. Source: (CIBSE 2006)

DEGREE OF ACTIVITY	TYPICAL BUILDING	TOTAL RATE OF HEAT EMISSION FOR ADULT MALE (W)	RATE OF HEAT EMISSION FOR MIXTURE OF OCCUPANTS (W)		
MODERATE	OFFICE	140	130	75	55

Table 5: Standards for Internal Heat Gains (Occupants, Lighting & Equipments) for Typical Office Buildings. Source: (CIBSE 2006)

BUILDING TYPE	USE	DENSITY OF OCCUPATION (PERSON/m²)	SENSIBLE HEAT GAIN (W/m²)			LATENT HEAT GAIN (W/m²)	
			PEOPLE	LIGHT	EQUIP'T	PEOPLE	OTHER
OFFICES	GENERAL	12	6.7	12	15	5	---

3. RESULTS AND DISCUSSION:

Results for both Office-Benchmark and DSF-Benchmark, in Amman, are presented and compared. Results were for natural ventilation scenarios, and presented in forms of temperature, solar gain and airflow rates.

3.1. Office-Benchmark:

Results are presented for the free running scenario of office-benchmark:

Temperatures: For given office-benchmark, results show temperature profiles for both hottest (187) and coldest days (23). In Amman, summer comfort band is 24-28.5°C and winter comfort is 18.5-23°C. Simulation was done for three scenarios named: N-ACH=10 (for both summer and winter: day-ach=1 while night-ach=10); N-ACH=1 (for both summer and winter: day-ach=1 while night-ach=10 "summer" and night-ach=1 "winter") and Natural Ventilation (NAT). In practise, this results in two summer scenarios (N-ACH=10 and NAT) and three winter scenarios (N-ACH=10, N-ACH=1 and NAT) presented through hottest and coldest days; respectively. Whereas NAT indicates natural ventilated offices (uncontrolled openings), N-ACH represents offices with fixed day-time and night-time ventilation rates however at temperature equals to outdoor aiming to use night-time cooling means. Infiltration was 0.25ach for all scenarios. Afternoon (1-2 pm) repetitive drop in temperature reflect working break for one hour in time schedules. Figure 5 shows dry bulb temperatures on hottest day for the two scenarios: N-ACH=10 and NAT. With NAT, adjustable windows were set at maximum for both daytime and night-time (max.=50% of the glazed construction). For natural ventilation, dry bulb temperature was lower by 2°C than N-ACH=10 as ACH during day-time would be 5-7 with NAT compared to ACH=1 by N-ACH=10. For night-time, there were no significant changes even first scenario gave slightly better results as natural ventilation would provide ACH=6-8 compared to ACH=10. As well, mean radiant temperatures, Figure 8, would be lower with natural ventilation leading to a resultant temperature lower by 1.5-2°C as shown in Figure 10. However, the resultant temperature is still higher than comfort band even with natural ventilation due to high outdoor temperatures. Thus, means of artificial cooling are still recommended.

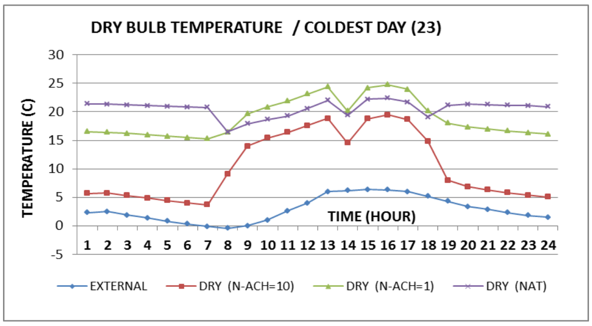

Figure 6: Dry Bulb Temperatures for Fixed-Rate Ventilation vs. Natural Ventilation; Coldest Day; Jan., 23rd (23).

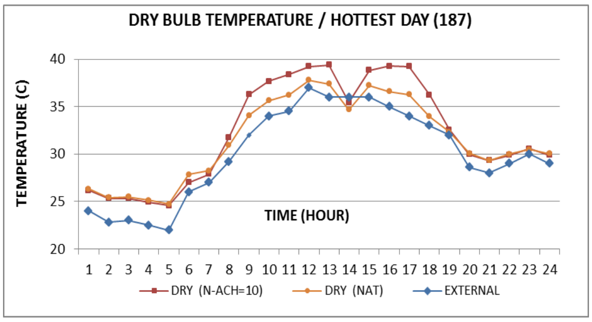

Figure 5: Dry Bulb Temperatures for Fixed-Rate Ventilation vs. Natural Ventilation; Hottest Day; July, 6th (187).

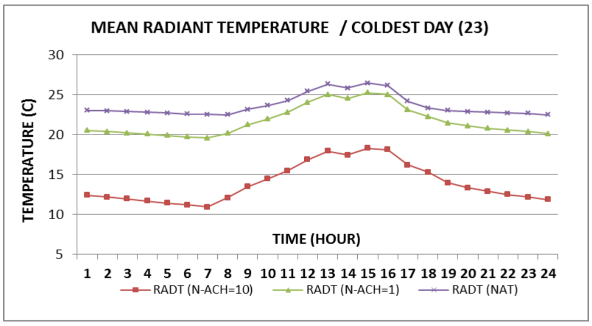

Figure 7: Mean radiant Temperatures for Fixed-Rate Ventilation vs. Natural Ventilation; Coldest Day; Jan., 23rd (23).

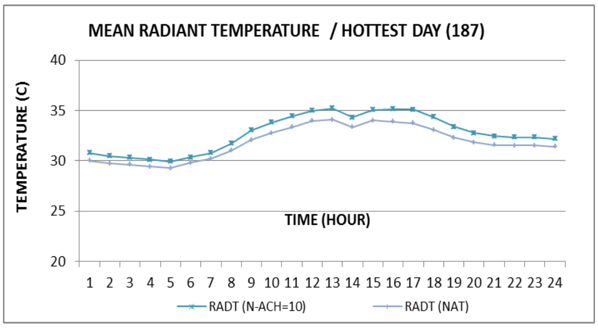

Figure 8: Mean radiant Temperatures for Fixed-Rate Ventilation vs. Natural Ventilation; Hottest Day; July, 6th (187).

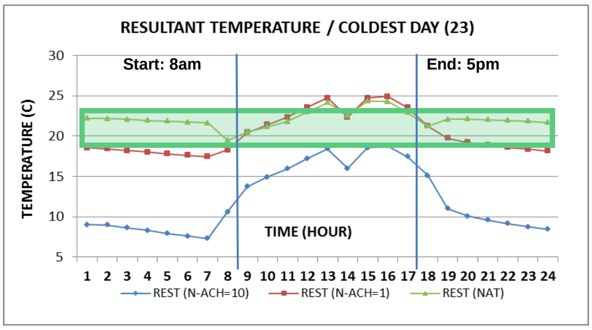

Figure 9: Resultant Temperatures for Fixed-Rate Ventilation vs. Natural Ventilation; Coldest Day; Jan., 23rd (23).

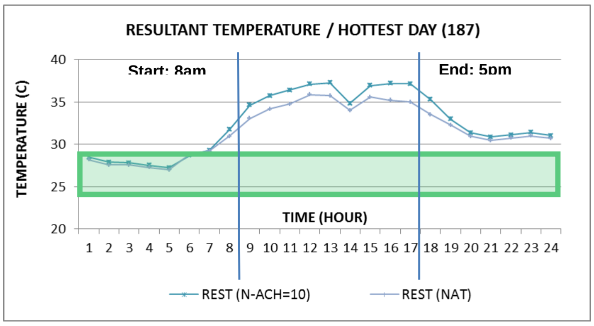

Figure 10: Resultant Temperatures for Fixed-Rate Ventilation vs. Natural Ventilation; Hottest Day; July, 6th (187).

For winter, three ventilation scenarios were investigated: N-ACH=1, N-ACH=10, and NAT. With NAT, windows were just open with 5% to ensure fresh air (this can provide 1.9-2.3 ACH fresh air during daytime compared to 1 ach as a minimum requirement). During night-time, all windows were shut down to prevent undesirable night cooling. Figure 6 and Figure 7 show dry bulb and mean radiant temperatures for the three scenarios. Generally, natural ventilation, **Error! Reference source not found.**, would provide better resultant temperature closed to comfort band (18.5-23°C) with maximum 24.3°C at 3 pm. However, such increase is still preferable. Generally, no heating would be needed as well as cooling.

<u>Solar Gains:</u> Summer solar gains would reach 16.3 W/m² at 1 pm; Figure 12. Space continued losing heat due to infiltration and natural ventilation. On winter design day, solar gains would reach 43 W/m^2 at noontime and 51.5 W/m^2 at 1 pm; **Error! Reference source not found.**. Such difference between summer and winter solar gains was due to the low winter sun altitude angle compared to summer. Winter losses due to infiltration and ventilation were significant.

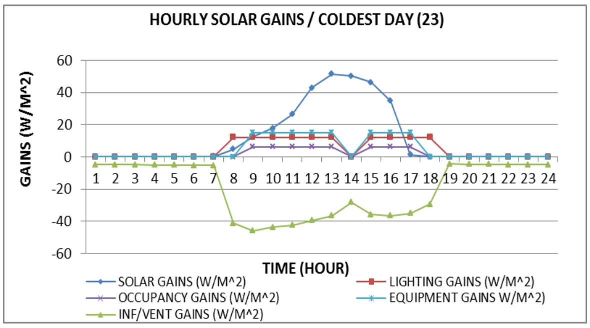

Figure 11: Heat Gains/Losses to Office with Natural Ventilation Scenario; Coldest Day; Jan., 23rd (23).

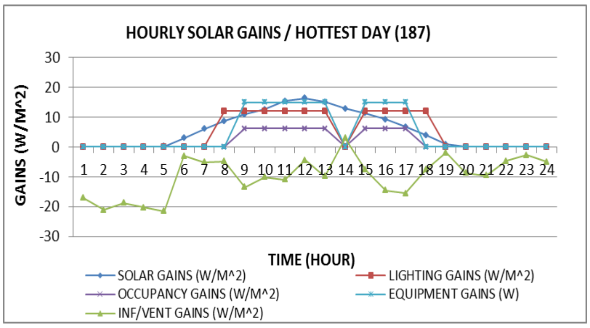

Figure 12: Heat Gains/Losses to Office with Natural Ventilation Scenario; Hottest Day; July, 6th (187).

3.2. DSF-Office Benchmark:

Results are presented for the free running scenario of DSF-Office Benchmark (mentioned afterward as DSF-Benchmark):

<u>*Temperatures*</u>: free running temperatures were recorded for these cases. Firstly, results are shown for cases 1-3. Then, results for cases 4-6 were presented.

Hottest Day: summer office's temperature would increase depending on internal and external skins opening's arrangements. DSF-3 showed the worst scenario as internal openings were almost closed leading to indoor overheating. DSF-1 (similar to DSF-2 in summer) showed better performance as both external and internal openings were opened, which helped in extracting hot air to outdoor through the cavity. However, the temperature still up to 2°C more than NAT (non-DSF); Figure 13. Radiant temperatures showed similar profiles; and DSF-1 caused an increase about 1°C compared to NAT, Figure 15, leading to an increase in resultant temperatures as it went up from 35.9°C (NAT) to 37.1°C (DSF-1) at 12 pm, Figure 18.

Coldest Day: compared to NAT, winter's indoor temperature would increase for all cases except for DSF-3 during night-time as internal openings would be opened 24hrs; Figure 14. DSF-2 showed a significant increase in temperature due to both internal and external openings were kept closed (internal gains were kept inside the office except little due to 5% openness for fresh air), in additional, temperature for trapped cavity's air (formed air supply to indoor) would also increase due to the greenhouse effect. DSF-1 (ext-opened and int-closed) results were more close to NAT (office-benchmark). Similar terends were also for mean radiant temperatures; Figure 17. Again, Figure 16 shows that resultant temperatures with DSF-1 would be more close to those by NAT. Most importantly, it fits the comfort band (18.5-23°C) with some exceeds around peak times.

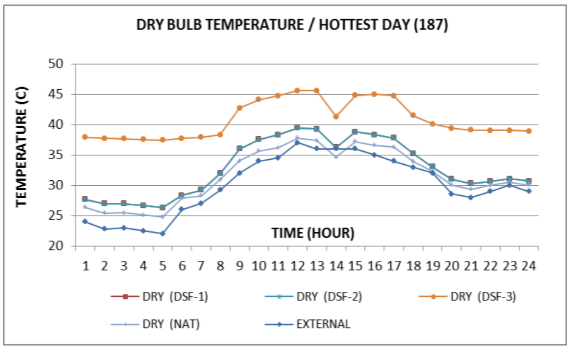

Figure 13: Dry Bulb Temperatures; Hottest Day; July, 6th (187).

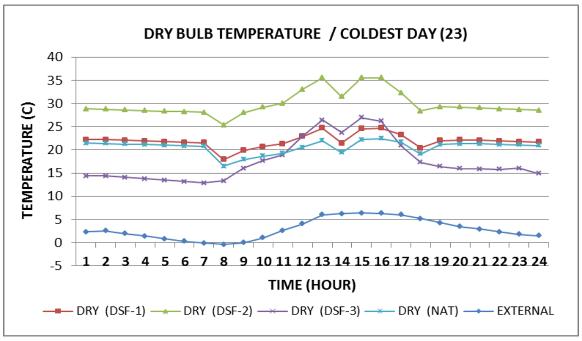

Figure 14: Dry Bulb Temperatures; Coldest Day; Jan., 23rd (23).

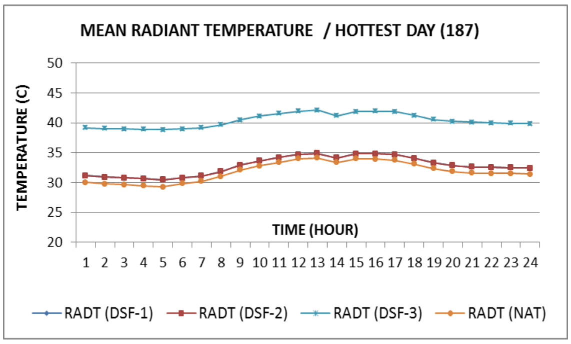

Figure 15: Mean Radiant Temperatures; Hottest Day; July, 6th (187).

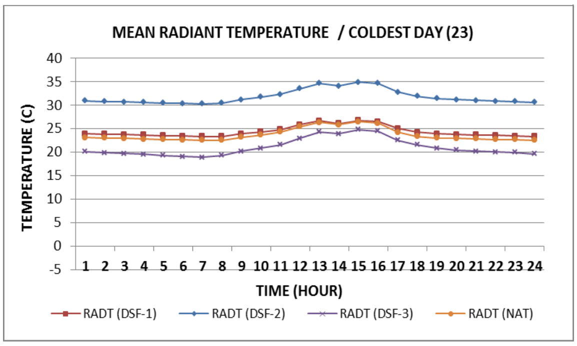

Figure 16: Mean Radiant Temperatures; Coldest Day; Jan., 23rd (23).

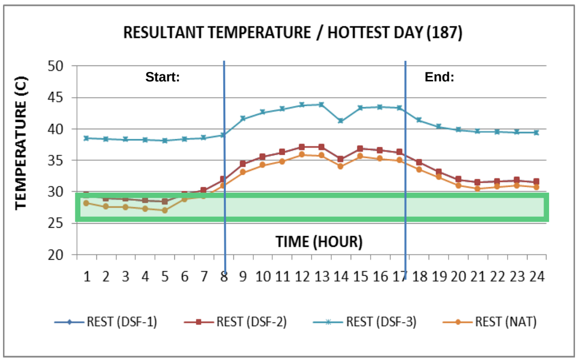

Figure 18: Resultant Temperatures; Hottest Day; July, 6th (187).

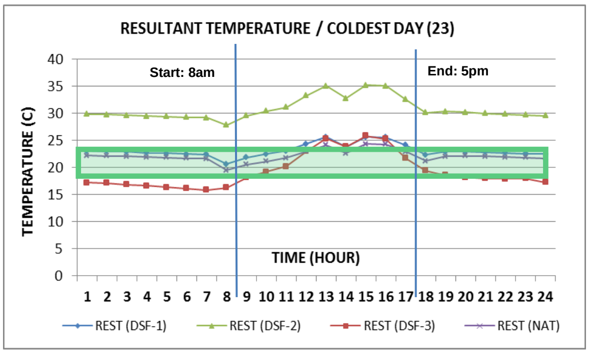

Figure 17: Resultant Temperatures; Coldest Day; Jan., 23rd (23).

Refering to DSF-3, while external openings would be closed, internal openings would be opened for 24h. This would cause undesirable night cooling during winter due to continous air-exchange between indoor and cavity. Thus, DSF-3 was amended as internal openings would be closed during night-times forming DSF-4. Also, external openings was set with 10% openness (DSF-5 & DSF-6) instead of 5% (DSF-1);

Table 3. Figure 19 shows resultnant temperatures for those scenarios. Closing internal openings through night-time (DSF-4) would increase operative temperature for the whole day and even, sometime, taken it out of comfort band. Amending DSF-4 by increasing the percentage of openess for external openings from 5% to 10% (DSF-5), the temperature would decrease during daytime and be close to comfort band. With DSF-6, leaving internal openings full-open during day-time and night-time while increasing percentage of external openness may achive comfort temperatures for the mid-day time.

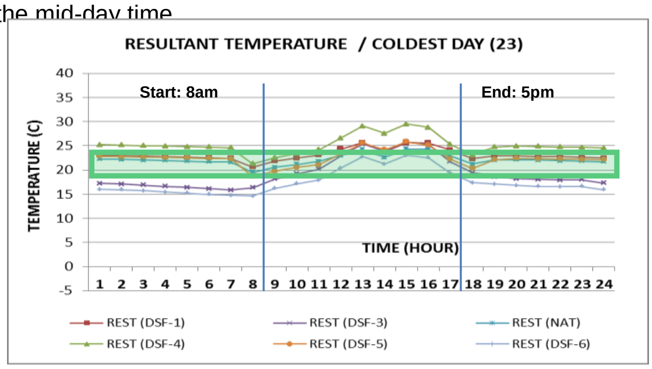

Figure 19: Resultant Temperatures; Coldest Day; Jan., 23rd (23).

To conclude, either DSF-3 or DSF-5 would help to provide thermal comfort conditions inside the office during winter. Initially, DSF-5 was selected for further investigation in winter as it would ensure more comfort temperature at early working hours. For the hottest day, both internal and external openings are recommended to be opened. DSF-1 was chosen for further investigation in summer. A new configuration for DSF named, DSF-Benchmark, would combine both summer of DSF-1 and winter of DSF-5; Table 6.

Table 6: Seasonal Openings Arrangements for Both Office-Benchmark and DSF-Benchmark Office.

Scenario	Ventilation	Summer		Winter	
		Internal	External	Internal	External
Office-Benchmark	Natural	Open (full=50% of window)	null	Close (except 5% fresh air during daytime)	null
DSF-Benchmark	Natural	Open (full=50% of window)	Open(full inlet/outlet)	- Daytime: Open: (full=50% of window) - Night-time: Close	Close (except 10% fresh air during daytime)

Error! Reference source not found. and **Error! Reference source not found.** show dry and radiant temperture profiles, respectively, for both DSF-Benchmark and Office-Benchmark on summer design day. Generally, temperatures would increase with DSF-Benchmark compared to Office-Benchmark. This is due to summer cavity overheating and, also, reducing offices' ventilation rate due to additional resistance by the second glass layer. Figure 23 shows that operative temperatures would further increase by about 1°C with DSF. However, the temperature for both cases are still out of comfort band; as it reaches 37.1°C and 35.8°C at nootime for Office-Benchmark and DSF-Benchmark; respectively. Thus other means of cooling are still needed including mechanical cooling.

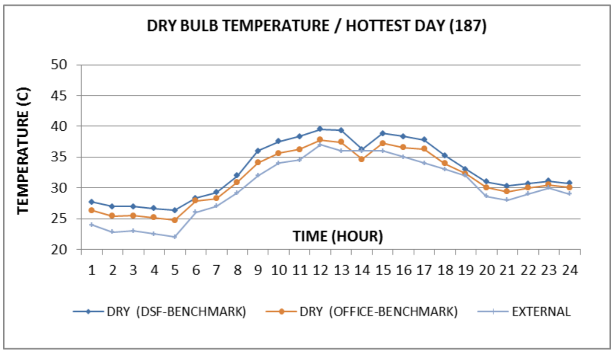

Figure 21: Dry Bulb Temperatures for DSF-benchmark and Office-Benchmark; Hottest Day; July, 6th (187).

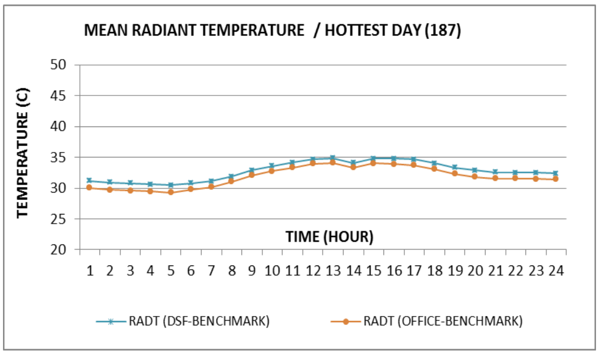

Figure 20: Mean Radiant Temperatures for DSF-benchmark and Office-Benchmark; Hottest Day; July, 6th (187).

Figure 22 and Figure 25 show dry and radiant temperture profiles, respectively, for both DSF-Benchmark and Office-Benchmark on winter design day. Indoor dry temperatures for DSF-Benchmark would be higher for mid-day time by up to 3°C. This increase was due to preheating of air inside the cavity before being exchanged with office's air. However, for DSF-Benchmark, air temperature would be lower for both 7-11am 4-7 pm periods as cavity air temperatures would decrease due to lower outdoor temperature. Figure 24 shows that both cases would achieve indoor thermal comfort and even slightly exceed upper limits for mid-day, however such increase (1-2°C) is still preferable in cold conditions.

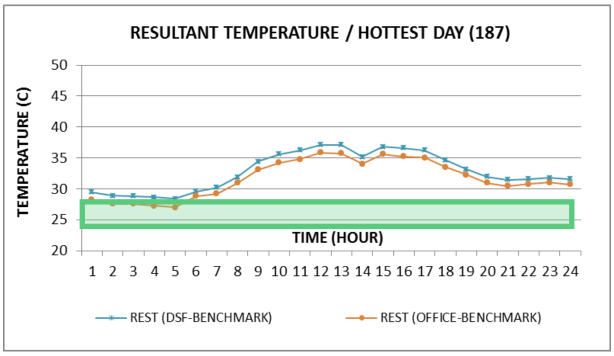

Figure 23: Resultant Temperatures for DSF-benchmark and Office-Benchmark; Hottest Day; July, 6th (187).

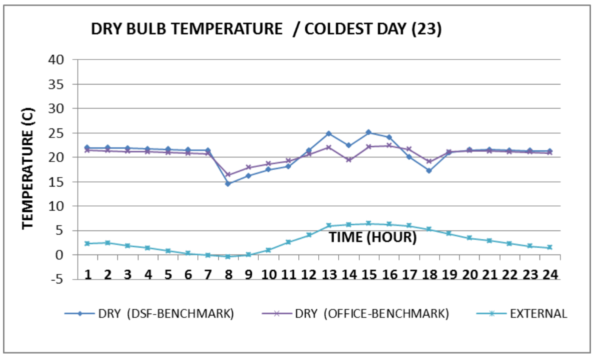

Figure 22: Dry Bulb Temperatures for DSF-benchmark and Office-Benchmark; Coldest Day; Jan., 23rd (23).

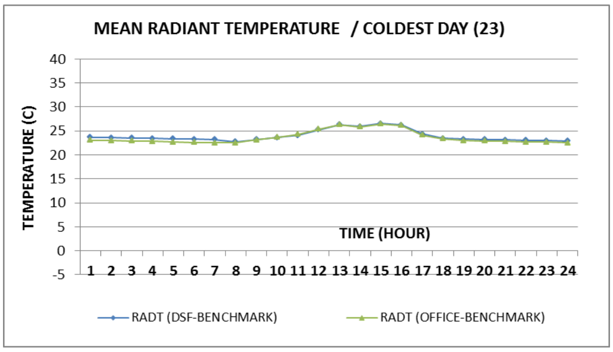

Figure 25: Mean Radiant Temperatures for DSF-benchmark and Office-Benchmark; Coldest Day; Jan., 23rd (23).

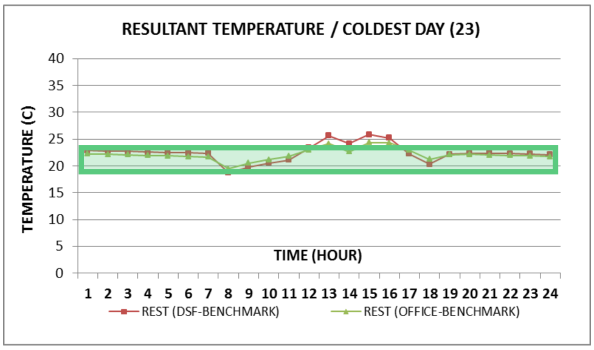

Figure 24: Resultant Temperatures for DSF-benchmark and Office-Benchmark; Coldest Day; Jan., 23rd (23).

Solar Gains: Solar gains, for DSF-benchmark, would be reduced by up to 40% around noon-time compared to office-benchmarck on summer design day; Figure 26. However, heat losses due to infiltration and ventilation would be reduced significantly and be more constant with DSF. As a result, indoor operative temperatures would increase by up to 2°C. On winter design day, afternoon solar gains would be reduced by up to 30% with DFS, which is undesirable for cold conditions; Figure 27. On the other hand, DSF would help to reduce heat losses mainly due to ventilation as fresh air will be heated within the cavity before entering the office.

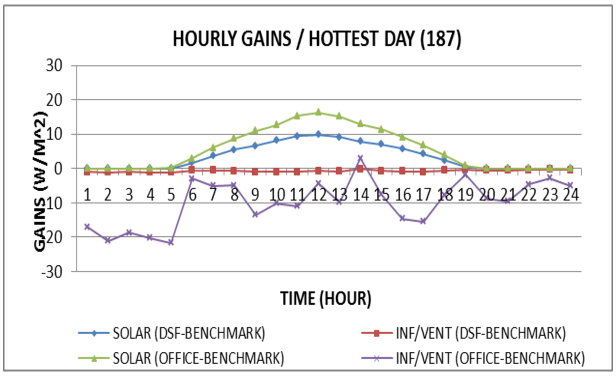

Figure 26: Heat Gains/Losses with DSF-Benchmark and Office-Benchmark; Hottest Day; July, 6th (187).

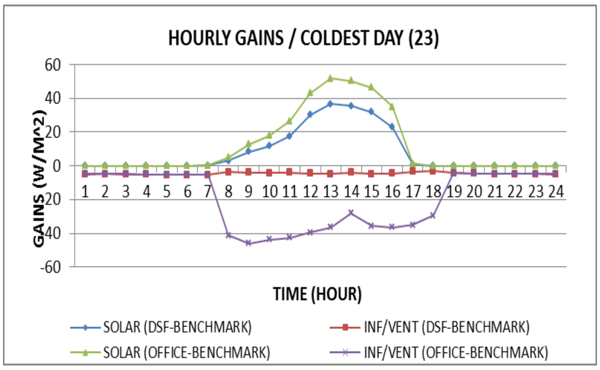

Figure 27: Heat Gains/Losses with DSF-Benchmark and Office-Benchmark; Coldest Day; Jan., 23rd (23).

Flow Rates: Based on facts that minimum fresh-air requirement for office space is 10 l.s-1.p-1 and having 16 occupants inside the benchmark open-office, the flow rate should be no less than 576 m³/h equal to 1 ACH (12m*16m*3m). Next figures show flow-in rates for both DSF-Benchmark and Office-Benchmark on summer and winter design days; respectively. Whereas flow rate is higher without DSF, minimum requirements are still achieved with DSF. In winter, hot air flow-in from the cavity to indoor through internal openings "window" would be increased significantly compared to office-benchmark. However, it is worth mentioning that internal openings were full open during daytime in DSF-Benchmark while those in office-benchmark were just 5% opened.

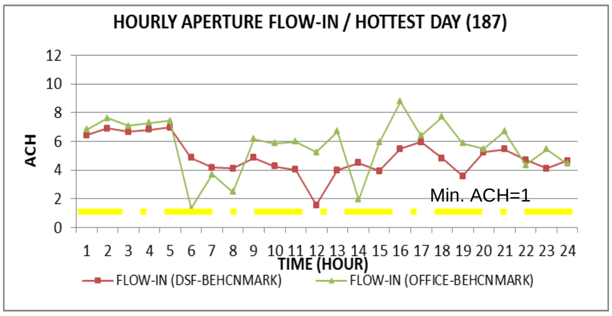

Figure 29: Air Flow through Space Aperture; Hottest Day; July, 6th (187).

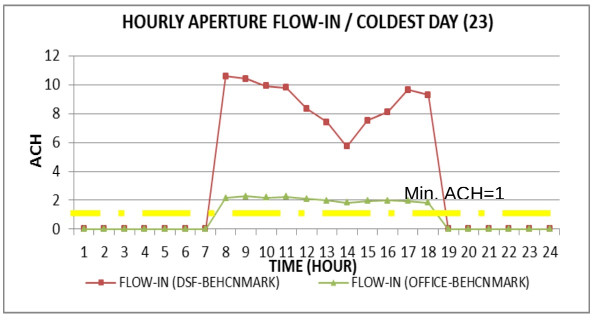

Figure 28: Air Flow through Space Aperture; Hottest Day; Jan., 23rd (23).

4. OUTCOMES AND RECOMMENDATIONS:

Firstly, the base office was investigated under two fixed ACH rates plus natural ventilation. Whereas indoor operative temperatures were high for all cases, natural ventilation would still have lower temperatures compared to others. Secondly, and for a feasibility study of DSF in AMMAN, Office-Benchmark (naturally ventilated office) was compared with DSF-Benchmark cases, which all naturally ventilated. All cases, here, were run freely where temperature, solar gain, and flow rates were studied. The following points summary the outputs for both summer and winter:

4.1. Summer:

- The indoor temperature was found to be too high inside office-benchmark and surly out of summer comfort band (24-28.5°C) as it could reach 35.9°C at 12 pm.

- Double Skin Façade (DSF) effect on indoor temperature was varying and would strongly depend on the ventilation efficiency. Having DSF with external single inlet/outlet kept full opened will not have significant changes to summer indoor temperatures compared to office-benchmark thus, at least, no significant overheating threats are raised due to DSF. As single inlet/outlet was, here, used for DSF, it is further recommended to use multi-vents for the external skin to enlarge ventilation rates.

- Additional means of shading like cavity-integrated devices would further help to minimise solar gains. As well, replacing double-pane glass by single-pane for inner layer would help to reduce indoor heat tarpping. Such enhacement would end up with less indoor overheating, however, still, need further investigations that are out of this work objectives.

4.2. Winter:

- In winter, keeping office-benchmark's openings almost closed (except 5%) would result in operative temperatures fit winter thermal comfort of Amman (18.5-23°C) and even exceed it during peak hours! To some extent, such increase is still acceptable and even preferable. However, such unpredictable high winter indoor temperature might be due to: *tightness of office-benchmark (Infiltration=0.25 ACH), high internal heat gains and/or using double pane glass at internal windows.*

- Obviously, office-benchmark can provide almost thermal comfort conditions during winter. Generally, adding DSF would increase indoor operative temperatures and might cause kind of uncomfort during peak hours. However, this could be controlled though adjusting both internal and external openings.

4.3. Conclusion:

- Serving offices, in Amman, with double skin facades (DSF), might increase possibilities of summer overheating particularly with insufficient ventilation. However, DSF would successfully reduce summer solar gains due to additional glass layer. Thus, proper design and operation of DSF (i.e. openings arragements) would lead to succeessful investment of such technology, hence, it is still worthy to do further investigations on DSF in Amman as it is being introduced to the state for several other reasons.

- This part of the work provided a better understanding of how DSF would perform under Amman climate, particularely summer. As well, it concluded with a base (benchmarks for DSF) for further detailed investigations on the system using ANSYS Fluent tool, which will include exammination of cavity-integrated shading. Also, investigation the effect of applying DSF to offices on daylight availability and glare control.

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