Façade Retrofit Material for Energy Efficiency in Hot and Humid Climate - Case Studies from Multistoried Office Building in Chennai, India.

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Abstract.

The commercial sector in India today, poses demand for energy saving and sustainability. The focus is on existing fully glazed office building sector, which exhibits great demand for energy efficient retrofits. This paper aims at determining energy efficient facade retrofit material in the early design stage for fully glazed multi-storied office buildings in Chennai for two selected case study samples, one with small area of 6300 m^2 and other with large area of 38000 m^2. The study involves creating simulation model for testing the energy use in E-quest and daylighting performance in Insight a plugin in Revit. 3 Types of retrofit materials, by changing the glazing types or adding to the interior or adding fins or by varying WWR percentage or by perforated screens / Jalli over the existing glazed façade. It is observed that the option with solar screens and GFRC jali performed the best with energy saving of more than 20 percent Finally it is revealed that adding to the exterior of the existing glazing are more energy efficient with good return on investment for both the case samples.

Keywords: *Façade retrofit, Energy-efficiency, integrated shading device, façade material*

1. Introduction

The climate changes that are prevailing on the earth has forced the architects to bring in innovation in the construction of buildings. The substantial share of the building sector in the world's overall energy use necessitates the need for increased awareness of the efficiency of existing buildings. Commercial buildings are among the key energy use markets globally. Office buildings have the highest energy consumption rates amongst the commercial sector sub- divisions since most of the office buildings function for longer periods in a day and there is a great energy demand for lighting and space heating / cooling loads. This shows that these loads have great potential to reduce by improving the thermal performance of building envelope including the retrofit actions of existing buildings. [1]

Growing interest in sustainable high-performance buildings and new construction is not enough to solve the problem. Firstly, modern high-performance buildings reflect just a small percentage of the buildings compared to the large numbers of existing buildings [2]. Secondly, new constructions require footprint, energy, materials, and financial capital. Demolition of existing buildings to build new high-performance buildings would demolish of all the embodied energy in the existing buildings [3]. Existing buildings have tremendous potential through energy efficient upgrades, reuse or adaptation practices to minimize adverse environmental impacts. Refitting existing buildings will greatly reduce their energy usage [4] and "work to the outside of the envelope is likely to be sufficient for most existing buildings" [5].

Building energy retrofit in general and façade retrofit in particular, are relatively new areas of practice. In fact, only 17% of the retrofits undertaken by Energy Savings Companies (ESCOs) include envelope upgrade [6]. Retrofit façade decision making is a complex area, with strategic decisions been made under conditions of uncertainty and use of right façade retrofit materials and its performances. To understand the dynamic parameters involved in the design and retrofit material application techniques by selecting the existing office buildings in the experimental study region of Chennai and simulation studies done to optimize the daylighting and space cooling energy demands. This research paper provides an insight into the material selection process for façade retrofit in multistoried buildings and explores the success of retrofit façade decision-making and adopts the following methodology.
The methodology used in structuring the paper consists of the following steps:

1) An extensive literature survey on energy retrofit process, applicable energy efficiency measures on façade system, and existing site data of the two case samples.
2) Extraction and systematic organization of case samples performances for both space cooling and daylighting as an initial step.
3) Generating façade retrofit options and comparing retrofit options with base case for its performances under implementation.
4) Results and Discussion
5) Conclusion

2. Literature review

Most buildings standing today will be a part of the building stock in 2050, there is a tremendous opportunity to reverse the pattern of energy consumption facing reduction targets [7]. Blumenfeld and Thumm [8] brought over 40 years of experience from both the public and private sectors to review the return of investment on building mechanical systems and envelope design, and they realized that building owners tend to: (a) over invest in active building systems; (b) under invest in passive envelope design; and (c) underestimate the maintenance costs of complex building active systems.Building retrofit, especialy façade retrofit is rapidly expanding as a research area in the last decade. Recently the approach to building retrofits have changed from upgrades to the mechanical system or lighting system to a comprehensive approach, known as “deep” retrofit, which investigates the building envelope and its direct link to energy efficiency[9].

In the article “Fundamentals of Façade Retrofit”, two online surveys were performed between 2013 and 2014 among building façade professionals. Over 310 building projects in the surveys. More than 200 façade-retrofitted buildings in 32countries in the first survey, whereas the second survey allowed the identification of 110 buildings in 16 countries [10]. First survey to identify predominant broad stroke façade retrofit practices. The second survey drilled down to a deeper level of design and construction, as well as motivations and goals. The survey results reinforce the notion of an early-stage trend of façade retrofit among the existing building stock. Commercial office building retrofit amounts to more than 2/3 of the survey buildings, and more than 50% of these office building are midrise (4-16 floors). The author concluded that in order to evaluate the effectiveness of façade retrofit in terms of energy efficiency improvement it requires further exploration and the availability of relevant data. Zhenjun [11] claimed that most previous studies have been based on numerical simulations; the actual energy savings due to the implementation of the selected retrofit measures have rarely been reported. These authors emphasized that more research and application work with practical case studies on commercial office building retrofits is essentially needed, which could help to increase the level of confidence of building owners to retrofit their buildings for better performance. Recent research has focused on the cost of energy and turned to financial evaluation of the building retrofit [12] .

India is still in the nascent stage of energy conservation for new buildings, For existing office buildings retrofit practices do not yet account as established actions, while India is faced with a vast stock of existing office buildings that will need to be retrofitted in the near future. Most countries in asia are retrofitting existing government buildings , whereas in India hardly a dozen projects have registered for façade retrofit of the office buildings owned by IT companies since 2012 [13]. The retrofit strategy to improving the energy performance with a focus on building facades with careful design could decrease the cooling load [14] energy by more than 30% with optimum visual comfort.

Material selection is an important facator in designing energy efficient façade system. The new and innovative façade material concept is fast catching up in India but it is not just for the aesthetic reasons. The new materials offer better natural lighting, air flow and are in line with the increasing adoption of green and sustainable building practices, an essential in current times. Recent trends show an array of structural practices and lightweight building such as rain screen façades and sun breakers, dual wall façades and even building integrated photo voltaic though at a very small scale. Since there are inavialablity of energy efficent retrofit data and unclarity of retrun on investement of the façade retrofit. This paper aims for improving the energy performance for private mutli-tenant / owner multi storied office buildings, which represents vast stock of existing building in this context by optimized selection of retrofit façade materail type, based on the equivalent annual cost that results from subtracting the expected façade retrofit cost from the expected annual energy use in the case study samples. After reviewing various articles the researcher adopted the methodology for his research as in the next section.

3. Methodology

The methodology flow chart into three major sections: Data, Analysis and Results as in Fig1. The following sub divisions:

1) Site Measurement Data of Sample Buildings
2) Base Case Simulation Data of sample buildings.
3) Generating façade retrofit for material options.
4) Comparing retrofit options with base case for its performances.
5) Comparing all options for investment cost for the façade retrofit and the cost saving by space cooling energy for a payback period.
6) More returns on investment will be the energy efficient retrofit option

3.1: Data

- Site Measurement Data of Sample Building as in table 1 and fig 2.
- Base Case Simulation Data as in table 1 and fig 2.

Chennai has a tropical wet and dry or savanna climate under the Köppen climate classification as *Aw* or *As* . The city lies on the thermal equator and is also on the coast, which prevents extreme variation in seasonal temperature. The hottest part of the year is late May to early June, with maximum temperatures around 37–41 °C The coolest part of the year is January, with minimum temperatures around 19–25 °C .

In Chennai, after the year 2000 a great demand for IT office spaces increased drastically and the typology of these office building facades were predominantly fully glazed curtain wall (WWR >70 %). The curtain wall systems used in these buildings are considered as substandard today. Six case samples in Chennai were analysed for its envelope performances , each of the sample is only office use buildings, multiple tenants, Electricity load more than 100KW and Annual electrical consumption data is available. Each sample has its own uniqueness and represents the typical typology of façade design of Chennai as in fig 2[15]. Among these 6 samples only 2 samples pass the ECBC 2017 [16] norms as in fig 1.

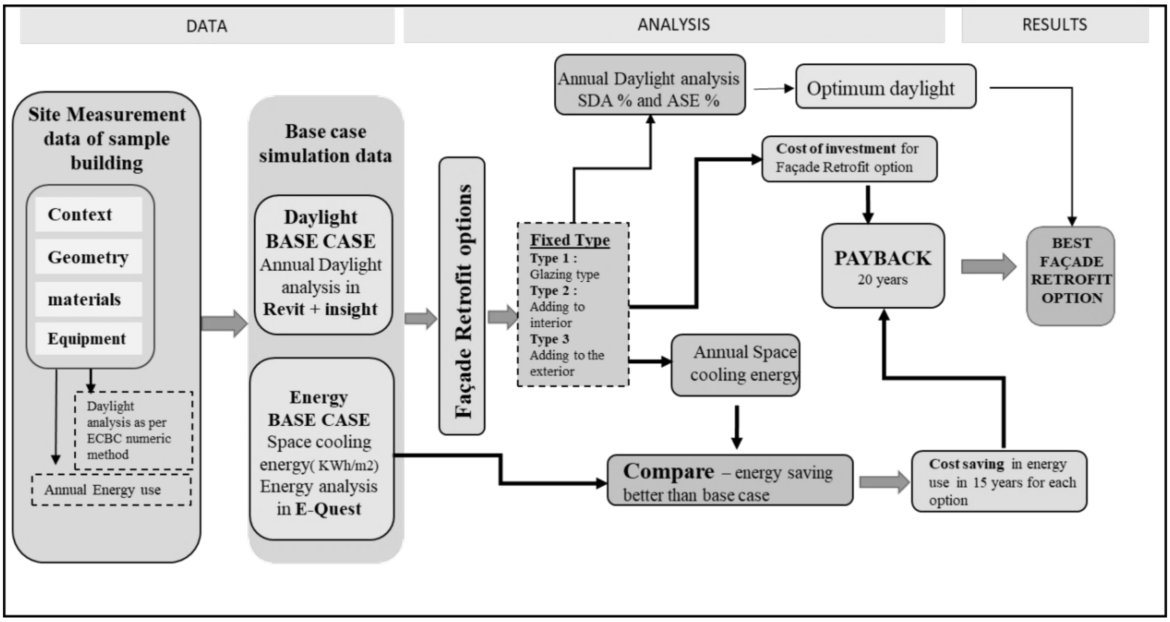

Fig .1: methodology flow chart

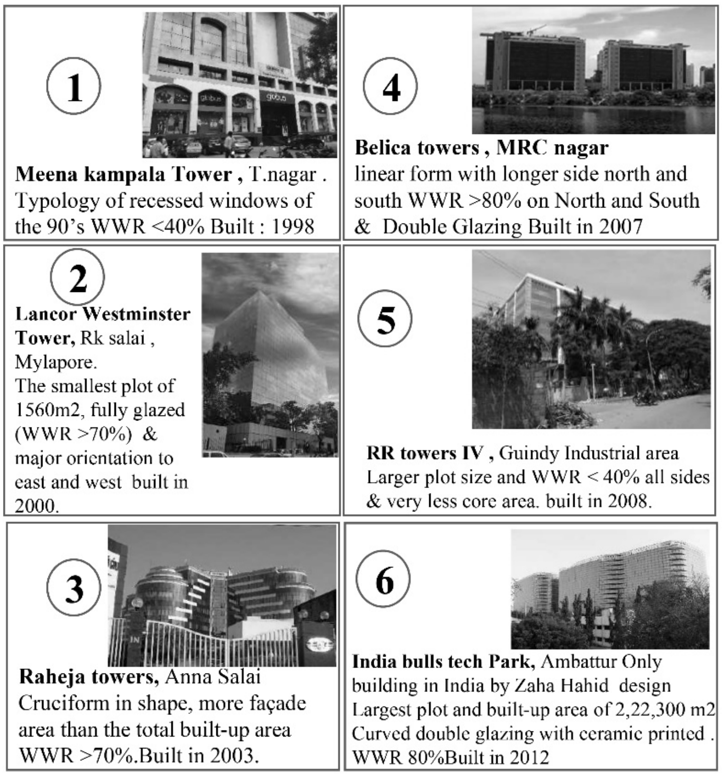

Fig. 2 List of sample buildings from sample 1 to 6 and its location map buildings in Chennai *(Source: autho*r)

The cretreria for selection 2 samples from these 6 case samples are :
1. The Sample 2 and 3 with same façade typology – single reflective glazing
2. Poor envelope performance as per ECBC 17 complainaces
3. Enevlope area % is more than 33% of the total built up area , requires façade upgradation for energy efficiceny. [15] as in table 1
4. Glazing area % is more than 25% of the office area , requires façade upgradation [15] as in table 1
5. WWR % more than 70% as in table 1.

Hence Sample 2 & 3 were selected to understand retrofit strategy and cost benefits and ranked last in the performance from both site data and simulation data [15].

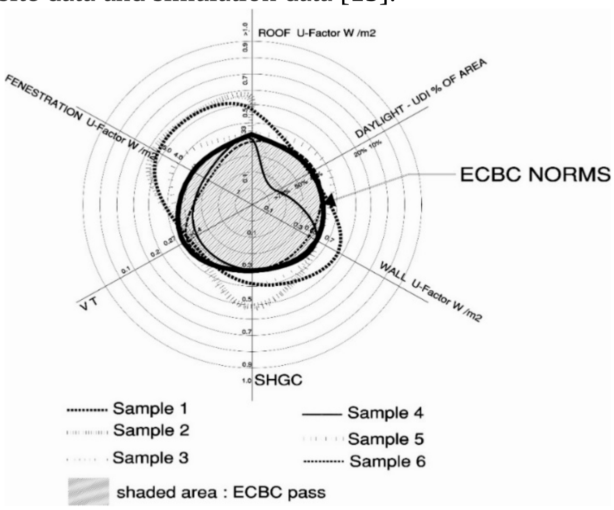

Fig .3 ECBC-17 compliance for mandatory provisions, black line and hatched is the ECBC norms pass zone. Sample 4 and 6 pass the ECBC norms.

These sample are multi storied (>18mts in height), multi-tenant, more than 100 KW use and fully glazed with single reflective glass as in table 1 and Fig 2. The selected samples for the façade retrofit are as:

Sample A: Lancor Westminster tower as small office

Sample B: Reheja Towers as large office

Case Samples

3.1.1 The Lancor west minister tower (sample A)

It is built in a small plot of 1530 m^2, rectangular, longer side east and west and total built-up of 5830 m^2. Energy use intensity (EUI) 546 Kwh/m^2/year of which 451 KWh/m2/year is the cooling load from exiting building data and had the best daylighting performance as per ECBC manual method [16] with HVAC equipment more than 18 years old. Fully glazed façade with a curtain wall system of grid size 1524 x 1030 mm of aluminum frame and 6mm single reflective glass as in fig 2 .

Table 1. Site measurements and simulation data for sample A and sample B.

		Site measurement data	A	B
building level	1	Site area in sqmt - area of the site	1530	13377
	2	Total gross area - sqmt	5830	42123
	3	% Core area : area of lifts, staircase , toilets and other services in one floor	18%	29%
	4	FTF in mts : Floor to floor clear height	2.85	3.05
	5	DOF in mts : Depth Of the Floor from window to window line	18	23
Envelope level		Glazing U- factor	5.1	5.1
		SHGC - Solar Heat Gain Coefficient for glazing	0.53	0.53
		% FA to TBA :Percentage of façade area to the Total Built-up area (TBA)	57%	91%
		% GFA to OFA :Percentage of Glazing per floor (GFA)to office floor area (OFA)	48%	78%
		WWR % Window to wall ratio for total façade area	72%	75%
		VT : Visual transmittance of the glass	0.35	0.35
Energy and Daylight	1	UDI % % 100 - 2000 lux : Manual method as per ECBC (% 100 - 2000 lux : Manual method as per ECBC 17 the window head height for each orientation and multiply by daylight extent factor(DEF) as mentioned in ECBC (ECBC, 2017) for warm and humid climate Daylight extent factor(DEF) for warm and humid climate	61%	47%
	1	Age of HAVC : age of the equipment in years	18	5
	2	EUI Kwh/m2 yr/floor. Energy Use for one floor – daytime and BPO moreover since data was not uniform for all the samples an average is taken	546	130
		simulation data	**A**	**B**
Solar insolation	1	AAIFA - Annual Average Insolation per m2 of floor area - Wh/m2	79	28
daylight	1	SDA % of floor area that receives 300 lux for <50% of the daytime (3650 hours)	69	50
	2	ASE % of floor area that receives >1000 lux for >250 hours	24	12
Energy Use	1	Space cooling energy use Kwh/m2/yr. of the total office floor area	119.7	120.5
	2	EUI - Kwh/m2/yr.	224	195

3.1.2 The Reheja towers (Sample B)

A total built-up area of 42,123 m^2 in 13377m2 plot area, cruciform in shape, north & south as longer wings with core in the center as in fig 2b. The Energy use intensity (EUI) 207 Kwh/m2/year of which 143 KWh/m^2/year is the cooling load, good daylighting performance and HVAC equipment less than

5 years old. Fully glazed façade with a curtain wall system in single reflective glass like the sample A and stepped terrace on the top floors
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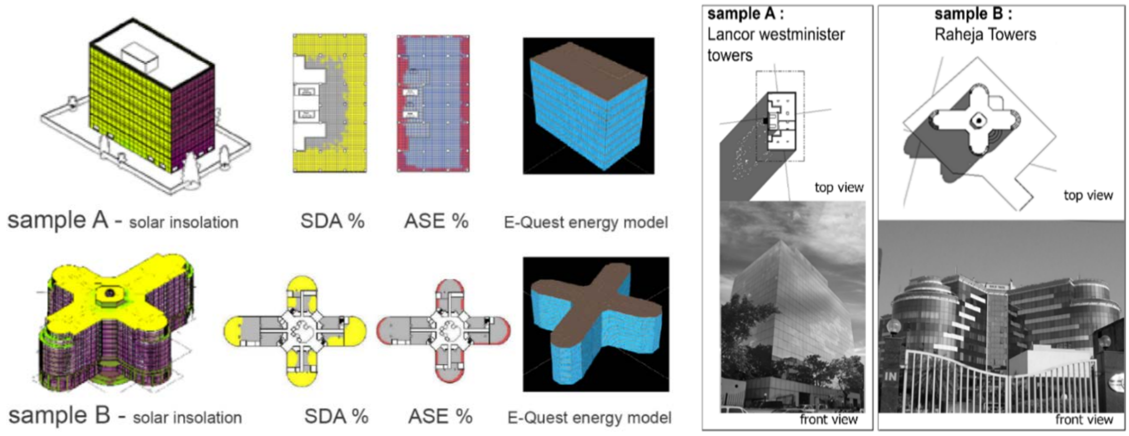

Fig.4 Simulation images of sample A & B for thermal, SDA, ASE and energy model in E-Quest. Plan and view of sample A and sample B

3.1.3 Base case model:

The two case samples A & B are office buildings with WWR more than 70% and curtain wall glazing with 6mm single reflective glazing on panel grid of 1500 x 1000mm . From the site measurements using the same context, geometry, and building materials a base case model created for daylighting analysis in Revit BIM for annual daylight performance such as sDA (Spatial Daylight Autonomy) spacial percentage and ASE (Annual Sunlight Exposure) percentage As in Table 1, fig 2. In E-Quest, the same model is created to get space cooling load results. The base case total EUI of 224 and 195 Kwh/m2/yr and space cooling load of 119.7 and 120.5 for sample A and B respectivly . For energy simulation for both the sample existing glazing is revised with standard DOE-2.2 glass library glazing no 1418 single reflective tinted glass with SHGC 0.48 and VLT 0.25.[17] . The SDA % for sample A is 69% and ASE is 24% which has more glare as the width of the building is only 18 mts. For sample B the SDA is 50% and ASE is 12% as in table 1. One typical office floor area for sample A & B is 467 & 2160 sqmt respectivly and retrofit façade area in south , west and east glazing for sample A & B is 198.4 & 1998.7 sqmt with ratio of GA : OA is 42% and 92% respectively.

3.2 Analysis

Creating a Revit BIM model of the two sample cases using the same context and building materials as the base case to compare.
Facade retrofit models to evaluate these case studies for east, west and south façades only:
Type 1: Glazing material refitting

- By changing glazing type (double glazing (DG), DG frit ceramic print & DG low E).

Type 2: adding to interior of existing glazing.

- Adding solar control film, frit printed on glass / films & interior blinds.

Type3: Adding to the exterior of existing glazing

- By adding fins (vertical, horizontal & egg crate)
- By varying WWR % (50 to 90)
- By integrating shading device (ISD) with perforated fabric: percentage of shading over existing glazing.
- Jalli with 50% perforation

The methodology flow chart is to determine the best facade retrofit option which will have optimum day- lighting, good energy saving and low investment on façade retrofit as shown in fig1.
Daylight analysis – Insight a plug-in for Revit is used as the daylight simulator to get the annual daylight results like Spatial Daylight Autonomy (SDA) and Annual Sun Exposure (ASE) % for all the options of façade retrofit materials and its performance compared with base case samples.

Space cooling analysis : In E-Quest the energy simulation software used for all the types. By changing the envelope type in the detail design wizard of the building shell for the base case simulation energy model.

*Results :*Among the facade, retrofit outcomes, the options that have the optimal day lighting and their energy use results are compared with the base case. For each option, the difference in the cost of cooling load energy saving for 20 years (payback period) by façade retrofit and the investment in the cost of façade retrofit will be the payback. The option with the highest payback will be the best option.

3.2.1 Retrofit Material types *as in fig 5*
All option are applied only to south, west and east curtian panel glazing area only for all three types of facade retrofit materials.

Type 1 : Different glazing types were created such as no 1,2&3 with double glazing

- *options 1:* 6mm clear + 12mm air gap + 6mm reflective double glazing unit. SHGC : 0.23 and VLT :0.18 as per DOE2 glass no 2406 [17]
- *option 2 :* Low e reflective + air gap + 6mm clear SHGC : 0.29 and VLT : 0.41. [17]as per DOE2 glass no 2667.
- *option 3 :* With Firt ceramic print in the inner glass layer can control light transmittance and reduce solar heat gain while enhancing aesthetic and performance characteristics. With 30mm dia frosted pattern in 30% of the glazing area for the same glazing system of option 1 and the revised SHGC as per solar spectra as stipulated in EN 410:2011[18] as DOE2 glass no 2433 with revised SHGC : 0.20

The SHGC of the selected glazing is revised in the glazing type of the building envelope of the base case model in energy efficient measures (EEM) in E-quest for energy analysis and revised material properties of the glass visual tranmittance value in Revit BIM model.

Type 2 : Films / blinds for option no 4,5 & 6 by adding film / layer to interiors

- *Option 4 :* The Film on the glazing has the ability to regulate the penetration of light and heat and also screen out ultravoilet light, whilst posing the least disturbance to the building occupant, However the life of these film is only 5-7 year [19]. sun control film by 3M PR 70 EX would reduce the 6mm single tinted reflective glass SHGC to 0.34 and VT to 25% [20].
- *Option 5 :* Curtains and blinds are a low cost intervention, of which there is limited data available with regards to their in situ performance. A number of laboratory-based studies have been carried out to assess the thermal performance of individual window coverings. Garber-Slaght and Craven [21] suggested that savings of 24–38% were achievable. Analysed in E-Quest and Revit by activating the blinds persets.

Type 3 : adding to the exterior of existing glazing [22, 23] The shading material with aluimuium composite panels in Alu. Frame work with light reflective of 30% is considered in this research.

- *Option no 6 :* overhang of 0.6m, 08.m and 1.0 m depth at 3.2m spacing.
- *Option no 7 :* vertiacal fins of 0.6, 08.m and 1.0 m m depth at 1.0m spacing.

- *Option no 8:* both overhang and vertical fin of 0.6m, 08.m and 1.0 m depth

In E-Quest the cooling load from EEM by changing building envelope components by adding window shades – overhang, fins or both for all the glazed panels

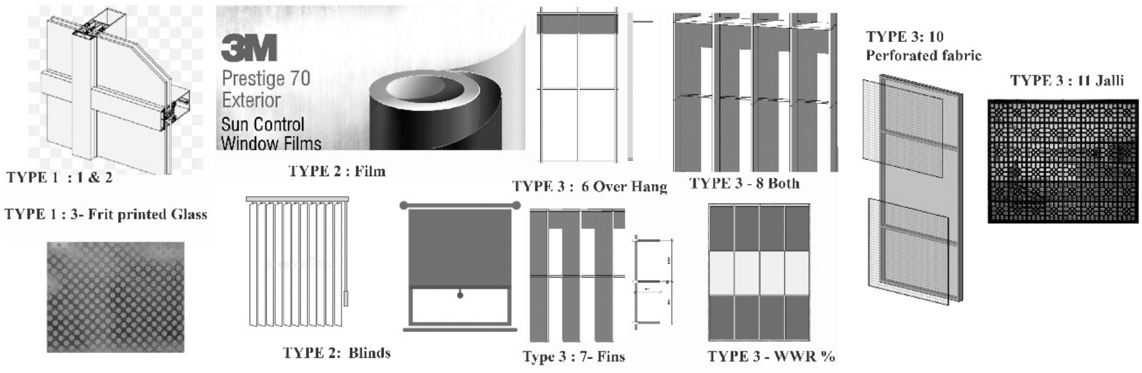

Fig 5 : image of materials types and its option nos.

- *Option no 9 A & B :* Changing of the % WWR option 9 : 50% & Option 10 : 66 % . Created by making few curtian panels with opaque Aluminium composti insulated panels and in EEM with the revised WWR % .
- *Options 10 A & B :* By added a perforated fabric screen in plane with the glazing plane, varying the shading % , option 11 with 80 % of the glazing area coved with perofrated fabric & option 12 as 100%. The *EN 13363-1* method of revised SHGC for fabric to calcuate the thermal radiation on glazing by shading screens, the EN 13363-1 is a simple method to revise the façade glazing SHGC, As the solar screen take the direct , indirect , solar reflcetance , solar transmittance and solar abrobtions. For a given type of solar screen the lab result gives the reduction of the SHGC[24] for specfic glazing type. This research used the Serge Ferrarai tensile façade fabric impulse 800 fabric[25].To calculated the cooling load in EEM of E-Quest by changing the glazing type with revised SHGC values [26] and creating a simlar cut pattern for this material property in Revit BIM model.
- *Option 11 – jalli / perforated wall* - Patterned massive screen shading systems are traditionally applied to vernacular buildings' facades in hot and humid climate zones, These screens are traditionally constructed from stone or massive materials and have geometric motifs and patterns with deeper profiles than lattice or solar-screens. While today with Glass fibre reinforced concrete (GRFC) which are light weight is used with 50% perforattion and width : opening size as 1: 1 ratio [27, 28] solar coefficnet (SC) is used to represent the solar shading performance over a glazing. It is the ratio of the solar radiation that impacts the glazing with and without the use of solar shading; the closer the SC to 0, the more effective the solar protection [29].Based on the SC value the SHGC is revised in E-Quest.

3.2.1 Energy Performance of fixed Retrofit options:

These options performance results are compared with the base case for space cooling energy for both case samples in as shown in table2. The following fixed data input assumptions were assigned for the energy simulation:

- Office space planning : Open office 70%, cubical 20%, conference 5% & reception 5%
- Occupancy rate : 10.5 persons per m^2

- Lighting load : 1 watt / m^2
- Power load : 2 watts/m^2
- Cooling set point : 23.3 ° C
- Analysis area :Office air-conditioned space.
- HVAC Type :VAV single duct system per floor
- Occupancy hours : 9 am to 6 pm for 6 days a week – total 2727 hrs.
- Supply air temp : 12 ° C
- Relative Humidity (RH) : 50 %
- Latent Heat gain /person : 58 W
- Sensible heat gain /person : 73W

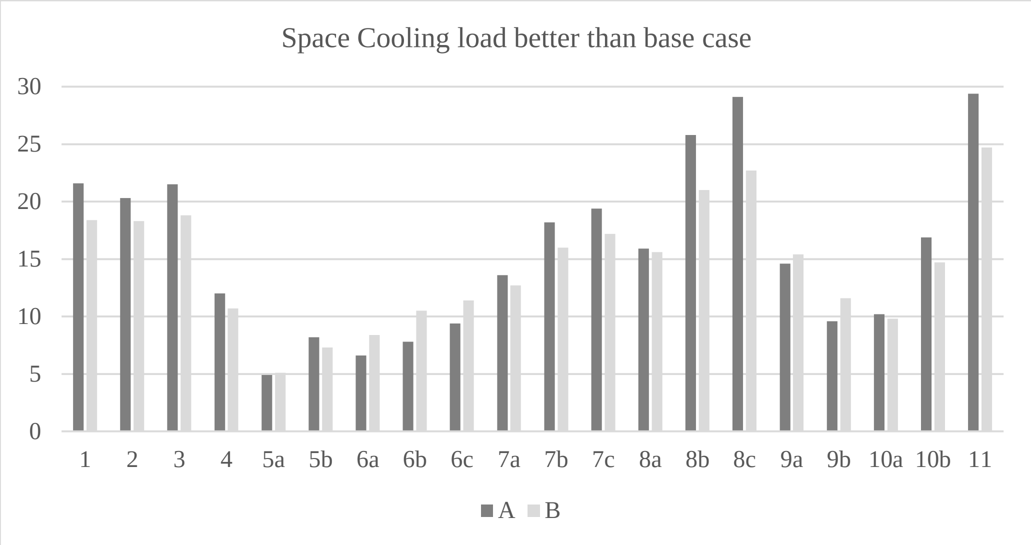

Chart 1: Space cooling load % saving better than base case. For both samples A & B in all options.

3.2.2 Daylight performance by all type of façade material :

From the base case model in Revit BIM the façade elements are created for daylight simulation in Insight - the Lighting Analysis for Revit (LAR) for annual daylighting for all options as in table 2. Annual Spatial Daylight Autonomy (sDA) as per analysis method LEED v4 [28] as preset in LAR , % of floor area that received 300 lux for > 50% of the daylight time of 3650 hours and Annual Sun Exposure (ASE) % floor area that receives more than 1000 lux > 250 hours of 3650 hours. By adding or changing on the glazing system will reduce the SDA% and ASE % to some extent. In this research to filter the better performinng options the reduction or thresold of 20% less the base is considered as optimum performance for both the cases. SDA % for base case sample A is 69 % and sample B is 50%, with retrofit options the thresold for optium performacne is > 54% and >40% for sample A and B repectively as shown in chart 2.

Simulation-based on the following input assumptions:

- internal partitions excluded from the model.
- Default surface reflectance of 80% for ceilings, 20% for floors, and 50% for walls.
- The analysis plane is 0.8 meters.
- Analysis grid is 0.6 x 0.6 m
- 8 am to 6 pm – a total of 3650 hours.
- Sky Component: as per Annual weather data for Chennai.

Table 2: Retrofit options 1 to 11- Annual daylighting and energy performance better than base case for sample A and B

Options	FACACE RETROFIT MATERIAL OPTIONS	SAMPLE A			SAMPLE B		
		% spacing cooling better than base case	SDA %	ASE %	% spacing cooling better than base case	SDA %	ASE %
	Sample A - Existing glazing with Bronze reflective 6mm single glass in 150 x 60 Alu curtain frame SHGC : 53 and VLT 35%	0	69	24	0		
	Sample B- Existing glazing with blue reflective 6mm single glass in 150 x 60 Alu curtain frame SHGC : 0.53 VLT 35%					50	13
1	Double glazing 6mm clear + 12 Air gap + 6mm Reflective	21.6	58	19	18.4	43	11
2	Low-E Double glazing 6mm clear + 12 Air gap + 6mm Reflective	20.3	48	14	18.3	38	11
3	Frit printed Double glazing 6mm clear + 12 Air gap + 6mm Reflective 30mm white dots 30% coverage for 70% of the glazing area	21.5	63	10	18.8	45	8
4	Sun control film with 3M PR 70 EX	12	54	15	10.7	41	11
5a	Blinds - vertical translucent with 80% when occupied	4.9	NA	NA	5.1	NA	NA
5b	Blinds - roller translucent with 80% when occupied	8.2	NA	NA	7.3	NA	NA
6a	horizontal overhang 0.6 m wide	6.6	56	14	8.4	35	10
6b	horizontal overhang 0.8 m wide	7.8	54	12	10.5	33	8
6c	horizontal overhang 1.0 m wide	9.4	52	10	11.4	32	6
7a	Vertical fins 0.6 m wide	13.6	60	16	12.7	41	12
7b	Vertical fins 0.8 m wide	18.2	58	14	16	39.7	11
7c	Vertical fins 1.0 m wide	19.4	54	13	17.2	36	10
8a	Horizontal & Vertical Fins 0.6 m	15.9	54	14	15.6	36	10
8b	Horizontal & Vertical Fins 0.8m	25.8	52	12	21	32	9
8c	Horizontal & Vertical Fins 1 m	29.1	48	11	22.7	30	8
9a	50% WWR	14.6	35	12	15.4	32	8
9b	66% WWR	9.6	44	14	11.6	38	9
10a	Perforated fabric shading for 80% of the glazing area	16.9	60	17	13.8	44	9
10b	Perforated fabric shading for 100 % of the glazing area	18.7	56	15	16.2	42	8
11	Jalli with 50% perforation and 1: 1 ratio of opening size to depth	29.4	51	10	24.7	38	6

3.2.4 Observation: As in table 2 , chart 1, 2 & 3

- Type 1 : All glazing option 1, 2, & 3 have 18-22% energy saving in both the samples
- Type 1: option 3 Frit printed glazing has the best daylighting performance and energy saving of 22%
- Type 2 : Adding sun control film would reduce the space cooling load by 10-12 % and cuts the glare.
- Type 2 : adding blinds to the interior have the lowest energy saving of 5% and day lighting analysis is not consider as it is controlled manually.
- Type 3 : option 6 energy saving by adding Over hang is 8-12% lower than vertical fins and both as in E-

quest over hang is added at the roof level only, were as the vertical fins area placed at a spacing of 1.0m.

- Type 3 : option 6 SDA% is lower than vertical fins and both
- Type 3: option 7 Veritical fins with good energy saving 12 -20% depending on the depth
- of the fins in both the samples and good Day lighting performance
- Type 3 : option 8 Both or Eggcrate type of fins have the highest energy saving of upto 30% but the poor daylighting performance for sDA % of less than 20% than the base case for both the samples.

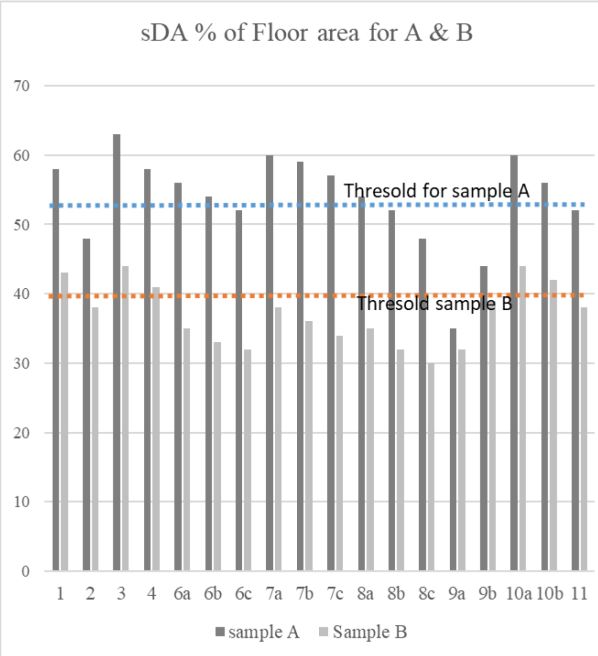

Chart 2 : sDA % for all option for A & B

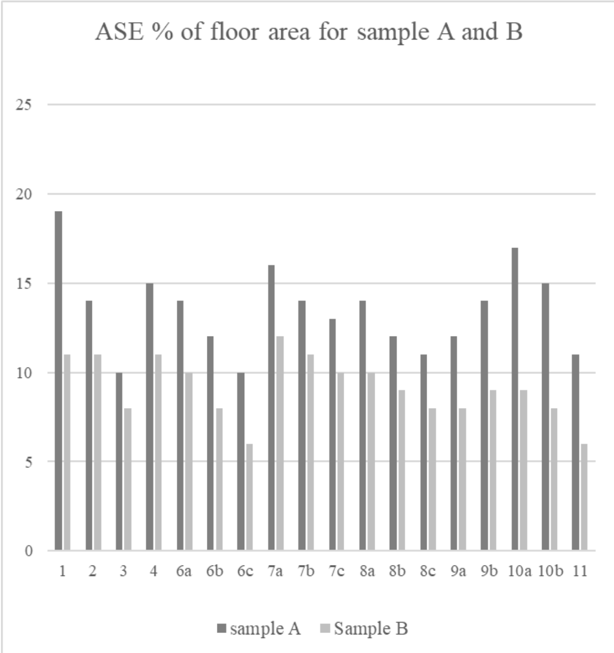

Chart 3 : ASE % for all option for A & B

- Type 3: over hang and fins daylighting performance can be incresed by changing the shading materials with more reflective % or transparency %
- Type 3 : option 9 , energy saving by reducing the glazing area is only 15% and daylighting is reduced to 50% of the base case results, which makes this option to be remove from payback results..
- Type 3 : option 10 could save energy up to 17-19 % and good daylighting results as the visual transmittance (VT) for the selected fabric is 0.3. [25].
- Type 3 : option 11 GFRC Jalli with maximum Energy-saving better than base case of 25-30% for sample A and B but SDA % low by 25% than the base case .

3.4 Payback in 20 years:

Cost concerns are major basis for façade retrofits and this research focus on the initial cost of implementation and future energy savings as paybacks; however, they lack in accounting for the indirect benefits that occur from improved façade performance [10]. The return on façade retrofit investment should be clear to the entire stakeholder as the case samples are multi-tenant/ owner, in order to make a retrofit a successful energy saving strategy. The investment cost for each façade retrofit material option is divided to the total office area to get the investment per sqmt of office, the 20 years cost of total energy saving in space cooling load for the office area is taken and the difference will be the payback for that as in table 3 and Chart 4. The best option with maximum cost saving will be with the best payback. The cost for façade retrofit material option is based on Central public works department approved rates and façade contractors, the electricity cost from TNEB for commercial connection of Rs.8 per KWh.

4. Results and Discussion

While comparing the results for both A and B samples , it was observed that the sample B with facadea area is 92% of the office floor area, the retrofit payback is less for all the option compared to sample A. Options 9 do not perform the optimum daylighting required; hence, it does not qualify for payback analysis

- More payback for sample A than sample B since the glazing area to office area is only 50% compared to sample B as in table 1
- Very less or no payback on glazing types as the investment is higher than the energy saving.
- Type 2 , adding blinds / film in the interior have payback for sample A and no payback for sample B, more over the life of the film / blinds is less than the payback period.
- Good payback on shading fins option 5 & 6 as the investment is low and energy saving is better for both the samples.
- Less payback on option 8 as the material for egg crate shading fins is more compared to vertical fins or overhang.
- The preforated fabric have better payback with good daylighting perforamce for sample A and no retrun for sample B as the retrofit façade area is more.
- The maximum payback was the options 11 GFRC jali , these are light weight opaque panels , by changing the material properties and finishes the daylighting performance can be improved.

Table 3: façade retrofit material cost for one typical floor area and cost of space cooling energy saving for the payback period in sample A and sample B

Options no	FACACE RETROFIT MATERIAL OPTIONS	cost per sqmt	SAMPLE A		SAMPLE A	
			cost per sqmt of floor area	20 years energy saving cost /m2	cost /m2 of floor area	20 years energy saving cost /m2
1	Double glazing 6mm clear + 12 Air gap + 6mm Reflective	9500	4036	4137	8788	3548
2	Low-E Double glazing 6mm clear + 12 Air gap + 6mm Reflective	11000	4673	3888	10175	3528
3	frit printed Double glazing 6mm clear + 12 Air gap + 6mm Reflective 30mm white dots 30% coverage for 70% of the glazing area	12400	5268	4118	11470	3625
4	Sun control film with 3M PR 70 EX	2550	1083	2298	2359	2063
5a	Blinds - vertical translucent with 80% when occupied	1400	595	938	1295	983
5b	Blinds - roller translucent with 80% when occupied	2250	956	1570	2081	1407
6a	horizontal overhang 0.6 m wide	2520	335	1264	718	1620
6b	horizontal overhang 0.8 m wide	3360	446	1494	957	2024
6c	horizontal overhang 1.0 m wide	4200	557	1800	1196	2198
7a	Vertical fins 0.6 m wide	2520	1003	2605	2153	2449
7b	Vertical fins 0.8 m wide	3360	1338	3486	2870	3085
7c	Vertical fins 1.0 m wide	4200	1673	3715	3588	3316
8a	Horizontal & Vertical Fins 0.6 m	3360	1427	3045	3108	3008
8b	Horizontal & Vertical Fins 0.8m	4480	1903	2796	4144	4049
8c	Horizontal & Vertical Fins 1 m	5600	2379	1839	5180	4377
10a	Perforated fabric shading for 80% of the glazing area	3850	1636	1954	3561	1889
10b	Perforated fabric shading for 100 % of the glazing area	5100	2167	3237	4718	2834
11	Jalli with 50% perforation and 1: 1 ratio of opening size to depth	4000	1699	5631	3700	4762

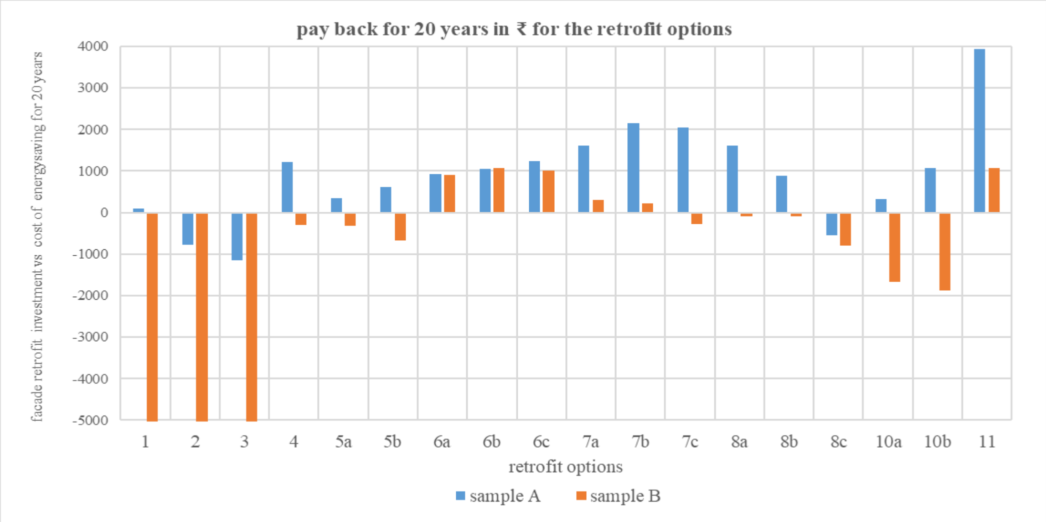

Chart 4.0 Façade retrofit investment VS payback for all option in sample A and B.

The selection of façade retrofit material for energy efficiency is based on this two case sample buildings only , In a differnent climatic context, shape, orientation , WWR % , façade type the material performance and payback would differ , Hence a climatic based simulation is necessary for early stage of façade retrofit decision.

5 Conclusion

The transpernt architect wih fully glazed office building built in 2000 and even now require careful selection of façade material , especiall glazing type as the evergy saving is than 15%. Before selecting the façade material, passive energy efficient strategies for shape of the building, orientation , WWR % for each orientation and the ratio of glazing to office area are important factors.

By retrofit, we can reduce the space cooling energy use by 25 -30% for both the size samples in the same context & glazing type but with different geometry. Among the retrofit option used in this research the return on investment on glazing types like the option 1, 2 & 3 is low since the cost of the façade retrofit is high and the payback is almost nil, moreover it would also interrupt the building occupant's workflow. By adding to the interior like blinds or film the energy saving is the lowest and life is also less, however they are easy to install at lower cost of investment. By perforated fabric shading screens & Jalli over the existing glazed facade, we can save 15% to 25% on space cooling energy use and it is the best thermal , light weight and good payback. Moreover, they do not interrupt the building occupant's workflow during the façade retrofit process. This simulation method will help the owners/ promoters to decide the materials and methods at the early stage of retrofit design stage for energy efficiency with better payback.

The approach of performacne based retrofit stategy is a clear understanding for the process of retrofit to all the stakeholders , however this study doesn't include the active actions. The proposed passive actions can only save a part of the space cooling energy use, but it might not be very feasible to rely only on passive strategies, the combined strategies need to be considered in the future studies and more innovative materials and methods should be adopted. Furthermore, it is required to create complete data of life cycle energy use, operational costs, environmental impact like CO_2 emissions, and etc for these existing fully glazed buildings for retrofit.

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