Heating and Cooling Application in Energy Efficient Buildings using Trombe Wall: A Review

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ABSTRACT

Solar energy-based applications increase in recent days because of renewable energy, pollution free, no fuel cost. For building related application solar energy used for heating and cooling purpose which by Trombe wall medium. Generally, most power consumed inside of every building for HVAC system. Heating and cooling load increases day by day due to climatic change and also increase of emission indirectly. So, the Trombe wall integrated building to reduce energy usage, operational cost and emission. This paper reviews on different Trombe wall methods, experimental and numerical analysis in recent years. The Trombe wall's seven different thermal storage parameters are analyzed and determine its impact on energy usage, economy, and environment. This review helps to understand the Trombe wall technology and design a building with Trombe wall in an economic way.

Keywords: Building Sciences; Trombe wall; Heating and Cooling.

Abbreviations

| Abbreviation | Description                        |
|--------------|------------------------------------|
| TW           | Trombe wall                         |
| HVAC         | Heating, Ventilation and Air condition |
| WTW          | Water Trombe wall                   |
| TMW          | Trombe Michel wall                  |
| TC           | Thermo catalytic oxidation          |
| PC           | photocatalytic oxidation            |
| MnOx-CeO₂    | Manganese oxide + cerium oxide      |
| PV           | Photovoltaic                        |
| BIPV         | Building-integrated photovoltaic    |
1. Introduction

Globally every year population increases tremendously; it makes an increase in usage of power, which creates energy demands. From total energy production around 40% of energy utilized by buildings [1-3]. In the building territory major of power consumed by HVAC which means heating, ventilation, air condition. HVAC mainly used in buildings for indoor thermal comfort, regulate air quality and maintain humidity. Buildings-related application 85% energy has been utilized only by HVAC system [4-6]. So, buildings are expected to design using renewable energy alternatives of fossil fuel power for heating and cooling application. In passive heating and cooling method helps to reduce of energy demands. Varies methods related to building architectural solar chimneys [7], passive wall [8], natural ventilation, solar roof [9], solar façade [10], Trombe wall, etc which are used. We discuss Trombe wall methods, which also called a storage wall or thermal wall or heating wall. Trombe wall be simple in structure, high efficiency, eco friendly and mainly pollution free method. It reduces of annually energy usage of power around 25%. The idea of paper is review on Trombe wall method used in buildings for the application of heating and cooling. Some review articles related to Trombe wall, different heat transfer medium, experimental work, numerical study, characteristics are discussed. Wang et al. (2020) review on different methods of Trombe wall technology concern in the building application. Research been carried out on several reference article from 2001 to 2019. Article well defined on technology involved on Trombe wall, modelling, experimental analysis, evaluation and also materials, structure, functions are discussed. Summary of Trombe wall concept help on for feature development, research purpose and improve of current trends [11].
Hua et al. (2020) write up the relevant topic on Trombe wall methods execute on resent fifteen year. Generally, exploit the Trombe wall in two methods which are cooling methods and heating methods. Three different parameters study (Trombe wall, site, building) been analyzed and three assessment point on environment, energy and economic in Trombe are been explored. Acritical mainly discusses of Trombe wall area, wall materials, glazing properties, insulation and analysis its performance on different perspectives [12]. Du et al. (2020) study on air flow analysis in Trobe wall to improve of building ventilation and most importantly it helps to improve indoor temperature and air quality. Air velocity of Trombe wall mainly focused on materials, structure and temperature. Velocity of air flow in storage wall boundary be faster and controllable. So, width of Trombe wall must be in boundary line. Height of Trombe wall increase which tends to increase of air velocity flow. Air velocity can be controlled by wall height. Result validate that size, temperature, structure makes benchmark the air velocity [13]. Dabaieha, Serageldin design a building with passive cooling and heating method to reduce of usage grid energy. Three passive methods Trombe wall, earth air heat exchanger, green wall is designed to implement the renewable energy in building. Result show that reduce of heating load around 7.9 kWh/m² per annum, cooling load close by 2.8 kWh/m² per annum. Using of passive method which reduce of CO₂ nearby 232.1 kg CO₂e per annum and show of payback period around 7.4 years [14].

2. Classifications of Trombe wall

Generally, Trombe wall constructed with buildings for heating the air fall on its surface, heat storage. Many researches tangled on Trombe wall and designed various methods. Different heat transfer medium, different heat storage material, structure which are involved in Trombe wall system. Different classification complex with Trombe wall listed in fig 1.

![Classifications of Trombe wall](image)

**Fig. 1.** Classifications of Trombe wall
2.1 Classical Trombe wall

Classical Trombe wall is a simple and basic type method. First patented by Edward Morse in the year 1881 [15] and this type of wall named as Trombe wall by Jacque Michel and Felix Trombe in 1967 [15]. Wall designed with glazing, air space, storage wall, and vent. Glass is used to transmit solar radiation, storage wall used to store heat, air space used for heat indoor air to make density different, vent used for circulating indoor air. Many modified methods for classical wall designed and constructed. Zhou et al. (2020) investigated different Trombe wall with traditional wall and thermal performance. First setup water wall paced between glass cover and composite wall (solar coated), Second wall setup water wall place directly to sunlight (WTW). Water wall covered with PC cavity made up of semitransparent sheet and filled with water. Result which 3.3% of thermal efficiency is high on WTW compare to traditional wall. On night heat loss from building reduced directly by low temperature water, which 33% heat loss reduced compared to normal Trombe wall [16]. Ma et al. (2018) design a Trombe wall room that adds more windows and insulation to increase storage capacity (heat storage). In this study to reduce heating load in air-conditioned room using air circulation system from Trombe wall.

Trombe room placed south facing shown in fig 2, collect heat and stored inside which insulation on wall will reduce heat loss. The air from Trombe wall is sent to air-conditioned room by air channel and outdoor air pass over air channel. Heat exchanger method room get heated and reduced heat load. Also noted that heat on Trombe wall remains high after heat recovered from the room [17]. Long et al. (2018) design a Trombe wall to produce thermal comfort inside the building on two season winter and summer. Solar flat plate collector placed between glass cover and massive wall. Massive wall which thermal reflector attached facing outdoor and radiation panel attached facing indoor. In summer season, collectors will heat water and use for domestic purpose, in addition, thermal reflectors will help for more insulation to a massive wall to maintain low temperature. On winter stored hot water circulated to radiation panel and provide thermal comfort. Result which heat transfer and insulation of wall is controlled on varying collector temperature [18]. Özdenefe et al. (2018) design a Trombe wall size to improve of economic viability, energy consumption and thermal comfort. Living room integrated with Trombe wall and tested by varying wall thickness by 6.0m² to 16.2m². Result which in winter season fully insulated building with TW gives better economic viability and without insulated building, required to increase TW size above 9m to thermal comfort. The summer season required additional cooling load due to TW's present but economic viability achieved only in insulated building. Thermal comfort, economic viability is achieved by varying TW size [19].
Briga-Sa et al. (2017) determine thermal performance of Trombe wall for different conditions like Ventilation and occlusion device. Experimental and analytical result are compared on temperature, heat flux and air velocity. Result which external wall surface reach above 60°C when occlusion device is removed and if its fixed temperature will below 30°C. When ventilation opening is closed, 3 times of normal heat required to reach inner surface and air flow rate on ventilation bottom to top around 0.10 to 0.30m/s. On this analysis thermal performance of parameter are been determined [20]. Corasaniti et al. (2017) design three different Trombe Michel wall configuration to analysis energy and exergy between them. Three configurations are TMW with sharp edge, TMW with round edge and TMW with guided flow which placed between glazing surface and massive wall. Comparing three configuration guided flow has narrow air flow channel and recirculation at the bottom negative on heat transfer. Three configuration makes equal heat transfer but guided flow makes heat transfer quickly, so guided flow takes good exergy and energy gain [21]. Hu et al. (2020) design a novel water blind Trombe wall which used for space heating, ventilation and domestic water heating application. Many microchannel tubes are placed between glazing and Trombe wall connected to the water storage tank shown in Figure 3. In summer season water blind block radiation and heat water for domestic application which reduces indoor air temperature. Result which it reduces overheating in summer season and thermal efficiency achieved around 20 to 60% during non-heating season, 30 to 50% during heating season [22]. The Classical Trombe wall are summarized in table 1.

Fig. 2. Indoor Hot Air circulation system in winter
2.2 Air Purification type Trombe wall

In this type wall used to heat indoor air and at the same time used for air purification. Thermo catalytic oxidation (TC) and photocatalytic oxidation (PC) are integrated with Trombe wall and used for air purification. Yu et al. (2017) determine net zero energy towards a building using novel Thermal catalytic layer with Trombe wall (TC-TW). Using TC-TW dual function is achieved which are Space heating and indoor air purification. Two main things: catalytic and formaldehyde gas (degradation gas) are used for space heating. Catalytic was a mixture of MnOx-CeO2 and deionized water and coated on TW. Solar energy heat over the catalytic layer, formaldehyde gas pass over on it and get thermal catalytic oxidation. Result which pure air circulated to indoor and space heated which the volume of purified air about 249.2 m³/day. Total energy saved about 97.4 kW h/m², on space heating about 64.3 kWh/m² and formaldehyde gas degradation about 33.1 kW h/m² [23]. Yu et al. (2018) design new Thermal catalytic Trombe wall (TC-TW) to increase air purification and reduce thermal load compare to existing method. Convectional TC-TW reduce of indoor thermal load by 28.3% and air purified up to 8328.7 m³/m² volume. New design introduced thermal insulation layer on TW which structure formed like sandwich. The sandwich method achieved an increase in the percentage of thermal load reduction and air purification of about 34.9% (10068 m³/m²) and 20.9%. (270.6 MJ/m²). At 20mm thickness of thermal insulated wall provides energy savings and thermal comfort to an indoor side [24].

Yu et al. (2018) design a novel Photocatalytic Trombe wall (PCTW) to reduce heating load and at same time air purification (formaldehyde indoor air). Catalytic layer (TiO₂+Na₂SiO₃·9H₂O) coated on inside layer of glass cover which absorbed ultraviolet rays for oxidation and other two rays falls on massive wall which used for room heating. The result of which normal conventional TW gives load reduction by 246.7MJ/m², PCTW achieved high load reduction of about 309.97 MJ/m² and air purified about 4765.9 m³/m² [25]. Yu et al. (2019)
design a Trombe wall on integrating photocatalytic and thermal catalytic methods (PTCTW) for thermal load reduction and air purification shown in fig 4. PC coated on glazing. It absorbed ultraviolet rays and TC coated on Massive wall surface, which absorbed visible and infrared light used for space heating and formaldehyde degradation. Result air purification on the PC Trombe wall, TC Trombe wall and PTC Trombe wall about 4764.9 m$^3$/m$^2$, 6608.9 m$^3$/m$^2$ and 9482.2 m$^3$/m$^2$ and thermal load reduction about 309.8MJ/m$^2$, 204.7MJ/m$^2$ and 296.1 MJ/m$^2$ [26].

![Schematic diagram of PTC Trombe wall](image)

Fig. 4. Schematic diagram of PTC Trombe wall

Wua et al. (2020) design a multifunction Trombe wall for air purification, power generation and thermal comfort on same time. Integrating of Photocatalytic layer (PC), Photovoltaic panel (PV) with Trombe wall (TW) shown in fig 5. PC placed at the outer side, observing UV for air purification, PV panel attached with Trombe wall, which receives energy and generates power. Air from indoor circulate through air channel which collect excess heat on PV panel (Chimney effect). Combined performance of PC-PV-TW which increase of overall efficiency when it compares to individual performance [27]. Wua et al. (2020) determine Trombe wall's operating condition on air purification and thermal performance. Photocatalytic integrated with Trombe wall (PCTW) and efficiency rate compared by different solar intensity and width for air purification. Result which thermal efficiency increase with increase of intensity but it makes reduce of air purification. Thermal efficiency and air purification rate achieved 52.98% and 2.91 μg/s [28]. Clear view of air wall is briefed in table 2
2.3 Venetian blind with Trombe wall

Generally venetian blind used in windows for blocking lights and lighting also can be controlled by vary its angle. Like same venetian blind used with Trombe wall for shading to control indoor air temperature. Hong et al. (2014) investigated a Trombe wall with venetian and discuss on its thermal performance and flow rate by varying position. CFD simulation result compared with experimental result on varying venetian blind positions, inlet and outlet vent duct and airduct width. Thermal performance increase on varying venetian from 0.04 to 0.09m and fall down after 0.09 so it fixed at 0.09m. Inlet and outlet vent thermal efficiency fall down on after 0.06m so it fixed (0.10 x 0.60m) height, width and thermal efficiency on air duct vary up to 0.14m and it get fall after 0.14m, air duct fixed at 0.14m [29]. Hu et al. (2015) investigated Trombe wall, which integrated with venetian blind for thermal comfort during summer and winter. Small DC fan placed at the bottom of massive wall, glazing, venetian blind, and top vent is shown in Figure 6. In winter season Fan at off condition, venetian slat angle varying about 0°,45°,90° shown in fig 7 and result which angle 45° makes thermal comfort in indoor. On summer season comparing of two room at air temperature of 22°C,24°C,26°C on temperature difference 1.95°C,1.71°C,1.71°C. Fan on condition maximum thermal gain in the room about 3.66×10³KJ for 8 hours, result shows structure makes thermal comfort at high efficiency [30].
2.4 Photovoltaic Trombe wall

In this method Photovoltaic panel or PV cell integrated with Trombe wall. Functions are to heat the storage wall and generating power at same time. PV panel placed at different position like outside of glass, between glazing, massive wall and attached with massive wall. Main advantages be reduced of overheating issue. Generated electricity can be used for house hold applications and at same time indoor temperatures are controlled. Many authors focused on PV with Trombe wall and below articles discussed are summarized in table 3. Hu et al. (2017) study on three different Building integrated photovoltaic (BIPV) with Trombe wall (TW) for cooling and heating system. BIPV with glass TW, BIPV with mass wall and BIPV with blind TW which three system is shown in fig 8. Result which electrical aspects BIPVBTW and BIPVGTW gives same value which 1.2 times higher than BIPVMTW. Cooling load reduced by BIPVGTW, heating load reduced by BIPVBTW and BIPVMTW. Overall electrical efficiency saved about 42% on BIPVBTW method [31].

Hu et al. (2017) design angle and flow rate for photovoltaic blind integrated Trombe wall (PVBTW) and compared with another existing method (PV glazing TW, PV mass integrated TW). Varying different flow rate and angle to check its thermal and electrical performance. Angle 50° and flow rate 0.45m/s are final efficient value for PVBTW. Electrical aspects glazing TW get lead and Overall efficiency combine of heat gain and electrical aspects PVBTW is high about 14.5% compare to PVGTW and 14.1% compare to PVMTW [32]. Ahmed et al. (2019) design a Photovoltaic panel integrated Trombe wall with porous medium, DC fan and glass cover shown in fig 9. This model PV-TW with porous medium and DC fan makes good efficiency and in addiction glass cover increases internal temperature. The result is that design with DC fan and porous medium reduces PV temperature and increases room temperature at the rate of thermal and electrical efficiency of about 13% and 4%. When glazing added with system which increase panel temperature which makes efficiency down but increase in thermal rate. Thermal and electrical efficiency around 20% and 0.5% [33].
Irshad et al. (2015) investigated Trombe wall, which integrates with Photovoltaic panel for cooling load reduction and improves PV efficiency. These three different glasses cover Single layer, double layer and double layer with argon gas used, and varying air velocity to increase air flow at indoor. Result which double layer with gas method reduce PV temperature and reduce cooling load. Air velocity at 1.75m/s gives more efficiency in double glass PV-TW compare to single glazing [34]. Jie et al. (2007) demonstrate simple integration of Trombe wall with PV panel (PV-TW) to increase room temperature and at the same time power generation. Fenestrated
room which wall are designed to act as heat storage and one side covered with PV panel with Trombe wall. PV panel generated power and glazing which transfer heat to thermal wall to increase room temperature. Fenestrated room compared with the normal room with a storage wall increases 7.7°C temperature and electrical efficiency of about 10.4% [35].

Lin et al. (2019) design Middle photovoltaic Trombe wall (MPVTW) and thermal and electrical performance are evaluated and compared with External PV Trombe wall (EPVTW). In the MPVTW section PV panel placed between glazing and massive wall, indoor cool air flow over it to get heated. Result which MPVTW gives electrical and thermal efficiency about 12% and 38.2%, EPVTE gives 14.5% as electrical and 27.9% as thermal efficiency. Overall efficiency of MPVTW is high then EPVTE about 10.83% [36]. Taffesse et al. (2016) design a semitransparent photovoltaic panel Trombe wall (SPV-TW) for thermal load reduction in winter season. PV panel design in the form of transparent glass for heat transfer to make thermal comfort, thickness of Trombe wall and packing factor also improves efficiency. PV panel direct method which by convection and indirect method by conduction heat will transfer to massive wall and stored, in night time massive wall heat air inside the room. In addition, wall thickness and packing factor are optimized about 0.4m and 0.25 for better thermal comfort [37].

Koyunbaba, Yilmaz (2012) determine Trombe wall performance by integrating single glazing, double glazing and semi-transparent PV. Trombe wall with three glazing method tested on winter season and evaluated through CFD software. Findings which double glazing provides insulation on night times and single glazing provides heat storage on massive wall. So single glazing with shutter provides better thermal storage performance, power generation at day period, and act as insulation at night [38]. Li et al. (2019) design a novel hybrid photovoltaic panel integrated with precast concrete façade (PVPC façade). The concrete wall is mounted with PV module, insulator, EVA, aluminium plate, and steel plate constructed and fixed. Experiment conducted by numerically and simulation and result are been validated. Output gives that 62.56kWh/m² power generated approximately per annum. PVPC made temperature different at inside and outside by 16°C on summer and 35.03°C on winter. Novel design makes cooling to buildings approximately 64.34 kWh/m² power saved per year [39]. Luo et al. (2019) Study on cooling/heating to a building by net zero energy buildings concept by introducing a double zero design integrated with thermoelectric. First zero type zero heat loss/gain on the building and second zero type, power consumption to satisfy first zero. In first type TE produce heating/cooling from PV panel power and battery unit, second type power and battery are controlled and optimized by model predictive control. Result that non optimized first zero type makes high energy savings about 72% to 92% (cold region), 88% to 100% (mixed region) [40].

2.5 Electrochromic wall

Electrochromic wall generally similar to the classical wall except of glazing cover. Electrochromic glass cover fixed at outer side of buildings shown in fig 10. Electrochromic property provide shading on summer season to protect from overheating and it reduce cooling load. Pittaluga (2013) design electrochromic Trombe wall for two season winter and summer shown in fig 11. Experiments are conducted on two different seasons compared to three different models like traditional TW, glazing with TW and electrochromic with TW. Electrochromic (EC) sheet used for two season which it has solar transmission factor. In the winter season EC will be
inactive, allowing sun energy to heat the wall and during summer season EC will be active, so it acts as reflector and prevents indoor from overheating. The result is that EC gives a higher energy saving method of about 29.5% compared to glazing with TW and 17.6% compared to traditional TW [41].

**Fig. 10** Electrochromic glass cover at on state

2.6 Trombe wall with PCM

Massive wall has a limit of thermal energy storage capacity. It stores capacity up to sensible heat. Increase of storage capacity by introducing PCM in Trombe wall. PCM Trombe wall working is like a classical wall but has high thermal storage capacity (Latent heat). Combine of PCM with TW increase heat transfer and improve thermal comfort. Zhou et al. (2018) demonstrate a thermal performance on Trombe wall with phase change material in summer and winter season. Dual PCM board is integrated with outdoor PCM coated with high reflectivity/absorptivity and second PCM placed at the indoor side with active pipes. On low temperature natural cooling will absorbed by exterior PCM and transfer by conduction method to
interior PCM to cool indoor. During winter season exterior PCM store heat on day time and transfer through air channel to heat indoor air. Energy store and energy release efficiency improved about 10% in summer and 13% in winter [42].

Gracia et al. (2013) determine the thermal performance of ventilated (DSF) double skin facade with PCM for heating a building in winter season. Ventilated DSF operated at three different methods which are free floating (works on natural ventilation mode which not use of HVAC), Controlled temperature (required electricity to operate heat pump), demand profile (operate on both mechanical and natural ventilation mode which controlled by timer). The result is that DSF with PCM provides indoor temperature on severe and mild winter season and free-floating method makes better thermal comfort than other methods [43]. Kara and Kurnuc (2012) determine function of Novel triple glass (NTG) with phase changing materials (PCM) for space heating applications shown in fig 12. Two PCM material which GR35, GR41 are coupled with NTG and compared. NTG is used as glazing, on summer season it protects PCM from overheating and in winter season it reduces heat loss and increase heat storage. Result which overall efficiency varies between 20 to 36% and NTG about 0.45 to 0.55 and GR45 PCM provide high thermal comfort compare to GR55 [44].

Li and Chen (2019) design a thermal storage Trombe wall using the PCM encapsulated powder capsule to reduce power consumption in the building. Proving thermal comfort inside the building, novel heat storage using PCM capsule arranged in porous layer and which are compared to without PCM porous layer. In daytime PCM inside the capsule melt and stores the heat. On night capsule will release heat to produce thermal comfort inside the building, resulting in efficiency reaching around 20% for without PCM and PCM encapsulated powder capsule gives high about 76.2% [45]. Luo et al. (2017) determine the PCM wall for building comfort on winter and summer season for a whole year. It operates on four modes which are passive solar heating,
solar cooling, heat preservation and insulation. In summer day time heat insulation mode, indoor, mid-layer vent closed and outdoor door two vent are opened so it prevents indoor temperature, night time passive cooling mode which indoor vent closed and both mid, outdoor vent open so it makes PCM temperature down, PCM cool the indoor by conduction. On winter outdoor vent closed, middle and indoor vent opened. Aluminium absorber plate heat indoor air and stored in PCM, also heat the indoor. Night time all vent closed and by conduction method PCM transfer stored heat to indoor to produce thermal comfort [46]. Sun and Wang (2016) design a novel passive solar collector storage wall with PCM to increase heat transfer to a building. PCM wall designed for increase heat storage capacity to maintain temperature difference. The result of PSCSW with PCM increases indoor room temperature, and thermal storage helps maintain air temperature during winter. Increase the room temperature around 5°C compare to normal room temperature [47].

Li et al. (2019) design a Trombe wall with PCM to produce thermal comfort at indoor on both summer season and winter season. Two PCM layers separated by insulator attached to the concrete wall with upper and lower vent are shown in Figure 13. In summer season two went close, outer PCM layer resist heat and protect from overheating. On winter season vent opened, indoor air circulated to air channel to increase air temperature and inner PCM layer help to maintain indoor air temperature. Result with Trombe wall with PCM provide thermal comfort for whole year [48]. Leang et al. (2017) determine the Trombe wall's thermal storage capacity to maintain indoor from overheating and cooling. First Concert Trombe wall designed and it compared with microencapsulated PCM. The result is that the PCM Trombe wall contains high heat storage capacity (latent heat) and provides thermal comfort for a large period of time compared to the class wall [49].

![Fig. 13 PCM Trombe wall a. Summer, b. Winter](image-url)

Graciaa et al. (2012) determine experimental work on ventilated double skin (DSF) to maintain thermal comfort on winter season. DSF operates on natural or mechanical ventilation mode which depends on thermal comfort level. Result which ventilated façade with PCM provide
better thermal comfort level compared to traditional buildings. It also reduces the usage of power, mainly for HVAC systems [50]. Duana et al. (2020) designed a PCM with Trombe wall to provide thermal comfort on buildings at two different temperature modes. Mixture of PCM about decanoic acid 55% and Lauric acid 45% with melting point and latent heat about 21.33°C and 133.2KJ/kg are integrated with Trombe wall. Outside of Trombe wall covered with electrothermal film to simulate solar radiation with low and high temperature modes. The result is that the Trombe wall increase of the building temperature is about 0.82 to 1.88°C for low temperature mode and 1.72 to 3.27°C for high temperature mode [51]. The list of used PCM materials and their melting temperatures are compared in Table 4.

2.7 Composite Trombe wall

High thermal loss in classical wall due to low thermal resistance of outdoor environment temperature can access easily. To avoid the thermal losses a composite Trombe wall (CTW) is designed. CTW consists of glazing, storage wall, air channel, duct, and ventilation layer. It is designed with insulation layer which helps to differ the indoor and outdoor temperature. Chen et al. (2004) determined the function of composite wall for indoor air temperature in winter season. It has glazing, composite wall (thermal storage wall) and porous layer placed between the glass cover and storage wall shown in Figure 14. Sunlight heats the porous layer and by convection method heat will transfer to indoor and thermal storage wall. The result is that passive method room temperature increases and porous layers act as insulator to avoid heat loss [52]. Ma et al. (2018) determined the performance of composite Trombe wall by optimizing ventilation air gap. Composite wall designed with two modified ventilation and in addition pipe with fan placed between it. Ventilation layer heat the indoor air temperature and fan controlled at 40m³/h. The result is that composite wall with controlled ventilation layer reduces energy usage by about 3.7% compared to normal Trombe wall without air layer [53].

![Fig. 14: Basic structure of composite Trombe wall with porous layer](image)

2.8 Translucent Insulation

Due to less space, reduce of Trombe wall size by using Translucent insulator. In Trombe wall multiples of glazing layer can be replaced by translucent insulator. It has high insulation surface
which reduce thermal loss and good transparency. Berthou et al. (2015) determine the translucent solar wall for thermal storage, daylighting to a building and insulation at same time. It has two layer which are inner layer and outer layer shown in fig 15. Outer layer formed on silica aerogels, it acts as insulation and provide day lighting. Inner layer formed by bricks filled with eutectic PCM, it will provide thermal comfort. Result which translucent wall provide indoor air temperature 9°C higher than outdoor and 500 lux to inside of buildings [55]. Silica aerogels and fatty acid PCM are used in wall which provide better thermal comfort on winter but in summer season it has overheating problem. To overcome this problem by replacing glazing by Prisma solar glass without disturbing PCM configuration. Result on changing glass surface, reducing indoor air temperature and providing thermal comfort on summer season [56]. PCM provides better economic feasibility and payback period 7.8 years compared to another climate season. Also found that an increase of area will reduce the load [57]. The utilization of solar energy system with thermal energy storage materials is useful for thermal management of buildings [58-60].

![Translucent insulator with PCM.](image)

**Fig. 15** Translucent insulator with PCM.

**Table 1.** Studies on Classical Trombe wall.

| Reference | Year | Experiment method | Medium     | Functions               |
|-----------|------|-------------------|------------|-------------------------|
| 16        | 2020 | NM                | Water      | Heating                 |
| 17        | 2018 | NM                | Air        | Heating                 |
| 18        | 2018 | EW&NM             | Water      | Heating & Cooling       |
| 19        | 2018 | EW&NM             | Concrete   | Heating & Cooling       |
| 20        | 2017 | EW&NM             | Solid bricks | Heating & Cooling     |
| 21        | 2017 | NM                | Concrete   | Heating                 |
| 22        | 2017 | EW&NM             | Water      | Heating & Cooling       |
**Table 2.** Studies on Air Trombe wall.

| Reference | Year            | Experiment method | Medium | Functions                     |
|-----------|-----------------|-------------------|--------|-------------------------------|
| 23,24     | 2017,2018       | EW                | TC     | Heating + Air purification    |
| 25,28     | 2018,2020       | EW                | PC     | Heating + Air purification    |
| 26        | 2019            | EW                | TC+PC  | Heating + Air purification    |
| 27        | 2020            | EW                | PC+PV  | Heating + Air purification +  |
|           |                 |                   |        | Electricity                  |

**Table 3.** Studies on Photovoltaic Trombe wall.

| Reference | Year            | Experiment method | Medium     | Functions                     |
|-----------|-----------------|-------------------|------------|-------------------------------|
| 31,38     | 2017,2012       | NM                | PV panel   | Heating & Cooling             |
| 32,33,37  | 2017,2019,2016  | EW                | PV panel   | Heating                      |
| 34        | 2015            | NW                | PV panel   | Heating                      |
| 36        | 2019            | EW&NM             | PV panel   | Heating                      |
| 39        | 2019            | EW&NM             | PV panel   | Heating & Cooling             |
| 40        | 2020            | NM                | PV + TE    | Heating & Cooling             |

**Table 4.** Studies on of PCM.

| Reference | Year            | Experiment method | Medium                                         | Melting point   | Functions                     |
|-----------|-----------------|-------------------|-----------------------------------------------|-----------------|-------------------------------|
| 42        | 2018            | NM                | Calcium chloride hexahydrate                  | 22°C            | Heating & Cooling             |
| 43,51     | 2013,2012       | EW                | Macro-encapsulated salt hydrate               | 22°C            | Heating & Cooling             |
| 44        | 2012            | EW                | Rubitherm GR 35 GR 41                        | 13°C -41°C      | Heating                      |
|           |                 |                   |                                               | 13°C -51°C      |                               |
| 45        | 2019            | NM                | Eutectic inorganic hydrated salt             | 27.5°C          | Heating & Cooling             |
| 46        | 2017            | EW                | Crystalline hydrate and organic PCM          | 25°C -27°C      | Heating                      |
| 47        | 2016            | EW                | Paraffin + Expanded Perlite + Graphite       | 14.45°C         | Heating                      |
| 49        | 2017            | NW                | Micronal PCM DS 5001 X                       | 26°C            | Heating & Cooling             |
| 50        | 2020            | EW                | Decanoic acid + Lauric acid                  | 21.33°C         | Heating & Cooling             |
3. Conclusion
Trombe wall takes a stand on buildings related application in the way of energy conservation and eco-friendly. The Present on Trombe wall for heating and cooling functions. Various experimental and numerical work are discussed to consider materials, structure, facings and different configuration. Overall statics report of Trombe wall efficiency achieved on different views is shown in figure 15 [11]. The summarizing conclusion of review are follows:

- Considering the whole year for designing the Trombe wall will reduce power usage and increase thermal comfort for all seasons.
- Implementing of Hybrid system in the design of Trombe wall like PV with TW, Air purification with TW will improve overall efficiency.
- Storage wall area, materials, thickness are takes important role. Materials with high storing capacity, proper thickness, larger in area are increase durations of thermal comfort.
- Insulation over the buildings should be considered. Trombe wall used to make temperature difference between indoor and outdoor. Thermal loss show be considered and providing proper insulator to reduce it.
- Dimension, position of air channel and vent are to be pointed. Vent opening/closing, air flow channel enhances the indoor temperature. Also, it will improve of overheating problem.
- Glass cover materials, no of glazing layer and its properties will affects staging of Trombe wall. Season should be considered before selecting of glazing.

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